Public Health England

Protecting and improving the nation's health

UK recovery handbook for chemical incidents

Version 1.1

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UK recovery handbook for chemical incidents

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Abstract

The UK Recovery Handbook for Chemical Incidents (UKRHCI) has been developed to assist in the management of contaminated food production systems, inhabited areas and water environments following a chemical incident. The handbook has been developed in conjunction with a wide range of expert stakeholders.

The handbook is a user-friendly guidance document, specifically designed to aid the decision-making process for developing and implementing a recovery strategy in the aftermath of a chemical incident. The handbook focuses on environmental decontamination and provides guidance and checklists on how to manage the many facets of a chemical incident during the recovery phase. The handbook is aimed at national and local authorities, central government departments and agencies, environmental and health protection experts, emergency services, industry and others who may be involved in the recovery from a chemical incident.

The handbook is divided into several independent sections comprising: supporting scientific and technical information; an analysis of the factors influencing recovery; compendia of 85 comprehensive recovery option sheets; guidance on planning in advance of an incident; decision-aiding frameworks for each environment, decision trees; look-up tables and several worked examples. Sources of chemical release considered in the handbook include industrial accidents and deliberate chemical dispersion devices

The handbook can be used as a preparatory tool, under non-crisis conditions to engage stakeholders and to develop local and regional plans. The handbook can be applied as part of the decision-aiding process to develop a recovery strategy following an incident. In addition, the handbook may be useful for training purposes and during emergency exercises. The handbook can be downloaded from the PHE website.

The UKRHCI project was funded by Defra, Home Office, Food Standards Agency, Scottish Government, Northern Ireland Environment Agency and HPA.

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Executive summary

The UK Recovery Handbook for Chemical Incidents (UKRHCI) has been written to support the functions of Public Health England (PHE) (formerly the Health Protection Agency (HPA)) which are "to protect and improve the nation's health and wellbeing, and reduce health inequalities" (https://www.gov.uk/government/organisations/public-health-england). PHE provides support to, and works in partnership with, others who have health protection responsibilities through its role in reducing the dangers to health from infections, chemical and radiation hazards. PHE also advises all government departments and devolved administrations in the UK through the Department of Health.

The handbook provides a framework for choosing an effective recovery strategy following a chemical incident as well as a compendium of practicable, evidence-based recovery options to assist with the remediation of environmental contamination. The handbook is designed to support decision-makers in developing a recovery strategy for food production systems, inhabited areas and water environments following a chemical incident.

The response to a major chemical incident in the UK would involve numerous government departments and agencies, public services and other bodies. Each of these will have their own emergency plans, which cover the detail of their specific areas of responsibility. Expert advice on the particular chemical(s) will be needed from the outset. The response is likely to be complex, and decision making on recovery and remediation will need to take account of a variety of factors. This handbook provides guidance on how to manage the many facets of the impact of a chemical incident on the environment and should therefore augment existing detailed emergency plans held by individual organisations. Sources of contamination considered in the handbook include industrial accidents and deliberate chemical dispersion devices.

The handbook is aimed at national and local authorities, central government departments and agencies, environmental and health protection experts, emergency services, industry and others who may be affected or involved with the remediation of the environment following a chemical incident.

The handbook can be used as a preparatory tool, under non-crisis conditions, to engage stakeholders and to develop local and regional plans. The handbook can also be applied as part of the decision-aiding process to develop a recovery strategy following an incident. In addition, the handbook is useful for training purposes and during emergency exercises. The handbook draws on the model of the UK Recovery Handbook for Radiation Incidents (UKRHRI).

Contents

Disclaimer

Version 1.1 of this handbook has been updated to reflect the change from the Health Protection Agency to Public Health England. The main changes are to formatting and links to relevant guidance and do not reflect an update in the evidence base that underpins the recovery handbook.

The Health Protection Agency's role was to provide an integrated approach to protecting UK public health through the provision of support and advice to the NHS, local authorities, emergency services, other Arms Length Bodies, the Department of Health and the others. The Health Protection Agency became part of Public Health England in 2013.

Where applicable links to websites have been updated.

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1 General introduction

The handbook has been developed according to the framework and model of the UK Radiation Recovery Handbook for Radiation Incidents (UKRHCI)[1], and forms part of Public Health England's (PHE) (formerly HPA) guidance to help users develop an effective recovery strategy after an incident, with a compendium of practicable, evidence-based, recovery options for the remediation of contaminated environments.

The handbook is designed to support decision-makers in developing a recovery strategy following a chemical incident for Food production systems, Inhabited areas, and Water environments, and is a compilation of information to help users identify the important issues to evaluate recovery options.

The handbook should be used as part of a participatory process involving members of the Recovery Coordination Group (RCG) and other stakeholders to develop a recovery strategy. The RCG will form part of the multi-agency response arrangements for a chemical incident. A key role of the RCG is to identify options for clean-up and waste disposal, including making recommendations on those considered to be the best.

1.1 Structure

Section 1: General introduction

Section 2: Factors influencing recovery

Section 3: Planning for recovery in advance of an incident

Section 4: Food production systems

Section 5: Recovery options for Food production systems

Section 6: Inhabited areas

Section 7: Recovery options for Inhabited Areas

Section 8: Water environments

Section 9: Recovery options for Water environments

Section 10: Worked examples

Section 11: Case studies

The sections can be linked together as illustrated in Figure 1.1.

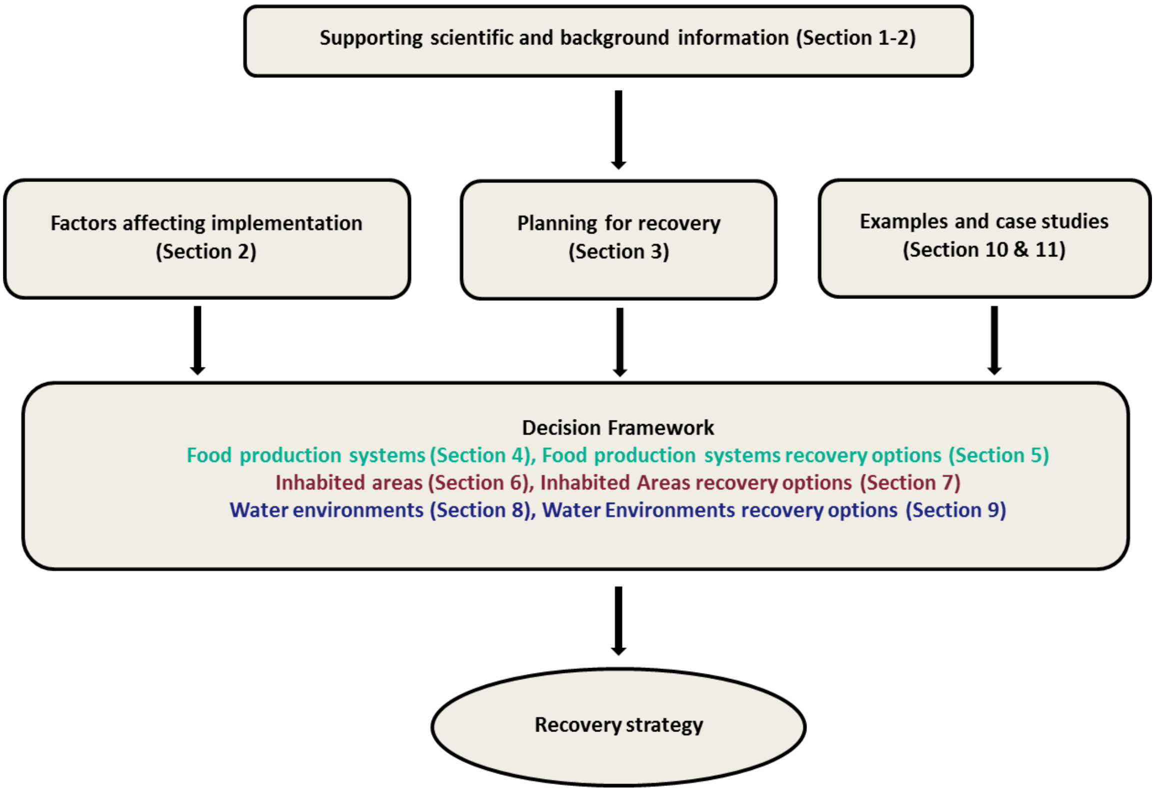


Figure 1.1 Overall structure of the UK Recovery Handbook for Chemical Incidents (UKRHCI)

1.2 Objectives

The handbook has been developed as a reference document to meet several inter-related objectives which are:

- to provide up-to-date information on recovery options for reducing the consequences of contamination of the food chain, inhabited areas and water environments
- to outline the many factors that influences the implementation of recovery options
- to provide guidance on planning for recovery prior to an incident
- to illustrate how to select and combine recovery options and hence build a recovery strategy specific to the chemical incident being managed

The UK Recovery Handbook for Chemical Incidents also has a series of secondary aims which are:

- to generate awareness amongst emergency planners and those who might deal with the aftermath of a chemical incident
- to promote constructive dialogue between all stakeholders tasked with chemical recovery
- to identify under non-crisis conditions specific problems that could arise, including setting up working groups to find practical solutions
- to elaborate plans and/or frameworks for the recovery of contaminated inhabited areas at local, national or regional levels

1.3 Audience

The UK Recovery Handbook for Chemical Incidents is specifically targeted at:

- central government departments and agencies and inspectorates
- emergency planners
- experts in health protection and environmental protection
- enforcement bodies (local authorities, public health agencies)
- health authorities
- emergency response personnel (Police Force, Ambulance and Fire and Rescue Services)
- water companies and distributors
- representatives from agriculture, feed and food production sectors
- other stakeholders, including members of the public who may be affected or concerned, depending on the situation.

1.4 Application

The handbook can be considered solely as a reference document containing well-focused and generic state-of-the-art information on scientific, technical and societal aspects relevant to recovery and remediation of contaminated environments. Information on planning for recovery is provided in Section 3. The Handbook has been developed through a process of stakeholder participation, it is intended to be used or applied using a similar participatory approach to realise its full potential. Examples of the most likely applications of the handbook are:

- in the preparation and pre-planning phase, under non-crisis conditions, to engage stakeholders and to develop local, regional and national plans
- in the recovery phase by local and national stakeholders as part of the decision-aiding process e.g. recovery co-ordination group (RCG)
- for training purposes and contingency planning
- in the preparation for and during emergency exercises

1.5 Context

Experience from past chemical incidents has shown that the consequences of a chemical incident involving a mixture of chemicals can be widespread and complex. For example, in Minamata, Japan, a chemical incident has shown the consequences of widespread and long-lasting contamination incidents are complex and multidimensional[2].

Reducing or preventing chemical contamination is only one aspect of managing a chemical incident. It has been recognised that, to be efficient, effective and sustainable, the management of the consequences of chemical contamination must also consider other dimensions of living conditions, such as economic, social, cultural and ethical issues.

Therefore, this handbook also addresses aspects that go beyond those which just provide health protection (see Section 2).

Chemical contamination – what's the problem?
Contamination of Food production systems, Inhabited areas and Water environments by chemicals is a worldwide concern. Contamination may occur through pollution of air, water, soil or surfaces from accidental or intentional (e.g. terrorist) release of chemicals. In some cases, contamination may be historical and discovered later or may be due to an ongoing incident such as particulate material contamination from a chemical fire. Clean-up and remediation may result in large volumes of contaminated material (i.e. buildings, food produce and water) requiring disposal.

1.5.1 Legislation

This document was produced by PHE. This handbook and the information it contains is for guidance only. Other issues may arise while dealing with the particular circumstances, and the handbook should not be treated as a substitute for obtaining appropriate expert guidance, including legal advice. It is provided free to use but may not be copied or reproduced in any part or form by or for any non-UK governmental or commercial purpose without the prior written agreement of PHE. Comments made on technology, techniques and legislation are based on available information at the time of publishing. They cannot be used as PHE endorsement of technology and techniques or as a replacement for appropriate legal advice. Applicability of technologies, associated techniques and adherence to relevant UK legislation should be sought at the time of use by the responsible authority, from legal advisers and expert organisations listed throughout.

1.6 Scope

The term 'chemical incident' is used throughout the handbook to cover both accidents and other types of chemical releases. Chemical incidents are not infrequent and may occur very rapidly, such as chemical accidents (e.g. spills), or may be determined over a more prolonged period, such as land contamination.

The UK Recovery Handbook for Chemical Incidents covers the recovery in the post-accident (acute) phase and focuses on environmental clean-up methods. Guidance is available for managing the acute phase of a chemical incident on gov.uk* [1].

There are several worked examples demonstrating how to use the handbook (see Section 10), and case studies (see Section 11), including:

- asbestos contamination of a school
- accidental release of sulphur mustard on a beach
- dioxin contamination of livestock

[1] Health Protection Agency Chemical Incident Checklists. Available [February 2019] at; https://webarchive.nationalarchives.gov.uk/20140714084944/http://www.hpa.org.uk/ProductsServices/ChemicalsPoisons/ChemicalRiskAssessment/ChemicalIncidentManagement/IncidentChecklists

- nicotine contamination of ground beef
- a heating oil leak into soil and contamination of a water supply
- the loss of dangerous cargo and chemicals to the sea and beaches as with the MSC Napoli shipwreck
- volcanic ash

Expert input will be needed to supplement the guidance within the handbook, particularly in providing detailed advice on the selection of recovery options, and the practicability of their implementation.

1.6.1 Topics not covered

Topics that are not covered by the UK Recovery Handbook for Chemical Incidents include:

- details of how to perform a risk assessment (e.g. to determine whether clean-up of a contaminated area is required or whether an area can be re-used following implementation of a recovery strategy) – appropriate risk assessment(s) would need to be performed as an incident progresses and used in conjunction with the handbook
- details of how to sample and monitor within a contaminated area (e.g. to determine the extent of the contamination following an incident or the effectiveness of decontamination). However, some important considerations are covered in Sections 1.11 to 1.12
- lists and details of contacts, contractors and the responsibilities of organisations in the event of a chemical emergency; refer to strategic national guidance [3]
- links between responses at different levels e.g. local, regional, national
- detailed planning for chemical emergencies, including pre-drafted press releases and standard answers
- a detailed communication strategy, although some important considerations are covered in Section 2.10
- wider socio-economic issues of blight, damage, compensation, recovery of business, personal and private losses
- detailed aspects of statutory legislation. Please seek expert opinion and guidance regarding legislation and legal aspects of implementing a recovery strategy

1.7 Recovery and health protection

1.7.1 Definition of recovery

For the purposes of the handbook the term recovery is defined as; “the process of rebuilding, restoring and rehabilitating the community following an emergency”[2]. However, for actions undertaken during the recovery phase, an equally important aim is to promote an early return to ‘normal living’[3]. Thus, decision makers should consider not only the expected consequences of implementing the strategy (e.g. the averted exposure, costs, resources required, likely duration, level of disruption), but also how implementing this strategy will contribute to the re-establishment of 'normality', and how remediation measures will be considered successful and as a result can be terminated.

1.7.2 The recovery phase

The handbook concentrates on the recovery part of the post-acute phase, with a focus on reducing exposure to chemically contaminated:

- air (e.g. vapours / dust)
- surfaces in inhabited areas
- food products, animal feed or animals which might eventually enter the food chain and affect humans
- water environments (including drinking water supplies and other water environments (e.g. recreational or coastal waters)

The immediate multi-agency response to the crisis or acute phase of a chemical incident will be co-ordinated by the Police Service with the Fire and Rescue Service taking responsibility for safety management within the inner cordon. The immediate multi-agency response may involve implementing urgent measures such as sheltering or evacuation to protect individuals from short-term, relatively high risks. These measures may include restricting the spread of contamination by decontamination and transferring casualties to hospital for acute medical management. However, irrespective of the nature and scale of the incident, there is a need to consider recovery-related issues from the outset of the incident response, although there are no exact boundaries between these 2 phases. For large scale incidents, the amount of resources required during the recovery and remediation stage may be greater and required for longer than during the initial acute response (see Figure 1.2).

The Environment Agency (EA), Northern Ireland Environment Agency (NIEA) and Scottish Environment Protection Agency (SEPA's) can provide expert advice and guidance during the response and recovery phase of incidents to:

- prevent or minimise the impact of the incident on the environment across air, land and water
- investigate the cause of the incident and consider enforcement action
- seek remediation, clean-up or restoration of the environment

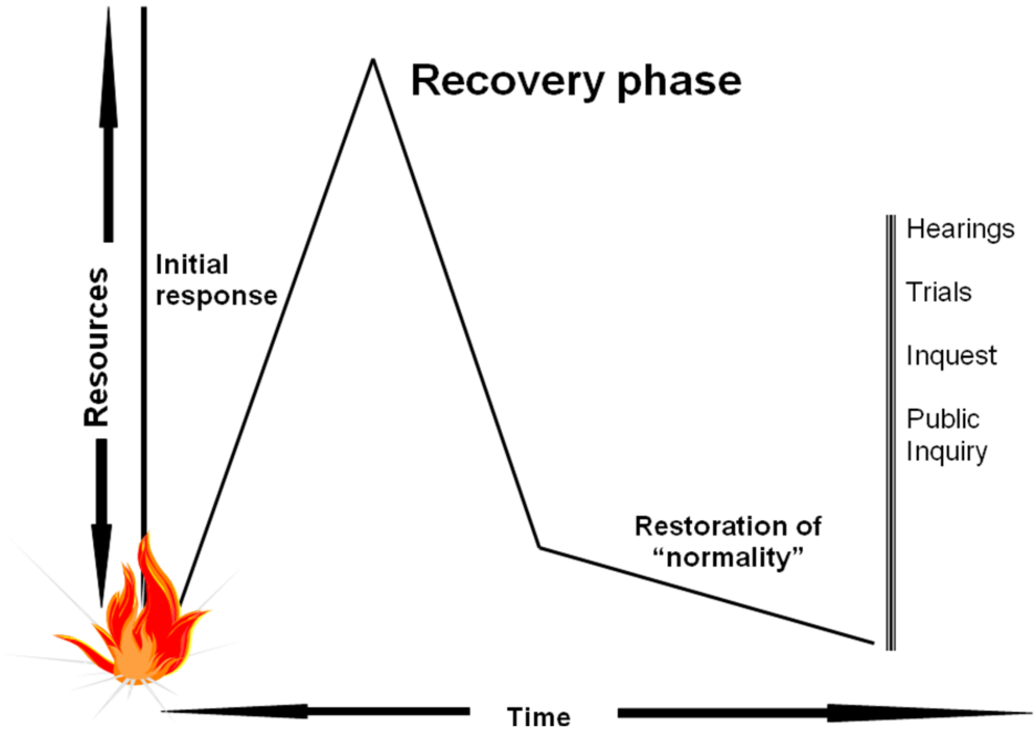


Figure 1.2 Overview of incident response and recovery phase of managing an incident [4]

It is important to stress that the decisions and actions taken during the acute response phase should be designed to limit the spread of contamination, and that planning for recovery must be considered from the outset. However, depending on the type of incident there could be less of a distinction between the acute and recovery phase. For example, during the Sudan 1 dye incident in May 2002, food contamination occurred when contaminated chilli powder was imported into the UK. However, the contamination was not identified until over a year later by which time it had been used in several products, some with a long shelf life. Therefore, there was no distinct 'acute phase' to the incident[5].

The local authority will normally be responsible for co-ordinating the recovery phase (usually as chair of the Recovery Co-ordinating Group (RCG)). Local authority planning is carried out in close co-operation with the emergency services, utilities, other industrial and commercial organisations, and government departments and agencies. The transition from acute phase to recovery, and thus the change in lead authority, will be determined on a case-by-case basis, however some suggested criteria for handover are that:

- the emergency is contained and there is no significant risk of resurgence (e.g. further chemical release unlikely)
- public safety measures are in place and working effectively (e.g. area evacuated, cordons in place)
- the Recovery Co-ordinating Group (and any supporting Sub-Groups) is firmly established
- individual organisations are functioning effectively with adequate resources, communications and management of outstanding issues
- the local authority is able to accept the Chair of Recovery Co-ordinating Group

The recovery phase lasts as long as the effects of the incident can be expected to persist. Generally, more time is available to make decisions than in the immediate acute phase. However, public and political pressure may place time constraints on remedial action. There could be legal implications such as those related to recovering costs which may be important.

Often, once the acute phase is over, those affected start the process of coping with the repercussions of the incident, but it may take time before communities and the media tend to return to their usual activities and interest in the incident and its consequences decrease.

Recovery continues until agreed recovery criteria (i.e. clean-up goals) have been met. Whilst the handbook relates mainly to the recovery phase, it may also be useful in providing useful information and advice on the longer-term management of the incident and to look at the implications of early urgent actions on any subsequent recovery strategy[3].

1.8 Principals of chemical life cycle hazards

The environment into which a chemical has been released is an important consideration in any remediation plan. An urban area may require remediation to reassure residents and other users and to restore public confidence even when the hazard from the substance is relatively low. Conversely, a remote rural area which is not used for food production or recreational activities may need little in the way of remediation.

Whether a chemical is released into an indoor or outdoor environment is also an important factor as this may affect the dispersal of the chemical and hence present different management issues. This was exemplified by the deliberate release of sarin in Tokyo which targeted a crowded underground transport area; this meant management of the incident was more complicated than if it had been released into an outdoor environment[6].

A general awareness of these different types of source of contamination is important so that when a problem is reported the cause of the contamination can be more easily identified. This ensures that the most appropriate way to prevent any further exposure can be determined and the best remediation strategy (recovery options) selected. For many incidents the cause is obvious, so the incident can be described by what actually happened – the ‘event’ – such as ‘fire’ or ‘explosion’. However, for other incidents, the event may not be obvious or the contamination may be the result of more than one event. These incidents are often described according to the environmental medium affected.

Contaminants released into the environment are controlled by a complex set of processes, which include various forms of transport and cross-media uptake[7]. So when one environmental medium is directly contaminated, there is always the potential for secondary (indirect) contamination of another medium if the contaminant source is not contained and mitigated in an appropriate and timely manner. Environmental media include; air, land (soil) and water (including groundwater, surface water, coastal waters, rivers, lakes, streams and aquifers). Some examples of direct and indirect cross-media contamination are indicated in Figure 1.3, for example, an incident (chemical input) may result in a chemical plume that results in contamination of air (direct contamination), which may then subsequently contaminate outdoor or indoor air environments (indirect contamination). In addition, chemical contamination from the plume may deposit to land or water (or both) and result in subsequent contamination of buildings, farmland and water courses (indirect contamination).

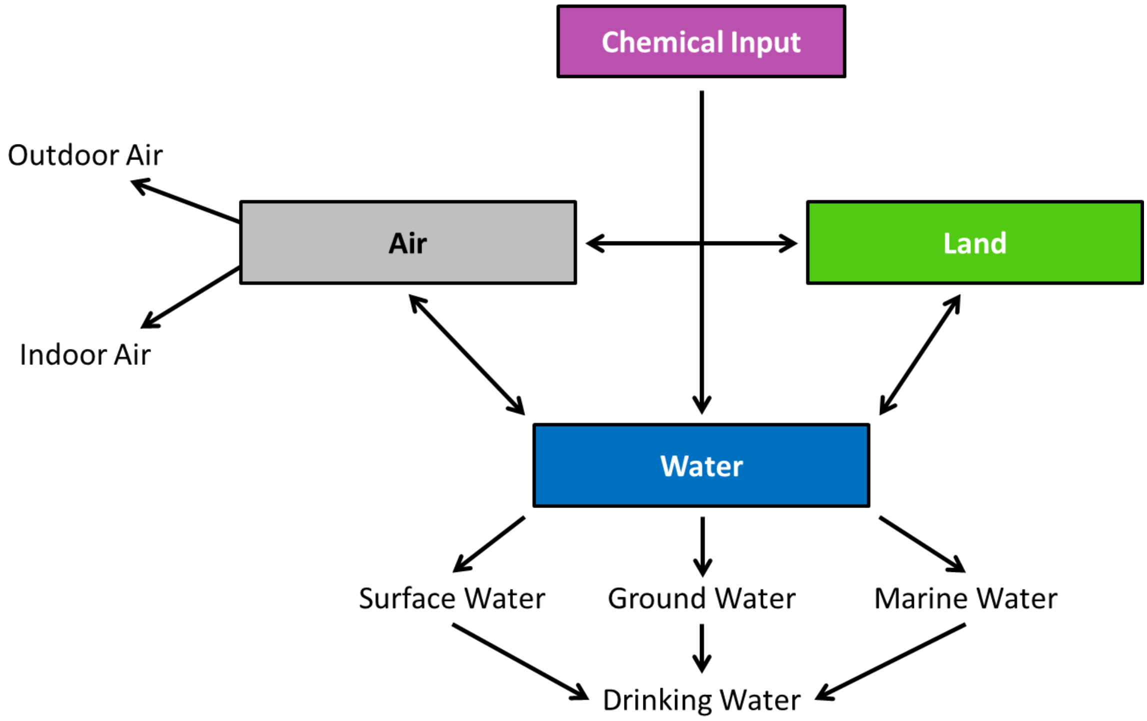


Figure 1.3 Links between direct and indirect contamination of air, land and water following a chemical incident

In many cases the long-term (i.e. months or years) impact on the environment due to a chemical incident or release will be small and limited in extent. There may be no substantial effects in many cases or relatively little effect even in the cases of very toxic, persistent chemicals[3]. However, substantial effects can occur, for example on land contaminated from previous industrial activity. The importance of considering all the possible links to other environmental media are illustrated in the technical sections for Food production systems (Section 4), Inhabited areas (Section 6) and Water environments (Section 8).

1.8.1 Chemical health hazards

Following a chemical incident, health hazards to humans depend on a number of factors which are:

- toxicity of the chemical
- time period and route of exposure (e.g. inhalation/ dermal contact/ ingestion/ eye/ injection) which would influence the overall exposure or dose of a chemical
- distance from the source of contamination
- the physicochemical properties of the chemical and how it behaves in the environment – this would include any degradation products, which may be potentially toxic
- the presence of any protective environment/material (e.g. buildings)
- background levels of the chemical in the environment

For an individual to be exposed to a substance there must be a pathway linking the source to the person. This is sometimes referred to as the source-pathway-receptor model (see Section

1.8.2). This relationship is often described by a conceptual model, describing all the exposure pathways(s) between the source(s) and the receptor(s) (e.g. people/food/animals). The exposure pathways which contribute most significantly to the exposure of humans are shown in Table 1.1.

Table 1.1: Human exposure pathways

Exposure	Pathways
Dermal	Direct dermal contact with chemical or contaminated water/ drinking water Direct dermal contact with chemical or contaminated material/dust may occur in the case of workers (e.g. farmers) using agricultural land or recovery workers implementing remediation.
Ingestion	Ingestion of contaminated drinking water or food, also consider water used in food production. Inadvertent ingestion of contaminated material.
Inhalation	Inhalation of air /vapour contamination on surfaces or water droplets, Inhalation of re-suspended contaminated material Direct inhalation of the chemical or of contaminated material/dust may occur by workers (e.g. farmers) using agricultural land or by recovery workers implementing remediation.
Eye	Contact with water/ droplets/ spray/ liquids, solids and atmospherically dispersed materials.

Following a chemical incident it may not just be a single chemical that contaminates the affected environment, but a mixture of chemicals. In some cases the concentrations of chemicals within the environment may be difficult to quantify and hence it would be more difficult to assess the potential exposure of individuals within a population. This may be due to difficulties in sampling, in the availability of laboratories for specific tests and in available resources; these are described more fully in Section 1.11.

1.8.2 Source, pathway, receptor model

For a hazardous chemical to pose a risk to human health, 3 factors need to be present: source of the chemical of concern; pathways by which it can come into contact with individuals including inhalation, dermal contact, and ingestion; and the receptor.

For example, a source with no pathway or receptor does not require remediation on the basis of health considerations but may still require remediation if there are pathways and receptors in the wider environment. This is known as the source–pathway–receptor linkage (Figure 1.4) and is an important concept in the investigation of both environmental contamination and chemical incidents.

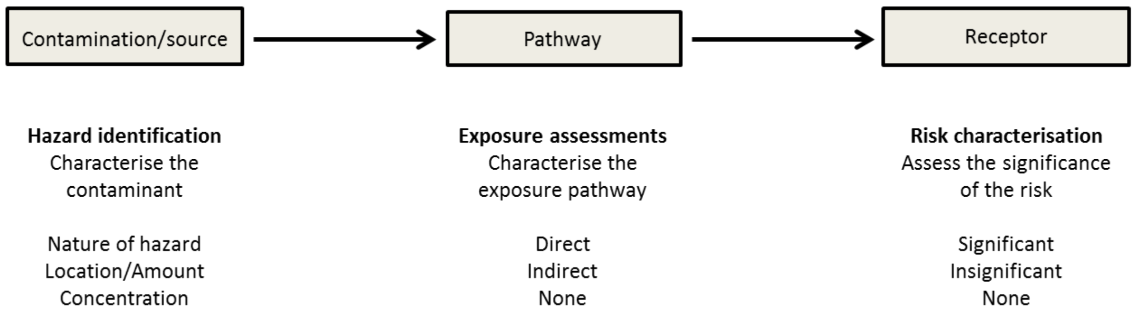


Figure 1.4 Source - pathway - receptor model

It should be noted that contamination of the food chain must be considered as a 2-stage process, as there is the route to contamination of the food (which may include the need to assess the risk of non-compliance), in this instance food is the receptor; coupled with the risk that the contaminated food has already entered the food chain, whereby the contaminated food is then the ‘source’ hazard and the receptor is the consumer.

Once an incident has been evaluated and the nature and extent of contamination characterised, the next stage is to determine what level of clean-up, or ‘remediation’, if any, is required. Remediation actions aim to remove at least one of the 3 components and hence to break the source-pathway-receptor linkage, for example by:

- removal or remediation of the source of contamination
- removal of the pathway of exposure between the source and the receptor
- removal of the receptor from the location of the contamination

1.8.2.1 Source removal

With most removal techniques, the chemical contaminant and affected media (e.g. contaminated food, water or object) still have to be disposed of. The aim is to either, render the chemical harmless (for example, by neutralising an acid), confine it to a more appropriate location away from populations and/or under conditions preventing its escape, and/or destroying it. Some remedial options have the potential to remove the source of contamination completely, rather than just moving it somewhere else. However, secondary contamination sources may result in additional exposure pathways and consequently also require removal or remediation. For example, following the foot and mouth epidemic in 2001, there were wide-scale concerns due to a number of potential routes. These included pollution from burning carcasses on mass pyres, contamination of land from deposition of emissions from burning carcasses, potential health impacts where agricultural produce from the land was consumed, groundwater pollution from disposal of carcasses in landfill sites or mass burial sites, and disposal of ash in landfill sites[8].

Another example includes mercury, which can be carried on clothing into homes where it can contaminate furnishings, and attempts at decontamination by occupants may result in contamination of vacuum cleaners and washing machines, and further exposure to receptors[9].

1.8.2.2 Pathway removal

Removing the pathway prevents the chemical from reaching the receptor which, in terms of risks to public health, usually means people but can also be animals, plants or buildings. For example, when land is contaminated, pathway removal may consist of fencing off part of a field to prevent access by grazing animals, or providing plastic coated metal pipes to prevent chemical contamination of water supplies through permeation. Alternatively, an impermeable barrier could be placed between chemical contamination within the soil so there is no pathway for uptake by plants for human consumption and contamination of water sources.

1.8.2.3 Receptor removal

When the receptor is a human or animal population, the standard method for removing the receptor is to move the population at risk away from sources or pathways of contamination. This is usually only a temporary measure. However, such action may be most appropriate in circumstances of significant environmental contamination. For example, during the Love Canal hazardous waste incident, tonnes of military and industrial chemical waste were deposited in the environment and subsequently led to land contamination. This resulted in people being relocated from the area for a number of months[10]. Similarly, animals may be moved away from a contaminated field onto clean pastures to limit further exposure.

1.8.3 Important physicochemical properties

Chemicals may occur as solids, liquids, aerosols, vapours or gases depending on their innate characteristics and their environment. Many of these chemicals can exert acute or chronic toxic effects, which may range from being immediate and obvious (e.g. cyanide poisoning) to insidious and/ or long-term such as the development of cancer (e.g. arsenic).

The identity of the chemical involved in an incident may not be immediately known . Various sources of information can be used to identify an unknown chemical, including sampling data, clinical symptoms and epidemiological investigations. If more than one chemical is present, there may be reactions between chemicals resulting in by-products which in themselves could also carry a risk (see Section 1.9.1). The quantity of the chemical present is extremely important as for some chemicals (e.g. cyanide) only a very small amount is required to cause a significant health or environmental effect. During the Irish dioxin incident (2008), although there was widespread contamination of food products (estimated cost €300m), the actual amount of dioxin involved was less than 4g[11].

The physical and chemical characteristics of the chemical must be considered when evaluating or characterising the potential extent of the contaminated environment during a chemical incident. In addition, experience from remediation and recovery of past chemical incidents indicates that the applicability of different recovery options to different chemicals may also be related to their physical properties. Physicochemical properties identified as of potential importance when choosing recovery options for the different environments are presented in Food production systems (Section 4), Inhabited areas (Section 6) and Water environments (Section 8).

For example, a chemical with low solubility such as oil will behave differently within a water environment than a chemical which quickly dissolves and is dispersed. Highly toxic water soluble chemicals could be a significant hazard if released into a lake. Therefore the chemicals' physicochemical properties will determine how the chemical behaves in the water environment (e.g. whether the substance floats on the surface, dissolves, hydrolyses or settles out within sediments). Other chemicals (dependent on environmental conditions) are able to penetrate plastic pipes and therefore have the potential to contaminate drinking water supplies. Identifying important physicochemical properties of chemical contamination is key when deciding if certain recovery options are applicable for use. The Chemical Abstract Service (CAS) has formally classified over fifty million chemical compounds[12] and whilst physicochemical properties of some chemicals are considered within this handbook, it is not practical to consider all chemicals in detail and it is advisable to seek specialist advice when considering chemical properties.

1.9 Important environmental factors influencing chemical exposure

When determining the risk to the public, it is necessary to carefully evaluate potential exposure from contamination on different surfaces based on monitoring and/or modelling data and exposure assessments[3]. Besides location of chemical exposure, issues relating to population behaviour may influence exposure risks. For example, surfaces with the highest chemical contamination may not provide the highest contribution to the exposure of the inhabitants; this would depend on the people's contact with the contaminated area. For instance, people in a particular area may spend more of their time indoors (either at home or work) than outdoors (around 90% vs. 10%) and therefore a recovery strategy would need to take this into account. Additionally people may not have access to contaminated areas, e.g. roof surfaces, or remote rural areas which could lower the priority for their decontamination.

Some important considerations of environmental factors influencing chemical exposure are outlined in Table 2.

1.9.1 Chemical degradation and reaction by-products

The degradation and reaction by-products of chemicals should be considered when managing the recovery phase of a chemical incident as they may lead to more important health impacts than the initial chemical., For example, potassium cyanide in contact with water (e.g. moist air) may liberate hydrogen cyanide which is highly toxic if inhaled and would pose a risk in enclosed spaces. The reaction time could also depend on meteorological conditions (e.g. rain/ humidity/ temperature)[14].

Microbes in soil may convert a chemical to a more toxic form, for instance elemental mercury may be converted into methyl mercury which has a far greater potential to bio-accumulate in the food chain and is a more potent neurotoxin as it readily crosses the blood/brain barrier[16].

Table 2: Factors influencing exposure

Factor	Description
Urban area	Likely to be heavily populated, number of different surfaces such as buildings, street furnishings, vehicles may be contaminated.
Rural area	Likely to be less densely populated. Surfaces such as soil and vegetation are likely to predominate.
Indoor release	Interior specific surfaces need to be considered. e.g. soft furnishings, electrical items, ventilation systems. Contamination less likely to be dispersed significantly by weathering. Indoor release is less likely to contaminate food production systems although the potential for deliberate food contamination (e.g. food processing plants / supermarkets).
Outdoor release	External surfaces need to be considered: external building surfaces, soil, grass street furnishings. Contamination is more likely to be dispersed and degraded significantly by weathering (e.g. rain/wind).
Dry conditions	Higher exposure from contamination of indoor environments. Higher contamination on vertical surfaces (e.g. house walls).
Wet conditions	Higher exposure from contamination of outdoor environments. Lower contamination on vertical surfaces.
Chemical properties (see section 1.8.1 – 1.8.3 also)	A chemical with low volatility, such as lead or dioxins, deposited on a hard surface is less likely to contribute to a significant inhalational exposure. In this case the only direct routes of exposure could be from accidental ingestion by children or ingestion of small amounts via normal hand to mouth contact (e.g. via eating) [13, 15]. Conversely, if a volatile chemical such as sarin was deposited onto a building surface, the vapour released could more readily cause a significant exposure via inhalation. Evaporation (dependent on temperature) and re-suspension of a chemical through vehicle or pedestrian movement from a surface (e.g. particulates) are other important factors to consider.
Chemical environmental behaviour (see section 1.8.1 – 1.8.3 also)	Certain chemicals remain close to the surface of soil or grass (e.g. Sulphur Mustard) increasing the likelihood of potential exposure. Other chemicals (e.g. petrol) may (dependent on environmental conditions) be more mobile in soil, resulting in a lower likelihood of exposure to inhabitants of an area although potential leaching from soil to water supplies would also need to be considered.
Type of surface (see section 4, 6 and 8)	The type of surface may also affect how a chemical is absorbed. For instance some chemicals (e.g. pesticides) may soak into an absorbent surface such as concrete and be more difficult to decontaminate and lead to the continued exposure to inhabitants of an area.

The release of reaction by-products also needs to be considered when carrying out decontamination options. For instance, if using a sodium hypochlorite bleach to decontaminate a surface exposed to an acid (e.g. sulphuric), chlorine may be released. This would need to be taken into account when selecting clean-up procedures and selecting the most appropriate use of PPE[17].

1.9.2 Meteorological conditions

Following a chemical release, the meteorological conditions at the time and subsequent to the release will be important factors. For chemicals released as a vapour or particulates, rainfall may increase the amount of chemical removed through wet deposition from the atmosphere and subsequently deposited onto various surfaces. Increased rainfall may also increase the quantity of chemical washed or leached into the surface water, soil and/or ground water. Again this will be dependent on the chemical's physicochemical properties.

Wind speed and direction will also influence how far a plume contaminated by chemicals will travel, how concentrated it will be and subsequently the chemical levels deposited. The higher the wind speed, the quicker the plume is likely to be dispersed resulting in it only posing a hazard to those in close vicinity. Conversely, the lower the wind speed the more likely it is that the plume will remain intact lengthening the downward dispersion and increasing the hazard area in relation to the incident location. The Met Office can provide useful information on the dispersion of chemical plumes which can be overlain on geographical information systems (GIS) to identify areas affected by the plume both in the short term and, following more detailed modelling, in the longer term.

Temperature will also influence the behaviour of a chemical in the environment. Dependent on physicochemical properties snow or ice may freeze a chemical. For example, sulphur mustard is known to persist far longer in colder environments as it freezes at 14 degrees centigrade[18]. Increases in temperature will also affect the dispersal as chemicals with relatively low boiling points are more likely to volatilise at higher temperatures[14].

1.9.3 Nature of chemical dispersion

The mode of release (as a gas/ vapour cloud, a liquid spill, aerosol, solid or particulate matter) will affect the dispersion of a chemical in the environment and how it may subsequently be decontaminated. Deliberate release could involve dispersion of a chemical in an aerosol form or intentional contamination of a water supply or food. Accidental release (e.g. industrial accident) could involve release of a large plume to the environment and the contamination of rivers and agricultural land.

1.10 Toxicological properties

The process by which harm is done to a living organism by a chemical (toxic effect) is a complex phenomenon which is affected or influenced by several factors, of which dose rate and duration of exposure are the most important. The target organs affected may vary depending on the route of exposure as well as the duration or dose. If the duration of exposure is short, possibly only the most vulnerable organs or tissues will be affected. The toxicity of breakdown products must also be considered[19] (see Section 1.9.1).

Chemical substances have physical and toxicological properties that determine the manner in which they are handled by the human body, and the nature of the harmful effects they produce. The harmful effects of chemicals may be apparent immediately, and pose an "acute toxicity" risk, resulting in clinical effects such as nausea, difficulty breathing or corrosive damage to the skin. Exposure to chemicals can also cause long-term health effects, termed "sequelae", which are a secondary consequence of the initial exposure, examples can include; difficulty with balance, vision, asthma or in severe instances brain damage.

However, clinical effects and symptoms associated with exposure to chemicals may not be immediately visible or detectable. For example, cancer may develop months or years after the initial exposure. In extreme cases, chemicals can damage the hormone system (endocrine disruptors), but the effects of these chemicals may only be apparent in children of the affected individual. Latency is the time period from the initial exposure to a chemical to the development of clinical symptoms. Some chemicals (e.g. cyanide) produce effects within seconds and have an acute toxicity risk, but others such as lead may have delayed effects therefore latency is an important factor to consider when managing the initial response and recovery phase of a chemical incident. If clinical effects are delayed it may not be immediately apparent that a chemical incident has occurred. Chemicals that have a long latency period before clinical effects and symptoms are apparent could result in individuals spreading contamination within the environment, as they do not realise they have been exposed [13, 14, 20]. For the purpose of the handbook latency of acute toxicity has been defined as follows:

Short: < 1 hour, Moderate: > 1 hour, Long > 24 hours

Important toxicity related information has been identified for 15 example chemicals and is provided in Table 1.3.

For chemicals not listed in Table 1.3 expert advice should be sought from relevant agencies (e.g. PHE and National Poisons Information Service). The PHE compendium is a useful source for toxicity data for a number of chemicals and is available at; https://www.gov.uk/government/collections/chemical-hazards-compendium

It is likely that, at the start of the recovery phase, decision makers may not have a detailed picture of the full distribution of the contamination deposition. Since recovery decisions should be based on a clear picture of the contamination pattern and the likely exposure of people in the area, detailed monitoring of the environment would usually be undertaken. Dependent on the chemical of concern, people may be monitored as part of an exposure assessment. Priorities for monitoring as well as the types and scale of monitoring required should be identified, as well as the need for monitoring in different situations.

The main reasons for undertaking an environmental monitoring programme in the event of a chemical incident are to:

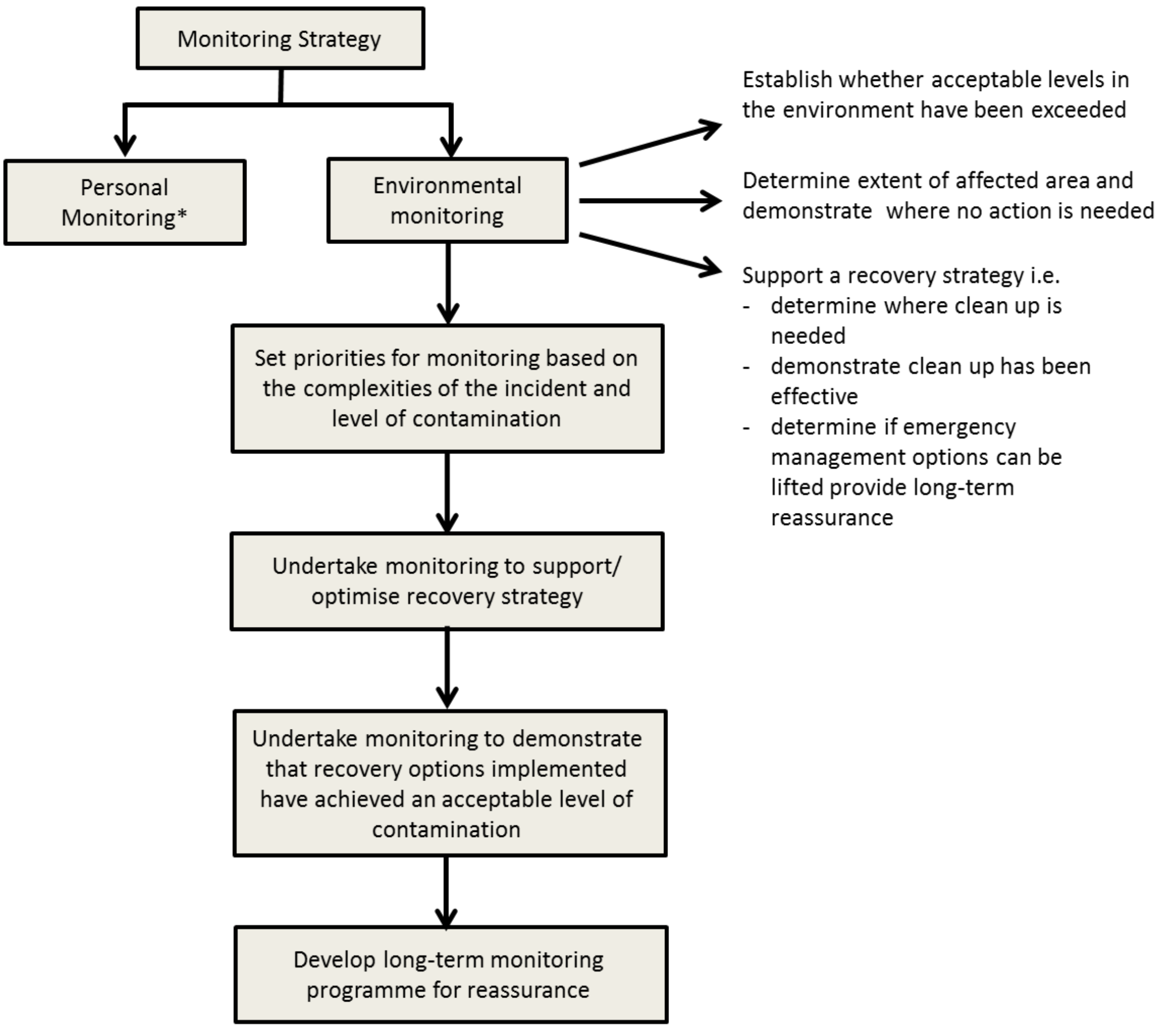
- determine the extent of the affected area and to demonstrate where no remediation is required
- identify the source/s of contamination and the chemical(s) involved
- establish whether tolerable levels of risk have been exceeded i.e. to undertake site specific health risk assessments and determine people’s potential exposures – this may be combined with personal monitoring
- support a recovery strategy i.e. determine where clean-up is needed; demonstrate clean-up has been effective; determine if emergency measures can be lifted
- provide long term reassurance

This is shown in Figure 1.5. It can be concluded that a series of monitoring programmes will be required to address these different objectives.

Table 1.3: Important human toxicity information for 15 example chemicals

Chemical	Main target organs	Acute Toxicity Risk	*latency of acute toxicity symptoms	Risk of sequelae	Carcinogen risk	Reproductive toxicity risk
Aldicarb	CNS/PNS	High	<1hr - >1hr	Yes	Not classified	Potential
Arsine	CNS, cardiovascular, blood	High	>1h	Yes	Yes (metabolites)	Potential
Asbestos	Respiratory	Low	>24h (years)	Yes	Yes	No
Cyanide salts	CNS, cardiovascular	High	<1hr	Yes	No	No
Dioxins	CNS, skin	Moderate	>24hr (years)	Yes	Yes	Probable
Lead salts	CNS, GI, liver, kidney	Moderate	>24hr (years)	Yes	Probable	Yes
Methylmercury	CNS, GI, liver, kidney	Moderate	>24hr (years)	Yes	Not classified	Yes
Particulates	CNS	High	<1hr - >1hr	Yes	Not classified	Yes
Phorate	Respiratory, cardiovascular	Moderate	<1hr - >24hr	Yes	Potential	Potential
Ricin	CNS, PNS	Moderate	<1hr	Yes	Not classified	Potential
Sarin	CNS, liver, kidney	High	<1hr - >1hr	Yes	Not classified	One case report
Sulphuric acid	CNS, PNS, respiratory	High	<1hr	Yes	Not classified	Potential
Sulphur mustard	Skin, eyes	Moderate	<1hr	Yes	No	No
Thallium	Skin, eye, blood, respiratory	Moderate	<1hr - >24hr	Yes	Yes	Potential
Toluene di-isocyanate	CNS, skin, GI	Moderate	<1hr - >1hr	Yes	Not classified	Yes

Key: CNS Central Nervous System; **PNS** Peripheral Nervous System; **GI** Gastrointestinal system
* latency (onset of symptoms): Short < 1 hour; Medium > 1 hour; Long > 24 hours
** for more detailed information see the PHE chemical compendium at https://www.gov.uk/government/collections/chemical-hazards-compendium or contact PHE.



**Personal monitoring is not considered further in the handbook*

Figure 1.5 General roles of environmental monitoring

1.11 Environmental monitoring

The sampling part of any environmental monitoring programme should be completed by a suitably trained and qualified individual. Before any environmental samples are collected, it should be decided what actions will be taken for positive sample results and for results which are ‘borderline’. Advice on precautions to minimise cross-contamination, suitability of sample containers and sample size may need to be sought (see Section 1.11.2). Any remediation activity is heavily dependent on the capability to survey and monitor; without effective surveying techniques it is difficult to establish the extent of the contaminated area (see Table 1.4).

Any survey needs to be conducted properly by trained sampling teams. It is possible for ineffective decontamination processes to look effective because of poor detection, sampling and analysis. Ultimately the process must be acceptable and considered to be best practice by the various stakeholders and regulators. Analytical techniques used for verification need to be sufficiently sensitive to detect concentrations of contamination which may be above clean-up goals. Even if no action is required, a monitoring strategy may still help to reassure the public. For example:

- at the beginning of the recovery phase the sampling strategy should initially focus on confirming the safety of the area outside the cordoned-off zone
- after remediation, the area will need to be re-surveyed to verify whether or not the remediation strategy (i.e. recovery options) have been effective

The Environment Agency (EA), Northern Ireland Environment Agency (NIEA) and Scottish Environmental Protection Agency (SEPA) would be able to advise on chemical spills or incidents and provide specialist advice and monitoring services to minimise the environmental impact and optimise the process of waste disposal. In addition, the environment agencies would also be involved in the post-incident investigations, not only to support enforcement action but also help with prevention planning.

1.11.1 Environmental media

Depending on the incident, samples may be required from several environmental media. Examples include the following:

Inhabited areas

- Air indoor or outdoor
- Soils or sediments
- Industrial discharges solid, liquid, gaseous

Water environments

- Surface waters – e.g. rivers, lakes
- Groundwater
- Marine water
- Drinking water supplies – customers' taps, main pipes, water treatment works, reservoirs, abstraction points

Food production systems

- Vegetation, crop and food samples
- Soils or sediments
- Samples from animals

Sampling to determine background levels of chemicals may also be required for comparison. These are often referred to as control samples.

1.11.2 Constraints with environmental monitoring programmes

Before any environmental samples are collected, it should be decided what actions will be taken for positive sample results and for results which are 'borderline'. This is especially important for long-term problems, such as an incident which releases chemicals which are very persistent in the environment. The major considerations are identified in Table 1.4.

Table 1.4: Considerations associated with implementing environmental monitoring programmes

Consideration	Description
Chemical specificity	It may be difficult to decide which chemicals should be monitored for, particularly if the chemicals in question have not been conclusively identified or there is the potential for toxic degradation chemicals. It may be necessary for initial sampling to use a variety of screening methods (which are commercially available) to identify chemical categories, the key is to select an appropriate screening method which will depend on the circumstances of the incident.
Limits of detection	If the purpose of the monitoring programme is to compare sample results with available chemical standards, then the analysis must achieve appropriate limits of detection (i.e. at least down to the levels of the standards). If the level set for clean-up standards is a lower concentration than the analytical limit of detection, then it will not be possible to determine if the clean-up method has been effective. This is further complicated by the lack of information on background chemical concentration levels; i.e. what was the level before the chemical incident and what is the level after remediation and clean-up to demonstrate that the clean-up has been effective.
Time	Samples should be taken as early as possible (as long as they can be taken safely) following an incident, to determine the distribution and concentrations of contamination in the environment. They should also be taken before any remedial action is carried out allowing the maximum possible level of exposure to be determined. However, there may be a time delay between the incident occurring and maximum levels of the contaminant being detectable in environmental samples if for example, a chemical is transient in a plume or the incident could still escalate to produce higher concentrations of the chemical at a later stage. This highlights the need for collecting repeat samples and not basing the recovery response on one set of sample data. Further samples should also be collected once any remedial work has been completed to confirm that the risk to human health or the impact on the environment has been reduced so it is no longer an issue. It is also important to be aware that the turnaround time for some tests may be a number of days, or even weeks in the case of dioxin analysis.
Access	Difficulties may arise in getting access to private property to collect samples. Legislation may be required to access land, depending on ownership.
Cost/responsibility	The financial burden of undertaking an environmental monitoring programme can be considerable. It may be difficult to identify the organisation responsible for and/or willing to undertake sampling and analysis. In recurring situations (e.g. minor food scares that are frequent occurrences), environmental sampling and analysis are usually the responsibilities of local authorities. In unusual situations (i.e. emergencies), these and other responsibilities are not always clear cut. Expert advice and guidance should be sought to address any uncertainties. Under the 'polluter pays' principle, however, costs may ultimately be borne by those responsible for causing an incident.

1.12 Monitoring environments

Environmental monitoring following a chemical incident will provide information on the extent and potential effects of contamination and will influence public health decisions. Further details on the purposes of monitoring particular environments are given in Table 1.5. Where there are clear lines of responsibility for monitoring particular environments, these have also been included.

1.12.1 Location and frequency of sampling

Selecting the most appropriate sampling methodology and location for sampling is of paramount importance to ensure a representative sample of the actual contaminant present within an environment is obtained. To determine the potential impact of a chemical incident on human health or the environment, the sampling positions should be related to exposure pathways for the population. Although sampling should generally be downwind of the source for an airborne release, upwind samples may also be useful in providing information on background levels. However it should be noted that dispersed contaminants may move upwind depending on the geography/ topography or (in an urban environment) buildings. Where there is homogeneous (well mixed) contamination, the exact location of sampling positions is not as important, and the number of samples required for an overall picture of the distribution of contaminants is smaller than for heterogeneous contamination. In that case, a larger number of samples will be required to establish the contaminant distribution and concentration at different points. In the short term, samples can be restricted to areas of greatest contamination – also referred to as ‘hot spots’ – if their location is known, or to areas of highest population density. Sampling around the potentially most vulnerable populations e.g. schools, hospitals, or those difficult to evacuate (e.g. care homes etc.) should also be considered as a matter of urgency.

Frequency of sampling (i.e. hourly, daily, monthly, yearly) must also be determined, as well as the duration of the whole monitoring programme, the aim being to be able to identify the highest concentrations experienced during the incident and to establish that concentrations have returned to a baseline level at the end of an incident. These are frequently referred to as ‘peaks’ and ‘troughs’.

1.12.2 Collection of environmental samples

Advice on precautions to minimise cross-contamination, suitability of sample containers and sample size may be sought from the analytical laboratory(s) that will be conducting the analyses. The outcome of any analytical test procedure can be no better than the sample on which it is performed. In devising a sampling protocol, the following factors must be satisfied:

- Protection - Personnel taking samples should be trained and supplied with adequate personal protective equipment
- Precaution – Avoid contamination whilst obtaining samples
- Reliability – Suitability of sample containers, required sample size
- Sufficiency – Determine how many and the size/ volume of samples required to enable appropriate analysis and statistical evaluation to be undertaken

Table 1.5: Monitoring environments

Monitoring	Purpose	Responsibility
Air	Air monitoring data, in conjunction with modelling and an appropriate risk assessment would be important for determining whether a given population should shelter in place (e.g. remaining indoors and closing windows and doors) or temporarily relocate, or be advised to avoid the use of certain areas. Indoor air monitoring could also be important especially if a chemical incident occurred within a confined environment. Indoor air monitoring could also be used to determine the levels permeating the property following an external incident.	The Air Quality Cell is an essential service run by the Environment Agency provided during major incidents to advise the emergency services on how to manage the effects on public health. It is a national, multi-agency group of technical experts chaired by the Environment Agency. There are up to 15 major incidents every year which could have an impact on air quality. In Scotland this is carried out by the Airborne Hazards Emergency Response service, run by the Scottish Environment Protection Agency (SEPA). Local authorities are responsible for ongoing air quality monitoring following the emergency/response phase of an incident. This means they need to be familiar with the AQC response and have arrangements in place to undertake ongoing monitoring after the emergency phase.
Soil and vegetation	If soil is severely contaminated, it may be necessary to temporarily or even permanently relocate members of the public from their homes or to restrict access to outdoor areas. Monitoring will inform decisions on whether it is safe for members of the public to grow food in their allotments or gardens, or whether children should be allowed to play in their gardens (given their susceptibility to accidentally ingesting soil) or recreational areas (e.g. parks/fields). The degree of contamination in soil would also be important for deciding whether remediation of land was required and when land was safe to be used again.	Private land owners, industrial land owners, local authorities (public land) are responsible for monitoring soil or vegetation following a chemical incident. However following large scale incidents other agencies may lead on the monitoring. In some cases costs may also be recoverable from the persons or businesses responsible for the contamination.
Public/private water supplies	If water supplies are thought to be contaminated, or if a water abstraction point is threatened, the water company or local authority (for private water supplies) will want to identify the nature and concentration of the contaminant, when it occurred and the area/population affected. Water samples will be taken and analysed in an attempt to identify the chemical(s) and determine their concentration(s). There may be combined microbiological and chemical problems, particularly if the effectiveness of water treatment processes has been affected. Monitoring should help ensure that all potentially affected premises are identified.	Local authorities / water companies carry out routine testing of water supplies, and results from these analyses may assist in identifying when the contamination of water first occurred. Only a limited number of contaminants are analysed routinely, and some chemicals will be much more difficult to detect and analyse than others, particularly at low concentrations. In identifying the area contaminated, the water company will need to assess the area of the distribution network being supplied by contaminated water or, if contamination has occurred within the distribution system, the extent of contamination. In Scotland, SEPA have plans in place including Scottish Waterborne Hazard Plan (Scottish Water, 2010), Major Services Incident Plan (Scottish Water, 2011) and Wastewater Pollution Incident Risk Management Guidance (Scottish Water, 2009).
Controlled water	If a raw drinking water source or controlled water, such as a river, has been polluted, monitoring will help determine the impact on the wider environment and on drinking water sources that derive from the affected controlled water body.	Environment Agency, SEPA in Scotland NIEA in Northern Ireland and water companies. The EA and water company may have access to computer models which are able to predict the rate at which a contaminant travels along a water body and thus the concentration at the drinking water abstraction point or area of concern, to give an estimate of the likely level of contamination. The Environment Agency and SEPA provide guidance on the general sampling of the aquatic environment.

Monitoring	Purpose	Responsibility
Livestock	Following a large scale chemical incident, animals involved in food production may become contaminated via their feed or water. Raised concentrations of chemical contaminants in animals destined for meat or other production (e.g. milk/eggs) may be detectable by live monitoring, and could indicate that they are unsuitable for this purpose. Live monitoring could also influence the use of certain recovery options, e.g. clean feeding of animals could reduce further chemical exposure. In certain cases slaughtering could be delayed until the level of contaminant in exposed animals had decreased sufficiently to not pose a health risk if ingested by members of the public[2]. For example, following the Seveso incident (Italy) monitoring of animal milk for dioxins was undertaken to help determine the spread of contamination through the environment. Live monitoring of animals also has important implications for food production systems following a chemical incident[21].	Probably the farmers in the first instance as they have a legal responsibility to ensure they don't place unsafe food on the market (e.g. some farmers paid for their own analysis in Northern Ireland during the dioxin incident). However for wide ranging incidents, the authorities may use emergency funds. Costs may also be recoverable from the persons or businesses responsible for the contamination.
Food products	Results obtained via food monitoring could help determine whether certain recovery options (e.g. food restrictions/ waste disposal) require implementation and would even affect further monitoring of crops, livestock or soil to determine the extent of the incident and identify applicable recovery options for those areas. Following contamination of food products there is the potential for them to be distributed widely (e.g. national/internationally) if an incident is not identified at an early stage.	Following incidents food businesses (e.g. farms) would be initially responsible. Routine testing of food samples is undertaken by a variety of food control laboratories in the UK. The Food Standards Agency (FSA) supports local authority food sampling programmes that are regularly carried out to ensure the safety of our food supply. The FSA has also commissioned the introduction, development and rollout of a UK Food Surveillance System (UKFSS). The FSA is also responsible for meat inspection duties in fresh meat premises in England, Scotland and Wales. It is the role of the Agency to help ensure that the meat industry safeguards the health of the public, and the health and welfare of animals at slaughter. Following incidents involving exposure to chemicals the Animal Health and Veterinary Laboratories Agency (AHVLA) are likely to conduct or commission any additional testing.
Food crops	Crops affected by a contamination incident must be monitored to assess their suitability to enter the food or feed chain. Where relevant regulatory limits apply, testing should be carried out to ensure compliance (non-compliant crops must not be used for onward processing). Where there are no applicable limits, restriction on entry into the food or feed chain must be on the basis of a risk assessment, taking into account the effects of onward processing. Crops may also be tested to assess the effectiveness of any remedial action following a contamination incident.	Responsibility would initially fall on the producer to ensure that their crops are fit to enter the food chain. Where there is uncertainty, they would be expected to liaise with the Local Authority or Trading Standards (in the case of feed crops), seeking further advice from the Food Standards Agency if necessary.

- Identification / traceability - All samples need to be labelled with details such as sample location, weather conditions and other potential variables
- Duplicate sampling - Several samples may need to be taken so that analytical results can be verified if required by repeat or independent analysis
- Transportation - Samples should be transported in an appropriate vehicle to store samples within the correct temperature range.

1.12.3 Sample preservation

The sample must be collected by appropriately trained personnel and be truly representative of the environmental medium at the time of collection. The sample should be stored and/or transported to a laboratory and should be adequately preserved. The particular technique will depend on what is being measured. Contamination through sample storage containers or collecting vessels or their stoppers can occur when collecting samples by a number of routes (examples below):

- Leaching of contaminants from the surface of imperfectly cleaned containers
- Leaching of organic substances or silica or sodium or other metals from glass or plastic
- Adsorption of trace metals onto glass surfaces or organics onto plastic surfaces
- Reaction of the sample with the container material.

1.12.4 Sample analysis

Analysis should be carried out by standard methods at an accredited UKAS (UK Accreditation Service) laboratory, at which satisfactory quality assurance procedures are always used (it should be noted that standard methods are not available for all chemicals and that certain competent laboratories may not be accredited to analyse all samples). Demonstrable high performance in Proficiency Tests would be an added advantage. One project, the Wide Area Sampling and Analysis project (WASA), has developed Standard Operating Procedures (SOPs) for CBR agents (see Appendix C). In some circumstances it may be possible to obtain portable apparatus for on-site analysis of some chemicals, but the accuracy of the results will vary. Analytical techniques and methods may vary in the levels of detection, which could lead to different results (i.e. concentration of contaminant) being attained for samples taken from the same source. Therefore, the most appropriate and robust method for sample analysis should be decided on prior to starting the sample analysis. Some analytical techniques or reporting methods may only provide general information, for example, total hydrocarbons or total dissolved solids. To determine the health impact, more specific information may be required on individual chemicals. Also, for some chemicals, there may be different species or forms that have different toxicities. For example, hexavalent chromium (VI) is an acute toxin as well as a carcinogen, whereas trivalent chromium (III) is of relatively low toxicity. It is therefore important to establish which form of the chemical is present in the sample.

If results from the sample analysis are confirmed to be below those that could cause a risk to health, the exact level of contamination is not of great importance. However, if data is not accurate (i.e. variation in results) a wide safety margin would be needed to apply this level of confidence. A more qualitative analysis is then appropriate: identifying whether levels are remaining reasonably constant, increasing or decreasing. If the results show that levels are above those specified in health, environmental or regulatory standards (i.e. No Observed Effect Level (NOAL)), or if appropriate health, environmental or regulatory standards do not exist, a more accurate quantitative result will be required to establish the exact extent of the contamination problem, to enable a risk assessment to be conducted to establish the threat to human health.

1.13 Modelling

An important part of both emergency preparedness and recovery planning is the assessment of the consequences of a chemical incident and the fate and transport of dispersed contaminants. Models are often used in addition to or in lieu of monitoring data to estimate environmental concentrations and exposures for use in risk assessments or epidemiological studies. Models are tools that can provide information to aid decision makers in managing a chemical incident, either in the acute phase or to refine the remediation strategy of the recovery phase.

Modelling for chemical incidents can be split into 2 categories.

- Modelling to **support incident response** (e.g. deployed during an incident)

Modelling during the acute phase of a chemical incident (*near real-time modelling to support incident response*) typically requires information to be generated rapidly after an incident has occurred, and is used to support the decision making process at an early stage. Input data will initially be incomplete and uncertain (e.g. concentration of the chemical involved, if known). It may also be used to identify areas requiring remediation.

- Modelling to **support recovery and remediation** (e.g. clean-up and decontamination)

Modelling during the recovery phase of a chemical incident is not subject to the extreme time pressure associated with near real-time modelling for the acute response. Post incident exposure assessment and modelling may be able to estimate actual exposures and inform epidemiological follow-up study design.

The following section focuses on modelling to support recovery and remediation.

1.13.1 What aspects of the recovery phase could be modelled?

Dispersion in environment over long timescales (weeks, months) before and after recovery:

- Pathways of exposure before and after recovery
- Effects of exposure on human health
- Levels of uptake into food
- Effect of recovery option on dispersion/availability/exposure pathways of contaminant (effectiveness of recovery option)
- How to implement the recovery option e.g. what concentration of treatment chemical is needed
- Exposure from waste disposal options and exposure of recovery workers

- Comparison of recovery options.

The use of computer models for assessment of contamination of different environments, scenarios, recovery options or remediation techniques may enable the evaluation of alternative recovery strategies in the context of preparedness or decision-making.

1.13.2 Types of models

A vast range of models exist, and these models vary depending on their intended purpose and user requirements. Models can be classified according to their function (i.e. for planning or regulatory use); or complexity and the resources required (i.e. computing power, expertise and data). Models range from simple calculations, charts or spreadsheets that can provide rapid estimates of chemical concentration levels, up to national resources such as those used by the Met Office.

Models can comprise of fate or transport models, exposure models or a combination.

Transport models

In general, fate or transport models assess the movement and transformation of pollutants in the environment, and provide predicted ambient pollution concentrations (in units mg/m^{-3}, mgl^{-1} or mg/kg^{-1}) in different environmental media (e.g. air, food, soil and water). The outputs of fate or transport models represent concentrations that receptors (i.e. animals, crops, humans) have the potential to be exposed to.

Exposure models

Exposure models incorporate information on exposure factors and time activity patterns, and yield predicted exposures or doses (in units of mg/m^{-3} or mg/kg^{-1} day^{-1}) based on actual (or assumed) contact between a receptor and the general environment or specific microenvironments. The outputs of exposure models are therefore the most representative of actual human or ecological exposures[22].

1.13.3 Considerations when using model results

The confidence that can be placed in modelling results will depend on the degree to which the model capabilities match the needs of the assessment, whether the model reflects the understanding of the physical processes involved and the extent to which the model has been validated, if at all. If they exist then actual measurements should be used in preference to model results.

Modelling results should be interpreted with caution, as their outputs are often reported with too great a degree of precision.

It is important to consider the constraints of inadequate data-sets that could affect modelling outputs, and that the cost of sampling and monitoring to generate an adequate data-set may also be prohibitive. It is also important to remember that the modelling results will be of limited accuracy and should only be used to guide decisions during the recovery process.

The type of conceptual model should also be considered: how well does it represent the affected area (i.e. inhabited, food production systems or water environments) and does it reflect the important aspects of processes that will occur i.e. parameters governing the deposition and distribution of chemicals in different environments and surfaces (indoors, outdoors, onto people or livestock). It is also important to remember that how a recovery option is included within a model will depend on the way the model works and the endpoints required from that model[23].

A model that has been validated for the chemical/processes modelled is likely to be more accurate than one that has not; therefore it is important to understand the level of evidence behind the model results. If the correct algorithms are used, increasing computational power will strengthen model results; however, at the moment there is no direct correlation between computational capacity and the quality of model results[24].

1.13.4 Examples of the application of modelling for recovery and remediation

Mathematical modelling was used during remediation of the Broomfield coal tip (near Wigan) to demonstrate the effectiveness of reducing worker exposure by restricting excavation of the site according to favourable weather conditions[25].

The potential for contamination of water supplies or surface waters affected by volcanic ash fall have also been successfully modelled, using a simple model to predict concentration increases in receiving waters due to leachate from ashfall[26].

Spill modelling was employed as part of the response and monitoring strategy at the Sea Empress incident in 1996, where 72,000 tons of Forties blend crude oil were released into the marine environment. The OSIS (oil spill information system) was used to predict the fate, trajectory and likely beaching of oil, thus aiding the decisions and optimizing response strategy. The operational use of OSIS during the Sea Empress incident demonstrated the benefits of a field-validated oil spill model in planning the response strategy for a major oil spill[27].

Recovery and remediation after chemical incidents involving water and soils may sometimes require a continuous supply of active agent to a target area, such as in situ redox manipulation and in situ chemical oxidation[28]. There have been problems in controlling the rapid dissolution of agents in water, creating high concentrations of chemical agents and making the treatment short-term, but modelling can improve the efficacy of these treatment methods by taking into account hydrologic factors such as aquifer characteristics and natural demands for active agents. There are also risks to river intakes by accidental spillages from industry, rail and road tankers and farm pollution. The protection of drinking water abstraction points from rivers normally involves predicting the arrival times and peak concentrations of the contaminant, together with the time that concentrations return to a safe level; which require remediation by closing the abstraction point or altering the type of water treatment to cope with the contaminant. These incidents can be modelled by using input/ output models such as the Advective Dispersion Equation (ADE) and Aggregated Dead Zone (ADZ)[29].

Inland flooding is also a principal cause of catastrophic loss in the UK and several major flooding events have occurred in the last 10 years, culminating with the devastating floods in summer 2007. Flood models are used by the Environment Agency to estimate the travel time of chemicals following an incident or release. Flood models take into account water flow and can be useful for risk assessments and allow temporary closure of water abstraction points until contamination has passed.

1.13.5 Modelling the effectiveness of recovery options

There is limited information in the available literature on the use of modelling to evaluate the effectiveness of recovery options as models usually have to be accurately calibrated. The effectiveness of air sparging as a remediation technique involving injection of uncontaminated air for the subsurface removal of dissolved organic contaminants (VOCs) such as petrol, aviation fuel and chlorinated solvents has been evaluated by applying mathematical modelling. However, the effectiveness of modelling air sparging technique in field applications requires the model to be accurately calibrated[30].

Natural attenuation (with monitoring) and modelling is a recovery option recommended in the Handbook. The success of this option is evaluated by being able to demonstrate that the contamination has been removed through natural processes, which can be achieved through modelling. For example, modelling could demonstrate that the rate and capacity for inorganic contaminant attenuation meets regulatory objectives and, in addition, that inorganic contaminant immobilisation is sustainable to the extent that future health risks are eliminated.

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2 Factors Influencing Recovery

The term recovery option is defined as an action intended to reduce or avert the exposure of people and the environment to chemical contamination. The implementation of a recovery option is therefore also likely to protect the environment from chemical contamination[1]. There are 85 potential recovery options for use in contaminated Food production systems (39), Inhabited areas (24) and Water environments (22) in this handbook. Recovery options are designed to target particular media (i.e. water, food and building surfaces) and contamination pathways (see Section 1.8.2). Recovery options are not only aimed at addressing public health concerns, but also a wide range of other issues, such as the local economy, societal and ethical concerns and disposal of wastes.

There are 3 types of recovery options considered in this Handbook that encompass; protection; remediation and restoration and waste disposal (or fate of affected produce) options. They are not mutually exclusive or stand-alone options and may have to be combined as part of the remediation strategy.

2.1 Protection options

Protection options can be used to reduce, or protect people from exposure to chemical contamination, usually via skin contact, inhalation or ingestion. Protection options are usually particularly effective in providing protection against all these exposure pathways. Some more permanent protection options, such as burial of contaminated material or permanent change of water supply, may also be effective for environments contaminated with extremely persistent chemicals.

The effectiveness of a protection option is defined as the reduction in the exposure from a surface (e.g. buildings, paved surfaces, grass and shrubs) and reduction of contamination levels in the target medium (e.g. soil, crop or animal products) or contaminated water source (e.g. mains water supply, private well, marine or recreational water source) after implementation of the option.

The effectiveness of protection options depends on the physicochemical properties of the chemical(s) present and the type of protection being used. There may be limited evidence to gauge whether one protective recovery option is more effective than another.

2.1.1 Types of protection

Several protection options exist, including:

- Removing the contaminant.
- Isolating the contamination.
- Burying and covering objects or crops.
- Restricting access of people or relocating people from the area, including storing of objects.

- Restricting entry into the food-chain.
- Fixing of contamination.

Protection materials can be placed between the contamination and receptors (burial and covering of objects or barriers and holding areas). Examples include:

- The use of clean topsoil in gardens, or resurfacing roads.
- The use of holding tanks or tankering away contaminated water for further treatment.

Other treatments may include deactivating or reducing the hazardous properties of a water contaminant. Personal protective equipment (PPE) can also be used to prevent chemical contamination of individuals in the area or assisting in the recovery phase

Exposure can also be reduced by relocating the affected population (temporarily or permanently) away from the contaminated area, or restricting access to contaminated areas, objects or water supply. In this case, distance is the protective factor. These options may be more useful for chemicals with a short persistency as they may naturally degrade in the environment and not require any active specific remediation. See Table 2.1 for issues to consider with protection options.

Table 2.1: Protection Option Considerations

Advantages
They are less likely to have a lasting negative effect on the environment. Some options may improve the environment beyond its pre-incident condition (e.g. resurfacing roads).
People may be able to remain in the area during implementation, except for relocation options.
They are easier and quicker to implement than removal options
Using holding tanks may be effective at protecting against chemical exposure until contaminated water is removed or treated.
Fixing contamination to a surface may be effective at protecting against chemical exposure. Fixing options may also limit re-suspension or inhalational exposure while the fixing material is in place.
The chemical may degrade in the environment over time requiring no specific clean-up methods.
Issues to consider
Contamination is not removed from the affected area. Therefore, it may be necessary to deal with a public perception that the area is blighted.
If storage of contaminated water/ sediment options are implemented, the assumption has to be made that a subsequent treatment option will be available, which may not be the case (i.e. Buncefield fire and contaminated run-off water).
Restricting access to areas, buildings, objects and water environments or water supplies limits a return to normal living.
Fixing contamination to the surface may cause problems with future maintenance of the surface, which could give rise to exposure to the workforce and waste disposal issues.
The integrity of the fixing material may diminish with time, reducing its effectiveness.
If protection is provided by temporarily fixing contamination to a surface, the disposal of the materials used may be required, as they will become contaminated.
Treating contamination in situ may cause problems with future maintenance of the system which could give rise to exposure to the workforce and waste disposal issues.
If protection is provided by temporarily treating contamination by absorption, the disposal of the materials used may be required, as they can become contaminated.
If burial options such as ploughing are implemented, it should be ensured that they are effective in reducing exposure so that there will be no need to remove contamination later, since burial would make it more difficult.

2.2 Remediation/restoration options

2.2.1 Removal options

Removal options involve the decontamination or clean-up of contaminated surfaces and objects, including personal items (e.g. jewellery/ electrical items). The aim of any decontamination regime is to reduce contamination to a safe level. If that is not feasible, or safe levels have not been defined, then it is generally agreed that the aim is to reduce contamination to a level that is ‘as low as reasonably practicable’ (ALARP)[1]. However, if an area remains unsafe, permanent relocation may be required (as was implemented following the release of dioxins in Seveso, Italy in 1976[2]) or permanent restriction of access and bans or restrictions on hunting and fishing may be required.

What constitutes reasonably practicable will vary according to the situation and the value, importance and intended use of the area being decontaminated. There is a need to demonstrate that decontamination has been successful and to quantify any residual contamination. The risk associated with any residual contamination will determine the subsequent use of that area and is dependent on usage, exposure pathways and the population that might be exposed.

Considerations for removal options are listed in Table 2.2 however; one of the main issues to consider is that contaminated waste material will be produced, often in large quantities. There may also be major constraints on the use of removal options for historic buildings or buildings that are in poor condition where unacceptable damage to the fabric of the buildings may occur. For example, high pressure hosing and surface removal (e.g. sandblasting) may cause significant damage to old or poorly maintained brick or stone buildings.

Similarly, it may not be practicable to carry out decontamination techniques that directly affect the surface of objects due to the damage that such techniques may cause. For example, this may be particularly true for objects found in heritage buildings and museums, personal items (e.g. mobile phones) or sensitive equipment (e.g. electronic devices). These objects may, however, withstand gentle washing or vacuuming without causing damage to their surfaces. It is likely that disposal of some objects will be unacceptable because of their monetary or heritage value, and therefore if all decontamination techniques prove unacceptable or impracticable, storage or covering of the objects could be considered. It should be recognised that these objects may contribute very little to potential exposure and their cleaning would therefore often have the primary purpose of public reassurance[1].

The effectiveness of a remediation/restoration option can be defined as the reduction in the amount of contamination initially present on a specific surface (e.g. buildings, paved surfaces, grass and shrubs), or other target mediums (e.g. soil, crop or animal products) or contaminated water source (e.g. mains water supply, private well, marine or recreational water source) to that remaining after implementing the option.

There may be limited evidence to gauge whether a recovery option is more effective than another (i.e. is pressure hosing more efficient at removing contamination that using foams, gels or bleaches). The effectiveness may also vary depending on the physicochemical properties of the chemical(s) involved and the type of surface(s) contaminated following an incident. Expert advice would need to be sought before deciding on the most appropriate or effective remediation technique.

Table 2.2: Remediation (removal) option considerations

Advantages
Removal options remove contamination from the affected area.
The outcome should be permanent.
Effective in reducing exposure.
Surface removal works equally well for all types of contaminant, although the thickness of surface layers to be removed may be dependent on the contaminant(s). Use of chemical reagents may or may not be contaminant-specific.
Issues to consider
There may be some waste created due to removal or disposal.
They create disruption.
Risk of contamination spreading
It is likely that the techniques will have to be used on several surfaces to provide significant reduction in exposure e.g. different types of ceilings / walls etc.
Unacceptable damage may be done to building surfaces and objects, particularly if old or in poor condition.
Ensuring detection limits of monitoring equipment are accurate to ensure clean-up has been effective
There may be limited information on clean-up standards for the chemical involved.
Difficulties in selecting appropriate cleaning technique for different surfaces
Negative effect on the environment, e.g. topsoil removal may affect local habitats
Depending on the properties of the chemical some contamination may remain in the affected area unless extreme, environmentally damaging removal options are undertaken (e.g. demolishing buildings)
For some options it may be necessary to move people out of the area while the contamination is removed. This would almost certainly imply temporary closure of schools, hospitals and businesses, for example.

2.2.2 Water treatment options

Water treatment options involve the decontamination or clean-up of contaminated water environments. Issues to consider with water treatment options are listed in Table 2.3 however; one of the main problems is that large quantities of contaminated waste water or material may be generated. There may also be major constraints on the use of removal options for sites of special scientific interest (SSSI) sites where unacceptable damage to the environment may occur. For example, excavation and in-situ water treatment may significantly damage locally protected habitats.

Table 2.3: Water treatment options considerations

Advantages
They remove contamination from the affected water system.
They reduce or remove exposure to the chemical
Issues to consider
Some treatment options create waste.
Some treatment options may create disruption.
Some treatment options could have a negative impact or effect on the environment.
Depending on the physicochemical properties of the chemical, contamination may remain in the affected environment unless extreme, environmentally damaging removal options are undertaken.
For some options it may be necessary to move people out of the area while the contamination is removed. This could imply temporary closure of schools, hospitals and businesses, for example.

2.2.3 Self-help recovery options

Self-help recovery options are simple measures that may be carried out by persons living in the affected areas rather than skilled workers and which, in general, require no specific expertise or experience to be implemented. For example, members of the public could use household cleaning agents to remove chemical contamination from surfaces within their homes or remove topsoil from their gardens using a spade. The main considerations and issues to consider with self-help recovery options are given in Table 2.4. Some technical factors require specific consideration prior to the initiation of self-help recovery options (refer to Table 2.5)[1].

Table 2.4: Self-help recovery options

Advantages
They involve people affected, with the aim of improving their own situation (take positive action). This can help them understand the relative importance of different exposure routes and lead to a better understanding of how exposures can be reduced.
Those affected are in control of the situation and the knowledge obtained through direct involvement can prevent unnecessary anxiety.
Those affected may know exactly what has been done to improve their situation and how well it has been done. They have the benefit of introducing an extra labour resource so that clean-up time can be reduced (e.g. grass cutting and collection).
Members of the public participating in recovery operations are not subject to the same regulations, legislation and occupational exposure limits as recovery workers (i.e. Health and Safety at work Act, 1974) but are subject to the standards applicable to members of the public (e.g. ambient Air Quality Objectives).
They comply with important ethical values of autonomy, liberty and dignity.
Issues to consider
People participating in recovery operations would require appropriate protection and education/training regarding clean-up.
Self-help options are carried out on a voluntary basis.
Carefully worded and detailed communication with the people participating would be required. This could take considerable time to implement.
May be difficult to control and standardise clean-up. For example, people may adopt different techniques with varied consistency across the affected household, i.e. some people may ignore the advice (inconsistent response to advice) and others may make an attempt, but not adhere to it particularly rigorously (ineffective or partial response).
Can be difficult to confirm completeness of clean up.

Table 2.5: Technical factors to consider for self-help recovery options

Factor	Comment
Safety precautions	These are listed in recovery options (see Section 3). As self-help recovery options introduce a higher degree of autonomy, it needs to be stressed that no recovery option should be implemented before adequate safety education, training, detailed instructions and equipment are in place.
Specific protection of unskilled people	Methods involving undue risk (e.g. work at elevated height or use of chainsaws) have been excluded by default. In addition, people may also not be physically fit for the work.
Safety in connection with waste handling	People may receive relatively high exposures near piles or vessels containing concentrated contaminated material generated by self-help measures (e.g. from topsoil removal). Inhabitants would need careful instruction to minimise time spent in such locations over the period before the waste is collected.
Information on objective	The objective of a recovery option should be clear. This may partially be done through leaflets, but for some recovery options (e.g. digging), initial supervision would be recommended, as adverse effects of incorrect implementation may be difficult to rectify.
Availability of equipment	Most of the primary equipment required would need to be readily available. Also need to consider the cleaning or potential disposal of equipment following implementation. Some additional equipment may need to be secured and this will need to be made available on the required timescale.
Monitoring in optimisation	Monitoring by skilled workers to determine the chemical(s) involved and contaminant distribution should precede techniques involving soil digging or removal of soil layers.

2.2.4 Implementing recovery options with people *in situ*

It may be difficult to undertake recovery in an area in which people are still living and working or using for recreational purposes. It is recognised, however, that it might not be possible to relocate people temporarily during this time, particularly if the number of people involved is large, or if individuals are reticent about moving. Relocation could also lead to spread of contamination to new areas (e.g. via dust).

If decision makers wish to avoid either moving people temporarily out of an area or restricting access to it during the implementation of recovery options, the following factors should be considered:

- Advise them to remain indoors and keep windows closed etc, ensure a good communication strategy.
- Awareness that many people may not avoid an environment known to be contaminated in which case the area will need to be made secure.
- Provision of a comprehensive information service. With relevant advice, reassurance and multi-agency information, many people may be prepared to avoid contaminated areas if they understand the risk (e.g. remaining in homes).
- Recovery operations should be carried out as quickly as possible which may influence the selection of recovery option.

It may not be acceptable for workers implementing recovery options to wear special clothing and personal protective equipment (PPE) if individuals choose to remain in the area. Workers may be required to wear respirators since they may cause some re-suspension by their actions. In this case, prior information would need to be provided to the watching public as to why similar protection was not provided for them.

2.3 Waste disposal (fate of affected produce) options

Some of the recovery options recommended in this handbook will result in the generation of waste or waste by-products (e.g. water run-off) due to the nature of the recovery and clean-up process. This waste will also require appropriate decontamination (e.g. incineration or burial). Remediation work may generate large quantities of waste which must be managed appropriately. When dealing with waste from the recovery phase of a chemical incident it is necessary to determine whether the contaminated material is hazardous or not, how it should be removed and whether it should be treated on site or off site.

An important factor to consider following a large-scale incident is whether normal waste disposal routes within close proximity to the incident will be fit for purpose. For example, there may be large amounts of contaminated soil or dismantled building materials for which local facilities (e.g. landfill and incineration plants) may lack sufficient capacity and technology to deal with the waste. Therefore, the handbook also includes less common waste disposal options such as disposal of contaminated milk to sea, burial of carcasses and burning in-situ which can be considered in extreme cases (see Sections 5, 7 and 9).

It should also be noted that, following a large-scale incident, the relevant statutory bodies and regulatory authorities can use exceptional measures to force companies to halt their existing activities at short notice and make their plants available for the treatment of contaminated material, subject to the technology being available at such sites. In such cases normal waste management regulations may be suspended temporarily to enable contaminated material to be treated subject to conditions being met. The Environment Agency has the power to vary an environmental permit so that the facility, subject to conditions being met, could process waste in an emergency[7].

Several important criteria need to be considered in the selection of the most appropriate waste disposal options, including:

- Characteristics of the waste.
- Legislation concerning disposal routes for the waste.
- Capacity of disposal facilities.
- Agricultural impact following disposal.
- Environmental impact following disposal.
- Potential impact of chemical during and after disposal.
- Societal/ ethical issues.

Each of these criteria is influenced by site-specific information, which is summarised in Table 2.6.

Table 2.6: Recovery options giving rise to waste

Food production systems	Waste produced
Restriction on entry of food into the food chain/withdraw from market	Crops, milk and meat
Control of entry into the food chain	Animal carcasses
Issue a FEPA order	Crops, milk, honey, eggs and meat
Processing or treatment of food products	Crops, milk, eggs, honey and meat
Culling of livestock	Animal carcasses
Rendering	Rendered food products (animal carcasses)
Incineration	Fly ash
Removal/ relocation of topsoil	Soil
Inhabited areas	**Waste produced**
Reactive gases and vapours	Waste by-products
Reactive liquids (bleaches, detergents, foams, gels)	Solution run off, Waste by-products
Physical decontamination techniques	Contaminated material (e.g. absorbent material)
Pressure hosing	Water run-off
Vacuum cleaning	Contaminated debris and dust
Surface removal (buildings)	Contaminated debris and dust
Other (water based) cleaning methods	Water run-off
Fixative/ strippable coatings	Contaminated media
Outdoor surface removal and replacement (road, soil)	Soil, debris
Water environments	**Waste produced**
Drain to temporary storage	Contained waste
Discharge off-site disposal (tankering)	Contained waste
In-situ treatment and discharge	Water
Flush out water distribution system	Water
Treatment of sludge	Concentrated waste
Drainage of inland, recreational or coastal (controlled) waters	Water
Removal/ containment of sediment	Concentrated waste
Containment: Use of booms, dams and absorbent material	Water and contaminant

The issues that need to be considered for waste disposal are summarised in Figure 2.1. For more information on waste categorisation and legislation refer to Appendix A.

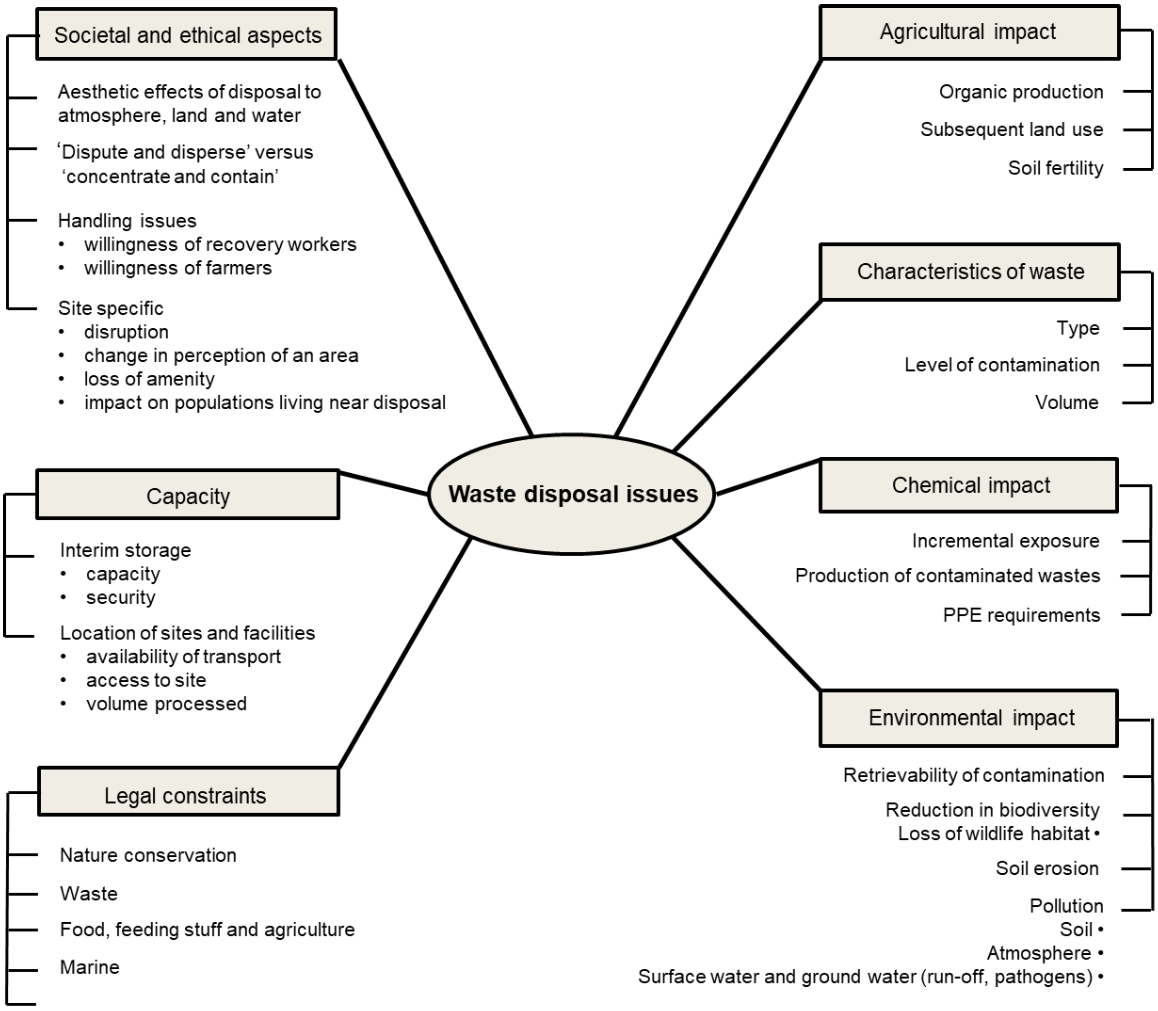

Figure 2.1 Summary of the principle factors influencing disposal of waste

2.4 Decision not to implement any recovery options

In some circumstances, the authorities may decide that the most appropriate course of action is not to implement any recovery options. If this decision is taken it should always be accompanied by a monitoring strategy and a good multi-agency communication strategy to reassure the local population. This option (natural attenuation (with monitoring)) should be considered if the information available (measurements from environmental monitoring and results of assessments) indicate that the exposures of people living in the area would be insignificant. No judgement is made here on what would constitute an insignificant exposure; that would need to be ascertained on an incident specific basis with appropriate specialist toxicological input. Other factors could make the decision not to implement any recovery action applicable, such as availability of limited resources, a very large area being affected or the chemical having a short persistency. The main issues to consider with not implementing any recovery options are outlined in Table 2.7.

Table 2.7: Considerations for not taking remedial action (i.e. natural attenuation with monitoring)

Advantages
Implementing recovery options may be perceived as indicating that there is a problem even if potential exposures are so low that they are being undertaken to provide reassurance.
Perception of affected area from outside may be better (i.e. incident is not perceived as a real problem; people are living normally). Economic and social blight may be reduced.
It sends out a clear message that risks are low and builds public confidence in decision-makers. Saying that the risk is low and still undertaking recovery options may give out a mixed message.
No waste is produced. Some clean-up options that may be undertaken for public reassurance can create a lot of contaminated waste, such as grass cutting.
Promotes faster return to normal living in the area.
Issues to consider
It requires very good communication with the community and media to reassure people that risks are low and that they should accept the decision not to implement recovery options. If risks are present a cleanup strategy should be implemented.
If recovery options are implemented the public may be more eager to return to their homes, as active remediation may be interpreted as ‘doing something’ rather than a ‘do nothing’ approach.
The implementation of recovery options is visible and may provide reassurance to people inside and outside the contaminated area.
Natural attenuation needs to be linked with a very rigorous monitoring strategy. Such monitoring might not be time or resource effective compared to the implementation of an active remediation approach. There may also be difficulties with the limits of detection of the monitoring equipment.
Not implementing any recovery options may send out a message that the response organisations and other organisations don’t care enough about the community.
Decision-makers need to define the boundaries of the area in which recovery options are not implemented (i.e. compared to where they are being implemented.
If restrictions have been placed on food consumption, there will need to be careful explanation of why these are required while no action is taken to deal with the contamination in inhabited areas.

2.5 Identified options

When selecting recovery options, it is useful to consider them according to their timescale for implementation. In the early phase (short-term), prompt precautionary protective actions may be necessary. For example, an incident resulting in a chemical plume may require rapid action such as; closure of air intake systems at food processing plants, protection of harvested crops from contamination, prohibiting public access to non-residential areas and advising people to remain indoors with windows closed.

Recovery options also need to be selected based on the levels of contamination present and land use. Typically, there will be areas where contamination levels are very high and priority has to be given to the direct protection of the population to minimise health effects (e.g. by sheltering and evacuation). In these areas, particularly if resources are limited, protective measures for agricultural production may need to be treated as a lower priority.

The type of area affected, location and size can influence the choice of recovery options. Area size may affect the speed with which a recovery strategy can be implemented, what it entails and the timescale on which it can be completed. Small areas of contamination may be more easily cleaned than large areas and more options may be practicable, however they might also be more isolated and harder to implement. Furthermore, the type of area and its location are important factors. If a residential area with high numbers of inhabitants is contaminated, there will be a greater pressure from the public to ensure that it is still safe to live there, send children to school or play in the parks or that the water is safe to drink. If the location of an incident affects priorities which may be linked to tourism, political sensitivities, economic stability or critical facilities and infrastructure, there will also be increased pressure to minimise or mitigate the contamination promptly[1].

The implementation of recovery options is generally the responsibility of local authorities; however self-help options, which may be implemented by the affected population, could also be useful. It is also important to note that the option not to carry out any recovery (i.e. natural attenuation) can be a valid alternative[1]. Recovery options may be used in combination and should be evaluated on an incident and site-specific basis, depending on the characteristics of the incident, as different options may be more relevant as an incident progresses.

The following timescales will be applied to the implementation of recovery options[1].

- **Early phase**, with a time scale of hours to days following an incident. This phase will require precautionary or protection measures to be in place while recovery options are considered. Monitoring and sampling analysis for measurements of chemical concentrations within the environment may be limited and decisions will be based primarily on predictions of likely exposure (i.e. modelling) and concentrations in the environment. The knowledge of the chemical involved may also be limited.
- **Middle phase**, potentially extending from weeks to months after the incident. During this phase, monitoring programmes will be in place and sufficient data will be gathered over time. Decisions to cease early-phase protective recovery options or to introduce new recovery options (i.e. remediation and restoration options) will be based on a reasonably complete picture of contamination and affected areas.
- **Late phase**, with a timescale of several months up to more than a year. In some environments (i.e. food related incidents) this could extend to decades in some instances (e.g. incidents involving dioxins). During this phase, an optimisation of strategies should be possible to reduce receptor exposure, minimise the impact of, or eliminate chemicals in the environment, permit long-term recovery and allay concerns (i.e. public health implications, economic impact, societal and ethical issues).

In total there are 85 recovery options in the handbook; Food Production systems (39), Inhabited areas (24) and Water environments (22), which encompass the main actions that can be carried out in these environments to reduce the impact of chemical contamination and consider most of the criteria that decision makers might wish to consider when evaluating different options. Table 2.8 – Table 2.10 provides a list of these recovery options with hyperlinks to the full recovery option sheets. It should be remembered that an incident may contaminate food production systems and/or inhabited areas and/or water environments and therefore it may be necessary to consult all relevant sections of the handbook.

Table 2.8: Index of recovery options for Food Production Systems

Protection options (actions taken to protect the food chain)
(1) Closure of air intake systems to minimise the contamination of food processing plants and foodstuffs within them
(2) Prevention of contamination of greenhouse crops
(3) Protection of harvested crops from contamination
(4) Short-term sheltering of animals
(5) Restriction of entry of food into the food chain/withdrawal from market
(6) Product recall
(7) Control of entry into food chain
(8) Issue of a FEPA order
(9) Precautionary (dietary) advice (non-commercial)
(11) Ban or restrictions on hunting and fishing
(12) Restrictions on foraging
Restoration options (return production system back to normal)
General applicability
(10) Processing or treatment of food products
(14) Selection of alternative land use
(23) Natural attenuation (with monitoring)
Soils/crops/grassland
(16) Ploughing methods
(18) Land improvement (for ‘natural’ pasture)
(19) Removal/ relocation topsoil
(20) Soil washing/ irrigation of agricultural land
(21) Adjust pH of soil
(22) Application of potassium fertilisers to arable soils and grassland
Livestock and animal products
(26) Administration of chelation to animals
(27) Addition of supplements to concentrate ration
(28) Administration of clay minerals to feed
(29) Clean feeding/ selective grazing regime
(30) Suppression of lactation
(31) Restrictions on animal breeding
Fate of affected produce (waste disposal)
(13) Temporary derogation

(15) Selection of alternative product use
(17) Ploughing in of a standing crop
(24) Biological degradation/ decomposition
(25) Bioremediation
(32) Culling of livestock
(33) Burial of carcasses
(34) Disposal of contaminated milk to sea
(35) Burning in-situ
(36) Rendering
(37) Incineration
(38) Landfill
(39) Land spreading of milk and/ or slurry
Notes: The order in which the datasheets are presented should not be taken as the preferred order of their implementation. All options should be considered.

Table 2.9: Index of recovery options for Inhabited Areas

Protection options
(1) Restrict public access
(2) Controlled workforce access
(3) Impose restrictions on transport
(4) Temporary relocation from residential areas
(5) Permanent relocation from residential areas
Remediation options
(6) Reactive gases and vapours
(7) Reactive liquids (bleaches, detergents, foams and gels)
(8) Physical decontamination techniques
(9) Other (water-based) cleaning methods
(10) Pressure hosing
(11) Vacuum cleaning
(12) Surface removal (buildings)
(13) Fixative/ strippable coatings
(14) Dismantle and disposal of contaminated material
(15) Modify operation/ cleaning of ventilation systems
(16) Cleaning vehicle ventilation systems
(17) Storage, covering and gentle cleaning of precious objects
(18) Natural attenuation (with monitoring)
(19) Outdoor surface removal and replacement
(20) Soil and vegetation removal
(21) Ploughing/ digging methods
(22) Snow/ ice removal
(23) Barriers to seal land contamination
(24) Burial in situ

***** The order in which the recovery options are presented should not be taken as the preferred order of their implementation. All options should be considered.

Table 2.10: Index of recovery options for Water Environments

Public water supplies
(1) Isolate and contain water supply
(2) Alternative drinking water supply
(3) Restrict water use (Do Not Use/ Do Not Drink notices)
(4) Changes to water abstraction point or location of water source
(5) Controlled blending of drinking water supplies
(6) Continuing normal water treatment (supported with a monitoring programme)
(7) Modification of existing water treatment
(8) Water treatment at point of use [tap]
(9) Drain to temporary storage
(10) Discharge off-site disposal (tankering)
(11) In-situ treatment and discharge (foul, land, surface water)
(12) Flush out water distribution system
Private water supplies
(1) Isolate and contain water supply
(2) Alternative drinking water supply
(3) Restrict water use (Do Not Use/ Do Not Drink notices)
(4) Changes to water abstraction point or location of water source
(6) Continuing normal water treatment (supported with a monitoring programme)
(7) Modification of existing water treatment
(8) Water treatment at point of use [tap]
Sewage Treatments
(14) Treatment of sludge
Inland, recreational, coastal and underground (controlled) waters
(15) Restrict access to inland, recreational or coastal (controlled) water environments
(16) Restrict transport within inland, recreational or coastal (controlled) water environments
(17) In-situ treatment of inland, recreational, coastal or underground (controlled) waters
(18) Drainage of inland, recreational, coastal or underground (controlled) waters
(19) Removal/ containment of sediment
(20) Containment: Use of booms, dams and absorbent material
(21) Retrieval of chemicals
(22) Burning in-situ

* The order in which the datasheets are presented should not be taken as the preferred order of their implementation. All options should be considered.

A number of factors should be taken into account when developing a strategy for the long-term recovery of a contaminated inhabited area, water environment or food production system. Figure 2.2 is an overview of the most important factors that might need to be considered although decision-makers, implementers and other stakeholders may identify additional ones.

Not all factors will be relevant for all incidents and their relative importance is also likely to vary depending on the nature, severity and scale of the incident. Some of these factors can be considered in detail as part of planning, as discussed further in the technical sections for Food production systems (Section 4) Inhabited areas (Section 6) and Water environments (Section 8). Other factors and their importance will only be able to be assessed at the time of an incident.

The most important factors to consider regarding the implementation of recovery options may include:

- Temporal and spatial factors.
- Effectiveness of recovery options.
- Toxicity and physicochemical properties of the chemical(s) of concern.
- Protection of workers.
- Protection of the general population and sensitive sub-populations.
- Waste disposal issues.
- Societal and ethical aspects.
- Environmental impact.
- Economic cost.
- Communication and information issues.

Each factor is considered in more detail in Section 2.6.

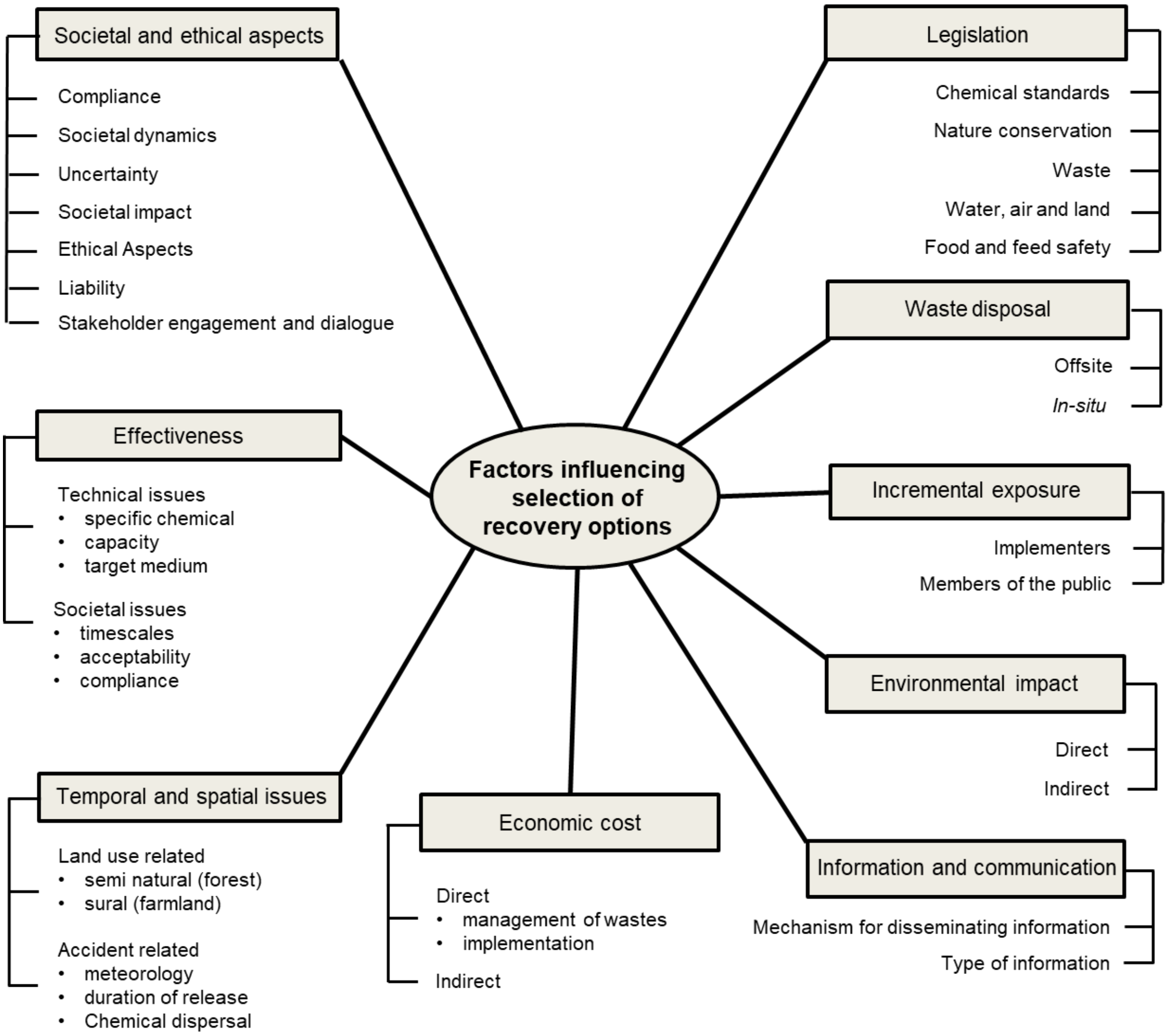

Figure 2.2 Summary of main factors influencing selection of recovery options

2.6 Factors influencing selection of recovery options

2.6.1 Temporal and spatial factors

The consequences of a chemical incident depend on the time of the release, e.g. if the release occurred in the middle of the night, fewer people are likely to be outside and directly contaminated. Similarly rush hour in an urban area / school drop off times could result in larger numbers of members of the public being exposed.

Some chemicals react very quickly and do not persist in the environment (e.g. hydrogen cyanide or sarin), whereas other more persistent chemicals can remain for years (e.g. dioxins and asbestos). Chemical(s) may also transfer from the location where they are deposited due to weathering (e.g. leaching from soils into groundwater), vehicle or people movement, or through the food chain to the food processing system. As a result, the time from when the chemical(s) is released and entry into the exposure pathway is of great importance. Furthermore, the spread of contamination in the area may increase or decrease over time, depending on the physicochemical properties and how the chemical(s) degrades and disperses in the environment[3, 4].

The background levels of a chemical in the environment may also be important, especially those with a toxic threshold. For example, if an incident was to occur on an industrial site that had already been designated as contaminated land then remediation would have been indicated prior to the incident occurring. It may then be more difficult to remediate the site to an acceptable level given the original contamination.

2.6.2 Technical factors

Technical factors that can influence the effectiveness of recovery options can be relatively straightforward to identify with appropriate planning in advance of an incident (see Section 3) and do not depend on judgement or societal issues, and include:

- Availability of staff, equipment, methodology, transport, resources and access to the incident.
- Duration of the recovery strategy to facilitate return to normal (i.e. treatment and application).
- Physicochemical properties of the chemical(s) involved in the incident.
- Surface type (i.e. robust or sensitive), land use (i.e. agriculture, livestock and domestic use such as allotments) and water use (i.e. drinking water or recreational waters).

2.6.3 Social factors

The effectiveness of recovery options is also influenced by a wide array of social factors including the ability of authorities to control the movement of people in and out of the contaminated areas and their compliance with instructions and advice, e.g. people cannot be forced to comply, may not understand the instructions or be able or willing to follow them.

Societal factors arise from people’s behaviours, attitudes and perceptions. Unlike technical factors, the impact of societal factors on the effectiveness of recovery options is difficult to quantify and may depend on the acceptability of the option, based on judgement. Societal factors include:

- Timescale for decision-making and implementation of recovery options.
- Acceptability and compliance with procedures (implementers).
- Expertise and training in new technology.
- Acceptability to general population, consumers and environmentalists.
- Willingness of local populations to accept wastes.
- Willingness of privately owned facilities to accept wastes (this may also be influenced by commercial capacity and licence issues).
- Market for end products.

2.6.4 Societal and ethical factors

The consequences of a chemical incident not only raise technical and health-related problems, but also societal and ethical issues. Chemical contamination on a large scale has an impact on living conditions at an individual and community level and may have a severe impact on the economy. The event can also affect the relationships between those living inside and outside the contaminated area, especially if the area or population living there become stigmatised in some way.

Several studies have acknowledged the complexity and importance of social aspects when adopting a recovery strategy following a chemical incident. Despite the beneficial consequences of implementing recovery options some of the associated implications can decrease the quality of life of those affected. The implementation of recovery options is disruptive to normal social and economic life and may cause panic, stress or upheaval to those affected, possibly resulting in damage to health and well-being[8]. Those particularly susceptible are elderly people, parents with young families and pregnant women. Failure to take positive action and carry out protective measures may also cause anxiety, often exacerbated by a lack of objective information[8, 9].

On the other hand, the implementation of recovery options may help provide reassurance to members of the public and workforce. They may also have a positive impact by making an area look cleaner than it was originally or improve the condition of the infrastructure (e.g. improvements to the road and railway network). Local companies may be involved in the clean-up operations and thus may benefit financially.

Societal and ethical factors are also relevant to the management of the contaminated areas. The implication of any actions on the population should be considered taking into account individual and community concerns and recognising the need to involve local stakeholders in the identification of problems and their solution.

Many studies have emphasised the importance of engaging with stakeholders to assess the social implications of a recovery strategy[8, 10, 11, 12, 13, 14]. The involvement of stakeholders may take account of attributes other than those directly related to protection from chemical contamination[8]. The objective is that those concerned with the situation should be involved and given the opportunity to participate in the decision-process under non-crisis conditions. Stakeholder involvement is an important component of the decision-making process, and in some cases, it is essential for arriving at an accepted solution and for building trust in decision-making authorities[13]. Societal factors that may influence recovery priorities are summarised in Table 2.11.

Societal and ethical aspects must also form part of the decision-making process. Decision-makers should define the strategy not only according to technical criteria, but also to cultural and ethical points of view. In practice, the choice of recovery option will almost always involve a balance or trade-off between public health, economic and social consequences, as well as trade-offs between the interests of different stakeholders and communities of stakeholders. Such complexity means that it is difficult, if not impossible, to predict the way in which these factors may impact on the situation. A process involving discussion of all the issues at stake with the people affected form a necessary part of any recovery strategy.

In this respect a variety of tools and procedures can be used to help initiate a discussion of societal and ethical aspects. Such processes need to be open, transparent and inclusive, and directed towards both citizens and technical experts (see Section 2.10).

Table 2.11: Summary of some societal factors that may influence recovery priorities

Factor	Comments
Health impacts	Has, does or will the contamination arising from the chemical incident adversely affect the health of people?
Number of people affected	If large populations are affected, the impact for public health may be significant even if individual exposures are not high. Similarly, the collective disruption caused by implementing recovery options will be high. There may be pressure to give priority to highly populated residential areas or areas where many people work compared with sparsely inhabited rural areas.
Location	The location of a chemical emergency affects priorities, which may be linked to tourism, political sensitivities, economic stability or critical facilities and infrastructure. Proximity to sensitive receptors (e.g. location of schools, hospitals, nursing homes)
Type of chemical incident	If an incident involves a deliberate chemical release (e.g. Sarin, Tokyo) the public may believe there is a risk of further chemical release. People may be less willing to return to their normal areas to work or live. An accidental industrial release may lead to mistrust in the installation involved and even authorities that were responsible for regulating the installation. In addition, if a persistent chemical has been released into the environment the recovery strategy may be more complicated and protracted requiring a prolonged period of relocation.
Societal dynamics	Societal dynamics will depend on politics (international, national and local), the economic situation and mobility of the population and workforce.
Are people living in the contaminated area? Have they been evacuated in the emergency phase?	Priority may be given to residential areas where people have not been evacuated. Subsequently, priorities within residential areas may be set based on predicted exposure. Practicability of options and priorities within an area may be affected by people not having been relocated. If people have been evacuated it may be possible to extend the time that they are out of the affected area to implement the chosen options but will affect stress levels / pressures on infrastructure. Some recovery options require access to public areas to be temporarily restricted. In addition, restrictions may be placed on some public activities following completion of recovery options (e.g. digging beyond a certain depth will be forbidden). Such restrictions may not be practicable or publicly acceptable and this needs to be considered when developing a recovery strategy
Economic stability. Need to keep businesses and infrastructure open.	Priorities may be biased towards commercial businesses, shops, roads, railways, hospitals, schools, crematoriums and other activities to ensure that the economy of the area isn't unduly affected and to support people living in the area.
Return to life as normal	Public or commercial facilities in the area which are considered critical may require high priority in any recovery strategy to ensure that they remain viable and safe.
Need to keep critical facilities and infrastructure open	It is likely that additional burdens may be placed on public services (e.g. schools and hospitals). Keeping schools and other public buildings open and allowing people to move freely in the affected area may become a priority to demonstrate life has returned to normal.
Damage to personal property	Personal property and objects, amenities and objects of heritage may be damaged or contaminated following the implementation of recovery options. Individuals may be unwilling to give up important personal items such as keys, phones, wallets, purses. These may need to be prioritised for decontamination. Issues regarding insurance of these items
Public perception of the affected areas from people living outside it	Public perception that the area is significantly contaminated can have profound social consequences. Industries and businesses may be affected as well as the identity of local communities and groups. It can be expected that tourists will not return to the affected area until normal life has been restored. It may take several years before the tourism industry is restored to the area, depending on the size of the incident.

Environmentally sensitive areas (officially designated or otherwise)	Pressure may be applied to give priority to a recovery strategy which favours the environment and protection of wildlife. Restricting or limiting access to workforce or the public may be sufficient to meet these needs.
Politically sensitive issues	At all levels of government political sensitivities and political agendas may influence recovery priorities.
Societal impact	There may be a loss of community cohesion or change in perception of an amenity or stigma attached to the location of the incident? There are additional factors to consider, including; disruption, change in confidence and trust of authorities, preserving local industry and reassuring the affected population.

2.6.5 Ethical considerations

Some of the key ethical considerations[14] that should be considered when developing a recovery strategy are given below.

- **Self-help options** (see also Section 2.2.3) that are carried out by the affected population, such as grass cutting, digging and indoor cleaning, can increase personal understanding or control over the situation. Furthermore, through their involvement, the population reinforce their autonomy, liberty and dignity. Conversely, imposed recovery options such as relocation can infringe upon liberty or restrict normal behaviour.
- **Animal welfare** is concerned with the amount of suffering the recovery option may inflict on animals such as zoo animals, pets, farm or wild animals.
- **Environmental risk** from changes to the ecosystem. Recovery options that change or interfere with ecosystems may have uncertain or unpredictable consequences for the environment. Environmental risk raises a variety of ethical issues including consequences for future generations, sustainability, cross-boundary pollution, and balancing harms to the environment/animals against benefits to humans. The acceptability of the recovery option will be highly dependent on the ecological status of the area and the degree to which the recovery option diverges from usual practice (e.g. shallow ploughing may be a normal practice whilst deep ploughing may not be). In most cases, environmental legislation must be considered.

2.7 Recovery workers

2.7.1 Protection of workers

Evacuation, recovery plans and remediation are likely to reduce the exposure of the public potentially exposed to contamination following an incident, but workers involved in remediation also need to be considered. Therefore, all the necessary precautions must be undertaken to safeguard their health.

Several protective measures may be chosen to reduce the risks to workers, according to the requirements of the specific situation and circumstances. Such measures include:

- Delaying implementation of recovery options (particularly if the chemical has a short persistency)
- Work time restrictions
- Ventilation

- Fixation
- Respiratory protection
- Eye protection
- Protective clothing.

Use of protective equipment should be optimised for the task and would depend on the physicochemical properties of the chemical involved. Excessive, unnecessary and clearly visible protection of workers (i.e. full HAZMAT suits) may contribute to the anxiety of local inhabitants of the area, therefore, its use would be justified. Safety precautions are discussed in general terms within individual recovery option sheets (see Section 5, 7 and 9)[1, 5].

2.7.2 Workers implementing recovery work

Recovery workers will be exposing themselves to an area which may have elevated levels of chemical contamination. Therefore, to safeguard their health and not expose them to unnecessary chemical concentrations, a risk assessment will be required and must form a fundamental part of any recovery plan.

Persons involved in recovery operations should be given occupational exposure health and safety advice. Those in charge of health and safety during the recovery phase should ensure that site specific occupational health and safety plans are developed appropriately. It is important to identify and assess the health and safety hazards from inception of the recovery strategy and to continuously monitor the safety of personnel working in the clean-up and remediation of the contaminated environment. Under certain circumstances, it may be necessary or beneficial, if possible, to carry out personal exposure monitoring for chemicals and/or to monitor physical stressors for responders/ recovery workers.

Recovery workers should be appropriately trained and provided with appropriate personal protective equipment (PPE) according to the level of alert or chemical hazard involved in the incident. This should be accompanied by appropriate decontamination of equipment and pre-planned entry and exit protocols to the site. The different levels of PPE involve the use of safety spectacles, goggles, face-shields, visors, helmets, disposable filtering respirators, air-fed helmets, breathing apparatus, overalls, boiler suits, specialist protective clothing, airtight suits, high visibility clothing, gloves, safety boots/ shoes with protective toe caps, gaiters and leggings amongst others. Generally, these are specific kits available to the recovery workers, the selection of which differs according to the level of perceived hazard. Categories of personal protective equipment range from I Simple, II Intermediate and III Complex, corresponding to increases in the level of protection[5]. However, excessive, unnecessary and clearly visible worker protection may contribute to the anxiety of local inhabitants of the area, therefore, its use should be justified[5]. Following a large scale chemical incident, it may be the case that volunteers are acting as recovery workers and hence require increased and intense training in the use of PPE.

Data (exposure, accident/injury documentation) should be collected and managed to facilitate consistent information sharing amongst the agencies taking part. This will also help in the provision of appropriate recovery worker medical surveillance and monitoring and highlight whether further long-term epidemiological studies are required. Workers should be supported with psychological aid during what may be exhausting work. All these tasks and insights into the specifics of recovery workers will help ameliorate future incident response training[5].

2.7.3 Occupational exposure limits

Worker Exposure Limits (WELs) are defined as:

“Concentrations of hazardous substances in the air, averaged over a specified period of time referred to as a time-weighted average (TWA). 2 time periods are used: long term (8 hours) and short term (15 minutes). Short-term exposure limits (STELs) are set to help prevent effects, such as eye irritation, which may occur following exposure for a few minutes.”

The WEL is derived as follows:

A: Set at a level at which no adverse effects on human health would be expected to occur based on the known and/or predicted effects of the substance;

or

B: Based at a level corresponding to what is considered to represent good control, taking into account the severity of the likely health hazards and the costs and efficacy of control solutions. Wherever possible, the WEL would not be set at a level at which there is evidence of adverse effects on human health[6].

Seek expert advice and guidance as WELS may not be available for a large proportion of chemicals, in which case a risk assessment and consideration of other occupational exposure guidelines may be required.

Secondary exposure of workers following implementation of recovery options also needs to be considered. For instance, if a decision is taken to asphalt (tarmac) over an area of chemical contamination, workers may be required access this area again in the future for other purposes (e.g. maintenance of water pipes).

2.8 Environmental impact

Recovery options could have both positive and negative environmental impacts therefore their impact on the environment should be considered during the decision-making process to ensure that the action is justified.

Positive environmental impacts may include removal of contamination from an area which may make land more fertile and local water courses cleaner, in some cases, as it may remove background contamination not associated with the incident. In addition, demolition of contaminated buildings could lead to regeneration of areas (e.g. new housing /infrastructure) and new technology to remove contaminants from water could lead to much improved water quality.

Negative environmental impacts may include the following:

- If a significant number of people are relocated temporarily, the area they relocate to may experience increases in traffic which may result in a negative environmental impact due to, for example, an increase in noise and air pollution.

- Where populations are permanently relocated, the siting of new buildings and infrastructure could impact negatively on the aesthetics of the environment (e.g. relocating to green belts).
- Where workforce access is prohibited to a building, the building and surrounding land could fall into disrepair depending on the duration of the access restrictions.
- Some recovery options could result in a decrease in biodiversity, a loss of plants and shrubs, a risk of soil erosion, partial or full loss of soil fertility, landscape changes, and other adverse effects. In addition, chemicals used as a fixative option can themselves contaminate soil.
- Covering a grass or soil area with tarmac to protect the population from contamination is likely to have a negative impact on the aesthetics of the environment, and therefore on the social acceptability of the recovery option[1]. It could also make an area more flood-prone.

2.9 Economic cost

The implementation of recovery options incurs economic costs, both directly and indirectly. Examples of direct and indirect costs are given in Table 2.12. The magnitude of these costs depends on many factors[1], including:

- Period over which a recovery option is implemented.
- Scale of the event: generally, costs are proportional to the area of land affected.
- Land use.
- Availability of equipment and consumables.

Table 2.12: Summary of some of the economic costs associated with implementing recovery option

Direct costs
Labour: salaries for the workforce involved (may need to be supplemented for work being undertaken), overhead costs to organise the work, requirement for additional staff to be brought in
Cost of hazard monitoring, such as equipment and medical follow-up.
Consumables: specific products are necessary for particular recovery options, including handling of waste (see recovery options in Section 5, 7 and 9)
Specific equipment: some recovery options (see recovery options in Section 5, 7 and 9) require dedicated equipment that may have to be hired or purchased (investment cost) and subsequently maintained and possibly decontaminated
Communication: information for the public (guidance on behaviour, information for transparency and reassurance, etc.), and for special groups such as the people implementing the options
Support from abroad (e.g. civil protection, police, military, overseas consultants etc.), leading to extra costs for travelling and subsistence, fees or salaries, etc.
Transportation

Verification of laboratory analyses or screening techniques

Direct costs for handling waste products

Labour
Storage as the cost of storage alone, without any added complexity, may be very significant
Special consumables for interim storage and processing of by-products after the intervention
Dedicated equipment: special containers etc.
The design of a short-, medium- or long-term storage facility
Decontamination of the equipment and clean-up
Transportation: distance to suitable disposal/ treatment facilities may be significant
Research and small-scale testing of waste recovery options
Biodegradability of food products may impose special requirements on their storage

Indirect costs

Changes to outdoor areas can have an impact on soil structure, fertility and may raise the risk of soil erosion. If options such as deep ploughing are implemented in areas where the water table is high, groundwater may be contaminated.
Loss of production because of the closure of business and industries with subsequent effects on individuals' salaries
Temporary or permanent restriction of access and a reduction or loss of tourism may have an impact on businesses (particularly small businesses). Impact may also be experienced across the whole region if tourists avoid areas near to the contaminated area for fear of contamination.
Restrictions on subsequent land use once recovery options have been implemented may mean that people cannot live or work in certain areas or return to a normal lifestyle. This may result in relocation costs or business closures.
Cost of replacing personal possessions / furniture following incidents indoors
Costs for relocation (feeding/ housing)
Infrastructure costs for closure if airports / railway station
Indirect loss down the supply chain when production is stopped, as particular supplies and services will no longer be required
The implementation of recovery options to restore or conserve both the agricultural potential of an area and the broader environment may cause changes in soil structure (e.g. in the case of deep ploughing) or acidity, and pollution of surface water (not only chemical but also biological)
The loss of market share. Even if the food products originating from the affected area comply with regulations, customers and, consequently, the retail industry may have lost confidence and refuse to buy the products even when the situation has returned to normality from a chemical point of view. Products from other regions will be imported to the market of the affected area, and this lost market share may prove difficult to recover.
Regional impact. Consumers may refuse to buy products from a much larger area than that directly affected (e.g. county, province, national or even international levels.
Indirect effects of recovery options such as reduction in fertility of soils and yields in the first few years after intervention

Restrictions on subsequent land use. Land may be used for non-food production requiring investment of resources in alternative seed stocks, expertise, new markets (e.g. processing industry) and marketing.
Impact on social and economic fabric, such as tourism but also on the whole economy of the region (if, for example the recovery option chosen is ‘alternative land use’). However, if it the outcome was that farmland was converted to a golf course, this would have a positive impact on the area and may even increase recreation use and attract tourism.

2.10 Information and communication issues

Following chemical contamination of the environment, information and communication issues will be of the utmost importance, regardless of the scale or extent of the chemical release. Effective handling of recovery depends on good and effective communication between the organisations involved in planning and implementing the recovery

When planning in advance of an incident (see Section 3), a communication framework can be set up. Such a framework would, in the event of an incident, ensure appropriate communication and provision of information to those affected. Should no planning be made for communication in advance, it may be extremely challenging to ensure that the process is accurate, appropriate and consistent in the event of an incident.

2.10.1 Mechanisms for communication and dissemination

One of the main challenges for the communication and dissemination of information is the maintenance of the public’s trust in the competence of the authorities and other organisations to deal with the situation. Trust is fragile, easy to lose and notoriously difficult to develop or regain once lost. Because knowledge will be limited in the early phase of an accident or incident, information should properly reflect such uncertainties, and any advice should be precautionary. In most cases, people also need information and advice on what they can do personally to reduce exposure, particularly with respect to their children.

2.10.2 Developing a communication framework

A framework for information and communication strategies should be developed under non-crisis conditions. This should be set up in the planning phase and be dynamic to fit with the evolution of the situation and problems through time and space. A few key points require consideration:

- From the earliest stage of an incident, it is essential that all communication comes from a single body, with an agreed process for agreement and clearance, to ensure that there is no ambiguity, inconsistency or contradiction in messages going out to the affected community (including local population, businesses and special interest groups).
- The type of information disseminated should be tailored to meet the needs of a variety of people (i.e. those inside and outside the affected area, those involved in implementing actions, those affected by the actions).
- The form of communication should be adapted to different levels of understanding, to reflect the circumstances under which people live, and to address the specific issues and problems being faced.

- The process of information and communication will work in parallel with the development of recovery strategies.
- At all stages of the response, authorities should not underestimate the constant need for information, the need to consult different stakeholders including experts and lay people, to learn about the needs and expectations of communities, what they know and what they do not know, what the uncertainties are and other issues.

Some of the communication and information issues that should be considered when developing a recovery strategy are:

- During the early phases of a chemical incident, there is generally a lack of information available. Therefore, at these stages, there is much reliance on predictions about the scale and impact of the contamination and expected consequences.
- Information concerning the public health impact or risk of associated health effects associated with the chemical of concern would have to be carefully considered, to avoid unnecessary anxiety or stress (i.e. "worried well") in the affected area.
- As the situation develops sources of information and routes for dissemination grow rapidly, therefore a robust communication strategy needs to be established and adhered to.
- Prior to and during implementation of recovery in the affected area, a well-focussed communication strategy and dialogue should operate between affected populations and other stakeholders. Information should deal with how the affected area will be remediated, how the process will work, by whom and what the societal, economic and environmental impacts might be.
- Care must be taken regarding what information is placed in the public domain, and by what means. Differences of opinion between stakeholders involved in the recovery process might lead to greater disquiet. It is essential that every opportunity for dialogue and debate about appropriate recovery strategies is taken to pre-empt these situations as much as possible.
- Clear, pre-planned protocols for communication with the media are essential. Media messages play a vital role in public order following a chemical incident.

The development of a detailed communication strategy is not discussed further in this handbook.

2.11 References

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3 Planning for Recovery in Advance of an Incident

The response to the effects of a major UK accident or emergency is managed primarily at the local level. The emergency zone could vary from a couple of hundred metres to a much wider area depending on the chemical involved and its dispersion. Emergency plans are drawn up in advance of an incident to provide an effective response within an emergency planning zone. They are easily applied and are universally accepted. Emergency plans do not always include actions to be taken in the post-emergency phase (i.e. recovery phase) when it is much more difficult to be prescriptive about actions to take due to variations in local circumstances. For example, emergency plans may give an indication of how to temporarily relocate a population but may not consider the issues arising from a population having to permanently relocate.

The purpose of this chapter is to support the emergency planning process by identifying the key topics that would need to be addressed and information that would be needed to support the development of recovery strategies. Although much depends on the nature of the emergency or incident (e.g. its magnitude and the extent of chemical contamination), consideration of topics such as ‘requirements for information’ and ‘outline arrangements’ prior to the occurrence of an incident would benefit the speed of recovery response and may also ensure a more successful outcome.

Planning and preparation is key to responding effectively to a chemical incident. There are a range of guidance documents available on the web to help with planning in advance of an incident and are outlined in Table 3.1.

3.1 Preplanning for the recovery of Food Production Systems

In agricultural areas, significant quantities of contaminated foodstuffs can arise following a release of chemicals following an incident. Restrictions on the movement and sale of this produce are likely to extend out to large distances on a national or international scale depending on the physicochemical properties of the chemical (i.e. well beyond any areas subject to emergency response within the detailed emergency planning zone). In general, the size of an affected area will dictate the complexity of a response and recovery plan. Given the perishable and biodegradable nature of foodstuffs it is particularly important to develop outline arrangements for disposing of waste food. These arrangements are likely to be site specific according to the characteristics of the local infrastructure[1].

Table 3.2 provides a breakdown of topics covering data and information requirements that could usefully be gathered in advance of an incident. The development and sharing of localised databases on commercial and private food producers, dietary habits, suppliers of raw materials, contractors, waste disposal facilities and other information need to be considered. Some of these databases may already exist, but even then, it is not widely known who the point of contact would be and who would have responsibility for maintaining the databases (the type of information stored could rapidly become out-of-date). The list of information requirements presented in Table 3.2 is quite wide ranging and it is appreciated that significant effort may be required to assemble such information. Clearly, priorities would need to be assigned to help make best use of available resources. Table 3.3 gives a list of factors, in addition to the information requirements listed in Table 3.2 that might need to be

Table 3.1: Summary of some of the National planning and preparation guidance

Name of document	Published by	Date (version)	Web Address
Guidance on development of a Site Clearance Capability in England and Wales	Department for Communities and local Government	2012	https://www.gov.uk/government/publications/site-clearance-capability
Strategic National Guidance: The decontamination of buildings, infrastructure and open environment exposed to chemical, biological, radiological or nuclear materials.	Cabinet Office	2012	https://www.gov.uk/government/publications/strategic-national-guidance-the-decontamination-of-buildings-infrastructure-and-open-environment-exposed-to-chemical-biological-radiological-or-nuclear-materials
Arrangements for Health Emergency Preparedness, Resilience and Response from April 2013	Department of Health	2012	https://www.gov.uk/government/publications/arrangements-for-health-emergency-preparedness-resilience-and-response-from-april-2013
National Risk Register	Cabinet Office	2012	https://www.gov.uk/government/publications/national-risk-register-of-civil-emergencies
Preparing Scotland: Scottish Guidance on Resilience	The Scottish Government	2012	https://www.gov.scot/publications/preparing-scotland-scottish-guidance-resilience/
Emergency responder interoperability. Lexicon of UK Civil Protection Terminology	Cabinet Office	2011 (version 2.0.1)	https://www.gov.uk/government/publications/emergency-responder-interoperability-lexicon
Nuclear Emergency Planning Liaison Group: Consolidated guidance	Department of Energy and Climate Change	2011	https://www.gov.uk/government/publications/national-nuclear-emergency-planning-and-response-guidance
Emergency Financial Assistance Scheme	Welsh Government	2011	https://gov.wales/emergency-financial-assistance-bellwin-scheme-local-authorities
Emergency Response and Recovery	Cabinet Office	2010	https://www.gov.uk/government/publications/national-nuclear-emergency-planning-and-response-guidance
Protecting against terrorism	Centre for the Protection of National Infrastructure	2010 (3rd edition)	https://www.cpni.gov.uk/system/files/documents/5a/c9/Protecting-Against-Terrorism.pdf
Support for Recovery from Exceptional Emergencies	Department for Communities and Local Government	2009	https://www.gov.uk/government/publications/support-for-recovery-from-exceptional-emergencies
UK Recovery Handbook for Radiation Incidents	Public Health England (Centre for Radiation, Chemicals and Environmental Hazards)	2009	https://www.gov.uk/government/publications/uk-recovery-handbook-for-biological-incidents
The Public Health Management of Chemical Incidents	World Health Organization (WHO)	2009	http://www.who.int/environmental_health_emergencies/publications/Manual_Chemical_Incidents/en/

CBRN incidents: clinical management & health protection	Public Health England	2008 v4	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712888/Chemical_biological_radiological_and_nuclear_incidents_clinical_management_and_health_protection.pdf
Management of Response to the Polonium-210 Incident in London.	City of Westminster	2007	https://www.researchgate.net/publication/228486299_Management_of_response_to_the_polonium-210_incident_in_London
Guidance on Claiming Emergency Capital Highway Maintenance Funding	Department for transport	2007	http://webarchive.nationalarchives.gov.uk/+/http://www.cabinetoffice.gov.uk/media/230802/dcsf-funding-guidance.pdf
Guidance on the Possible DCSF Funding for Recovery from Future Emergencies	Department for Education		http://webarchive.nationalarchives.gov.uk/+/http://www.cabinetoffice.gov.uk/media/230802/dcsf-funding-guidance.pdf
National Recovery Guidance	Cabinet Office	2007	https://www.gov.uk/guidance/national-recovery-guidance
Precautions to minimise effects of Chemical, Biological or Nuclear Event on Buildings and infrastructure	Department for Communities and Local Government	2004	https://www.gov.uk/government/publications/precautions-to-minimise-effects-of-a-chemical-biological-radiological-or-nuclear-event-on-buildings-and-infrastructure
Recovery Guidance – Economic Issues: Financial Impact on Local Authorities	Cabinet Office		https://www.gov.uk/guidance/national-recovery-guidance-economic-issues
The Release of CBRN Substances or Material – Guidance for Local Authorities	Cabinet Office	August 2003	https://www.gov.uk/government/publications/the-release-of-chemical-biological-radiological-or-nuclear-cbrn-substances-or-material-guidance-for-local-authorities
Strategic National Guidance: The decontamination of people exposed to chemical, biological, radiological or nuclear substances or materials	Cabinet Office	2004	https://www.gov.uk/government/publications/strategic-national-guidance-the-decontamination-of-people-exposed-to-cbrn-substances-or-material
The Civil Contingencies Act		2004	http://www.legislation.gov.uk/ukpga/2004/36/contents

Table 3.2: Summary of data and information that could be usefully gathered in advance of an incident for Food Production Systems

Topic	Category	Data and information requirements
Land use	Agricultural production – Milk	Availability of or access to databases providing information on the following: • rapid identification of milk producers in an area. • rapid identification of milk purchasers within an area, since the geographical size of this area could be large if milk is transported for use in the manufacture of other foods. • rapid identification of private dairies and on-farm consumers. • rapid identification of haulage companies that would provide drivers willing to enter a restricted area if milk tanker drivers refused to do so. • rapid identification of other milk producing livestock, including sheep and goats. • rapid identification of small holdings with domestic livestock (e.g. goats and hens). Availability of buildings for sheltering livestock during passage of a chemical plume Availability of alternative animal feeds
	Agricultural production - Crops	Information on scale and importance of crop production in an area Information on harvest times for different produce
	Domestic production	Information on scale and importance of domestic production in an area Information on feeding regimes of domestic livestock Information on seasonality of production within the affected area Availability of or access to databases providing information on the following: • rapid identification of areas with allotments and small holdings. Availability of maps? • rapid identification of allotment holders and other types of domestic producer. • rapid identification of houses with private gardens.
	Gathering of free/wild foods	Information on scale and importance of free/wild food collection in an area Availability of or access to databases allowing rapid identification of areas where gathering of free foods is common at different times of the year
	Hunting/fishing	Availability of or access to database of people with licenses for fishing and hunting in the area (Environment Agency)
Recovery options	Raw material	List of raw materials required for implementation of options (fertilisers, lime, clay minerals, chelating agents) Construct database giving local, regional and national availability of raw materials including list of suppliers
	Equipment	List of equipment required for implementation of options and indication if this is 'specialist' machinery and likely to be in limited supply (e.g. for specialist ploughing, topsoil removal) Construct database giving local and regional availability of equipment including list of suppliers List of types of monitoring equipment available for particular purposes Availability of or access to national database of suppliers of monitoring equipment, including arrangements for dispatching equipment
	Infrastructure	Availability of or access to database with local/regional information on road networks, sewage and water treatment facilities, licensed landfill and incineration facilities, composting sites, milk processing plants, slaughterhouses and rendering facilities List of locations where contaminated material, equipment etc. may be stored

Topic	Category	Data and information requirements
	Personnel	Availability of or access to database of available contractors and organisations that can be contacted for advice on techniques, equipment, staff protection, health protection advisory services etc. Establish whether skilled personnel are required to operate equipment and the numbers that would be available in a particular area/region Establish criteria for working in contaminated areas Prepare template for risk assessment Identify training requirements where shortage of skilled workers
	Impact on geography and weather on implementation	Availability or access to meteorological information, including weather forecasts for local area and region. Impacts of long periods of adverse weather. Availability or access to geographical information systems providing information on soil types, topography, nitrate sensitive area etc.
	Impact on the economy/environment	Consider the likely scale of the economic impact from implementing each of the Recovery options, both direct and indirect effects Consider whether some options could have a negative impact on the local environment, e.g. Sites of Special Scientific Interest; national parks; Areas of Outstanding Natural Beauty; Nature Reserves, Historic buildings
	Acceptability	This is likely to be influenced by the type of chemical-incident, its scale, how the response is handled, the cause of the incident etc. However, public and other stakeholder views on the acceptability at the local level of the types of Recovery options available could be sought to reduce the number of options to be considered in the event of a chemical incident. Establish whether there is a framework in place locally for stakeholder engagement and agree in advance how it would be used.

considered when developing outline arrangements for a recovery strategy, focussed at the local level, in advance of an incident[1]. However, the role of sub-national resilience is to help plan for and co-ordinate response and recovery efforts through national response and recovery resilience forums and co-ordinating groups as appropriate

Table 3.3: Summary of data and information requirements that should be gathered in advance of a chemical incident for Food Production Systems

Topic	Factors and actions to consider
Generic strategy	Ensure information requirements (see Table 3.2) are prioritised, put into action, achieved and maintained – there should be confidence that information is complete, reliable and up-to-date Establish mechanisms for accessing information Identify priorities for recovery based on the main type of agricultural production in the area. Note importance of milk in this respect Consider generation of putrescible waste food arising and have shortlist of disposal routes available Develop a communication strategy with pre-prepared information for consumers, farmers, allotment holders, those engaged in fishing and hunting. Establish the audience, message and how it will be conveyed Consider the impact of seasonality on the recovery strategy Produce and maintain a risk register for things that could go wrong in the development of the strategy (e.g. non-compliance, local population won't engage in dialogue). Identify drivers and barriers and establish which ones will make the biggest difference
Roles and responsibilities	Make sure the roles and responsibilities of those agencies that would undertake tasks in the recovery response are well known Identify leading agencies and legal responsibilities. Establish how the roles and responsibilities change along the timeline Consider for each Recovery option how available resources will be co-ordinated and moved to the affected area, e.g. the use of army, civil protection. This should be done at the national level to ensure consistency Explore the best role for the local government and local agencies
Role of stakeholders	Identify existing stakeholder groups in the area e.g. Parish Councils, community groups, existing for a (Primary Care Trusts, schools). Investigate whether these could/would be prepared to provide feedback on a recovery strategy for the area. Consider processes that could be used to establish bespoke stakeholder panels where no relevant groups exist. Establish steps for each process considered.
Recovery options	Identify practicable and acceptable recovery options for use at the local level based on information provided in the UK Recovery Handbook for Chemical Incidents in advance. Try engaging with the stakeholders. Consider: 1. any constraints on the use of an option 2. impact of season 3. generation of wastes and how it would be managed 4. which options might be applicable according to type of emergency/incident scenario? Identify aspects for each recovery option that will require consideration in advance of a chemical incident emergency and those that will be of particular importance to be taken into account in the event of an emergency Consider trials of the recovery options, to obtain a better understanding of the effectiveness and feasibility
Criteria for a successful strategy	Identify appropriate criteria to be used to determine the need for and scale of recovery options and to measure their success

3.2 Preplanning for the recovery of Inhabited areas and Water environments

In Inhabited Areas, there are a wide variety of surfaces that could be contaminated in the aftermath of a release of chemicals following an incident. In general, the size of an affected area will dictate the complexity of a response and recovery plan. These arrangements are likely to be site specific according to the characteristics of the local infrastructure[1].

There are a variety of water environments that could be contaminated following a chemical incident (i.e. chemically contaminated run-off water). In general, the size of the affected area and population will dictate the complexity of response and subsequent recovery strategy. These arrangements are likely to be site specific according to the characteristics of the local infrastructure.

Table 3.4 provides a breakdown of topics covering data and information requirements that could usefully be gathered in advance of an incident. The development and sharing of localised databases on businesses, suppliers of raw materials, contractors, waste disposal facilities and other information need to be considered. Although some of these databases may already exist in some form, the point of contact may not be widely known. Furthermore, information should be kept up to date and maintained accordingly. Responsibility for this task for each database would need to be assigned. Due to the wide-ranging nature of the information presented in Table 3.4 it is not yet clear how it would be assembled, and significant effort may be required to assemble such information. Clearly, priorities would need to be assigned to help make best use of available resources. The role of sub-national resilience is to help plan for and co-ordinate response and recovery efforts through national response and recovery resilience forums and co-ordinating groups as appropriate. Organisations at the local level would need to develop their own approach for preparing for a chemical incident, according to their responsibilities and involvement.

Table 3.5 gives a list of factors, in addition to the information requirements listed in Table 3.4 that might need to be considered when developing outline arrangements for a recovery strategy, focussed at the local level, in advance of an incident. Dialogue between different stakeholders is important to gain a balanced view on various aspects of topics at the national, regional or local level. It enables a common language and a shared understanding of the challenges to be developed.

Various approaches for co-developing regional handbooks with stakeholders can be used, including scenario-based workshops, feedback sessions on the recovery options and the establishment of subgroups for more detailed planning on specific topics (e.g. waste management).

Table 3.4: Summary of data and information that could be usefully gathered in advance of an incident for Inhabited areas and water environments

Topic	Category	Data and information requirements
Population	General Issues	Distribution and size. Groups, e.g. school children, religious groups, patients, prisoners, tourists. Movements, e.g. commuters, students, holidaymakers. Time that the population spend outdoors, e.g. farmers versus office workers.
	Relocation	Numbers of people. Availability of and provision of resources for accommodation / housing. Availability of transport, private car ownership. Transport infrastructure, e.g. roads, railways.
Type of buildings		Construction method. Configuration, e.g. multi-storey, terraced, semi-detached, detached. Air exchange / ventilation.
Types of sub-area / land use		Industrial, recreational, public buildings, residential, food production, critical facilities (factories, hospitals etc.). Infrastructure (water treatment works, sewage treatment plants, roads, railways etc.). Designated sites (special protection areas, nature reserves, areas of outstanding natural beauty).
Background exposure to chemicals		Determine whether there is any residual exposure to chemicals in the environment, e.g. contaminated land.
Recovery options	Technical feasibility	Will the development of specific skills and methods be required? Identification of necessary training
	Available resources to implement recovery strategy	Local and regional availability of equipment and materials required. Costs of resources: labour costs, cost of materials and equipment. Need to maintain any "call-on" equipment for response purposes, e.g. fire tenders. Are skilled workers required to operate equipment? How many skilled workers are available? Would they work in contaminated areas?
	Personnel to implement recovery options	List of available contractors and organisations that can be contacted for advice on techniques, equipment, staff protection etc.
	Impact of geography and weather on recovery options	Availability of meteorological information, including weather forecasts. Impact of long periods of adverse weather. Use of geographical information systems to provide information on soil types, topography etc.
	Impact of recovery options on economy and environment	What is the likely scale of the economic impact from implementing recovery options? What options may have a positive impact? What options may have a negative impact?

Topic	Category	Data and information requirements
	Acceptability of 'do no recovery' option / return to 'normality'	Draw on experience from other emergencies / natural disasters to identify what factors drive the return to normality, including experience of using different types of equipment. Look at whether decontamination or other recovery options promote or hinder this?
	Acceptability of recovery options	This is likely to be influenced by the type of chemical incident, its size, how the response is handled, the cause of the emergency etc. Public and other stakeholder views on the acceptability of the types of recovery options available could be sought to reduce the number of options to be considered in the event of a chemical emergency.
Waste management	Solid wastes	Authorised limits for incinerators, landfill sites, composting facilities etc. Number, type and capacities of facilities. Quantities of domestic refuse produced weekly, including garden waste. Ways to segregate contaminated garden waste from household domestic refuse. Normal practices for disposal of waste arising from the treatment of refuse, e.g. sewage sludge, incinerator ash, composted material. Disposal options for contaminated commercial goods that are un-saleable (not necessarily because they are highly contaminated) Site of waste storage and disposal facilities. Transport to the waste facility Legislation on construction of waste facilities.
	Contaminated waste water from natural run-off	Understanding of drainage and sewage plant systems in local area. What happens to excess water that bypasses treatment, e.g. water following rain storms or floods? What level of staff intervention is there during the sewage treatment process?
Legislation	Options	Environmental legislation may preclude implementation of some recovery options in the contaminated area (e.g. restriction placed on removal of trees).
	Workers and public	Establish exposure limits for all those involved in recovery Establish criteria for transportation of chemical wastes
Training		Consider developing a training programme for the roles required to be performed, e.g. decision-makers, decontamination workers and civil protection personnel. Provision of information on the objectives of the recovery option to ensure that those implementing the option understand why it is being undertaken and how the objective can be achieved. Leaflets to provide instruction on how to implement options correctly and effectively for situations where major training exercises are not possible.
Contacts		Lists of contacts in organisations that have a role in the event of a chemical emergency. Lists of contacts with local information. Lists of country / regional / local databases that provide useful background data and information on how to access them.

Topic	Category	Data and information requirements
Communication	Members of the public	Arrangements for communications via local/national TV and radio, websites. Timeline. Plan for engaging local people in decisions that will affect them. Compensation rights, including international agreements on compensation for chemical incidents Pre-prepared information that can be circulated to affected businesses. Receipts and record keeping. Pre-prepared information for others who may suffer financial losses due to the incident. Unlikely to be covered by insurance in event of deliberate act.
	Provision of information to implementers of recovery options	Provision of information on the objectives of the recovery option to ensure that those implementing the option understand why it is being undertaken and how the objectives can be achieved. Leaflets to provide instruction on how to implement options correctly and effectively for self-help options
Generic strategy		Ensure information requirements are prioritised, put into action, achieved and maintained – there should be confidence that information is complete, reliable and up-to-date. Establish mechanisms for accessing information. Procedures to characterise the longer-term situation will most likely be initiated in the emergency response phase. Therefore, recovery response plans should be consistent with their emergency response counterparts to ensure an uninterrupted flow of information and response. Think about how the recovery response strategy will link to options implemented in the emergency phase. Think about employing a phased approach in which some contaminated areas are dealt with promptly, whereas others are treated later. Think about the role of self-help. Consider what the impact of different weather conditions and the geography of the area will have on the strategy and choice of recovery options. Produce and maintain a risk register for things that could go wrong in the development of the strategy (e.g. non-compliance). Identify barriers and establish which ones that will make the biggest difference.
Recovery criteria		Identify appropriate criteria to be used to determine the need for and scale of recovery options and to measure their success.
Roles and responsibilities		Make sure the roles and responsibilities of those agencies that would undertake tasks in the recovery phase are well known by all. Need to clearly identify leading agencies and legal responsibilities. Establish how the roles and responsibilities change along the timeline. Consider for each recovery option how available resources will be co-ordinated and moved to the affected area, e.g. the use of army, civil protection. This should be done at the national level to ensure consistency. Explore the best role of the local government and local agencies.
Role of stakeholders		Identify existing stakeholder groups in the area e.g. Primary Care Trusts, parish councils, community groups, schools. Investigate whether these could/would be prepared to provide feedback on a recovery strategy for the area. Consider processes that could be used to establish bespoke stakeholder panels where no relevant groups exist. Establish steps for each process considered.

Topic	Category	Data and information requirements
Recovery options		Identify practicable and acceptable recovery options for use at the local level based on information provided in the UK Recovery Handbook in advance. Try engaging with the stakeholders. Consider: • Any constraints on use of options (from recovery options in Section 7 and Section 9). • Impact of weather conditions, i.e. when will options not be practicable due to snow, frozen surfaces, thunderstorms etc. • Which options might be applicable to the range of possible emergency/incident scenarios? How might they be implemented? How will waste be managed? Aspects for each recovery option that will require consideration in advance of a chemical release and those that will be of particular importance to be taken into account in the event of an emergency. Trials of the recovery options, to obtain a better understanding of the effectiveness and feasibility.
Protection of workers		Agreement between regulatory bodies, health protection specialists and employers on which recovery options are likely to require the use of respiratory protection equipment and/or protective clothing. This should take into account the nature and extent of contamination, the time since the chemical incident occurred and whether people are still living in the area.
Criteria for a successful strategy		Identify appropriate criteria to be used to determine the need for and scale of recovery options and to measure their success.

3.3 References

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4 Food Production Systems

What is a 'Food production system'?

For the purpose of this Handbook, food production systems include; cereals, fruit and vegetables, milk, meat, eggs, honey, freshwater, marine and shellfish, foraged/domestically grown foods and game, animal feed/silage, animal by-products (i.e. slurry and breeding (non-food animals.

There are a few types of products and production systems that are not explicitly included in this Handbook: certain farm certification schemes (e.g. free-range systems). Information on managing contaminated water used in Food can be found in Water environments (Section 8)

When developing a recovery strategy for managing contaminated food production systems, decision-makers need a framework for choosing between the many possible recovery options. Throughout this process, they will also require a significant amount of information to support decisions to implement timely and effective recovery measures. This Handbook provides a decision framework and a compilation of information to help users evaluate the available recovery options following a chemical incident.

For small-scale, single chemical releases the strategy may comprise of one or 2 recovery options that could be applied over the first few days or weeks following the incident. For a wide-scale, multi-chemical release or a release involving persistent chemicals, the recovery strategy is likely to be more complex, comprising a series of recovery options that could be implemented over different phases of the incident response and affecting several types of food production system. Some aspects can be considered in advance of an incident as part of contingency planning. A series of checklists are provided in Section 3 to highlight the type of information that can be gathered under non-crisis conditions to help manage the pre-release and early phases of an incident. Expert input and guidance will also be needed to supplement this information, particularly to provide decision-makers with expert advice on the suitability of recovery options for the chemical, and the practicability of their implementation.

4.1 Food production systems within the Handbook

4.1.1 Agricultural production systems

Most agricultural production in the UK is carried out under intensive management systems. There are nevertheless a few examples associated with meat and fish production where extensive systems make an important contribution to the diet. Tables 4.1 and Table 4.2 give an overview of the types of agricultural food products to which the Food Handbook can be applied to develop a recovery strategy. 'Food product' is a generic term for categories of foods that can be derived from several sources. For example, milk is a generic product that can be derived from cows, sheep and goats[1].

Table 4.1: Classification of intensive food production systems

Food product	Sources/examples
Milk and other dairy products	Dairy cow, sheep and goat
Meat	Grazing livestock: beef cattle, sheep, lamb, deer
Eggs	Hens
Cereal	Wheat, barley, oats, oil seed rape, rye, maize
Vegetable and horticultural crops	Root crops (carrots, parsnips), tubers (potatoes), onions, legumes (peas, beans), brassicas (brussels sprouts, cabbage, broccoli, cauliflower), salad (lettuce) and other glasshouse and other protected crops.
Industrial crops	Oil seeds, pulses, sugar beet, hops and watercress (watercress is grown in water).
Fodder plants	Silage, hay, root vegetables
Fruit	Orchard (apples, pears and plums), bush (blackberry, gooseberry), canes (raspberry), herbaceous (strawberry) and grapes
Honey	Commercial beehive
Fish	Fish farm (salmon and trout)

Table 4.2: Classification of extensive food production systems

Food product	Sources/examples
Meat	Hill lamb and hill beef, free range
Fish	Marine fish, wild salmon, freshwater fish, shellfish, mussels, oysters, cockles, scallops, crab and lobster

4.1.2 Domestic food production and free foods

Tables 4.3 and Table 4.4 give an overview of the types of domestic and free foods for which the handbook can be applied to develop a recovery strategy. Domestic food production includes all food that is produced by individuals in private or kitchen gardens or allotments; foraged foods are those that are collected from the wild[1].

4.1.3 Organic farming

Food produced from organic farming must meet the same legal requirements as conventional food regarding chemical contamination. Some of the major aspects specific to organic food classification with regards to chemicals are as follows[2].

- Restricted use of artificial fertilisers or pesticides
- Use of conventional veterinary medicines is focused on treating sick animals
- Emphasis on soil health and maintaining this through application of manure, compost and crop rotation

- Processors of organic foods have a restricted set of additives to use

The recovery option sheets (see Section 5) state where relevant if their implementation may affect the organic status of food.

Table 4.3: Classification of domestic food production

Food products	Sources/examples
Meat	Domesticated livestock & fowl such as cow, sheep, goat, pig, duck, goose, turkey, guinea fowl, quail, chicken
Milk	Domesticated livestock such as cow, sheep, goat
Vegetables, herbs, edible flowers, fruit, berries	Berries such as strawberry, gooseberry Fruits such as apple, plum, cherry Vegetables such as carrots, courgettes, lettuce Edible flowers such as elderflower, nasturtium
Herbs	For example, mint, fennel etc.
Nuts	Garden production of nuts such as hazelnut, chestnut, walnut, beech nut
Freshwater fish	Private lake
Honey	Private beehive
Eggs	Domesticated fowl such as duck, goose, quail, hen, peahen

Table 4.4: Classification of free foods

Food product	Sources/examples
Meat	Waterfowl, wildfowl, game fowl such as pheasant, partridge, grouse, goose, duck, snipe, woodcock Ground game such as hare, rabbit and deer Pests such as grey squirrel and pigeon
Mushrooms	Forage-able mushrooms such as field mushrooms, chanterelle, puffball and oyster
Fruit, berries, herbs, edible flowers, aquatic plants	Forage-able wild berries such as elderberry, blackberry and rosehips Fruits such as apple, damson and sloe Wild vegetables/herbs such as horseradish, dandelion root, nettle Edible flowers such as elderflower Forage-able wild aquatic plants such as seaweed, watercress
Nuts	Forage-able nuts such as hazelnut, chestnut, walnut, beech nut
Marine fish and shellfish	Fish such as cod, haddock, plaice, herring, mackerel Shellfish such as clam, scallop, oyster, cockle, mussel, winkle, crab, lobster, prawn, shrimp
Freshwater fish and shellfish	Fish such as trout, carp, eel, grayling, perch, pike, salmon Shellfish such as crayfish
Honey	Feral beehive

4.1.4 City farms and community gardens

There are several city farms and community gardens in the UK. Each city farm and community garden is different. This is to be expected, as each one has developed in response to the needs of the local people and has been affected by the availability of land. City farms and community gardens are commonly found in built up areas, where their creation was a response to the local communities' lack of access to green space. They can vary in size from a few m^2 (the smallest community garden) to several hectares (the largest city farm). City farms and community gardens are usually set up by local volunteers. Some larger community farms and gardens go on to employ paid workers, while smaller groups rely on dedicated volunteers. Most groups are run by a management committee of local people and some are run as partnerships with local authorities, whilst retaining strong local involvement. It is envisaged that following a chemical incident these areas are likely to be treated as larger agricultural areas although for remediation of small areas of soil the inhabited section of the handbook should also be consulted.

4.2 Health protection criteria for food production systems

Any health protection criteria aimed at reducing the risks of adverse health effects, e.g. liver damage, cancer or birth outcomes, must consider all the wider consequences of the proposed protective measure. Hence, for example, costs and disruption to implement the measure must be balanced against the expected benefits, which include public reassurance. This balance needs to take account of the specific circumstances of the event which are likely to vary between different types of incidents and contamination[1]. There are currently no international or national regulations outlining clean-up criteria that could be used directly following an incident involving chemical release in the UK.

In its published advice for radiation, PHE recognises that some clean-up techniques are considerably more resource-intensive and disruptive than others[3]. This principle, in part, could also be applied to chemical releases. In its advice, PHE recognises that it is difficult to specify numerical clean-up criteria in advance of an incident and that other aspects of planning for a response are important and should be given due consideration (see Section 3). PHE therefore advises that, following an incident, assessments should be undertaken of all the likely consequences of a range of clean-up strategies. These consequences should include cost, timescales, public acceptability and the availability of the necessary resources, as well as the expected reduction in risks of health effects. Clearly, collection, in advance, of information relevant to these assessments, such as the likely efficacy and resource requirements of different clean-up options, and prior identification and preparation of appropriate equipment and contractors, would facilitate the timely completion of such assessments in the event of an incident. Potential strategies that involve high levels of cost and disruption should only be undertaken if the expected reduction in risk of adverse health effects is also high, thereby maintaining a balance between the expected harms and benefits of the strategy.

4.3 Generation of waste from food production systems

Depending on the transfer of chemical(s) contaminants to the affected environment (i.e. water course, soil and subsequently animal or plant products), some or all of this subsequent produce may contain varying chemical concentrations which may or may not be in excess of regulatory limits. Food that breaches regulatory limits is deemed unsafe and must not be placed on the market. In the case of contaminants for which regulatory limits do not apply, food may still be deemed unsafe based on risk assessments. As the food products cannot be used for the purpose for which they were grown, they may be regarded as waste. Depending on the specific situation and the type of produce affected, various options exist for the recovery and clean-up (e.g. removal) of such wastes:

- No action is taken (the risk to health is insignificant and any action would be disproportionate).
- Contamination can be removed from the food product using established techniques and the food is re-introduced into the food chain (if this is not expressly prohibited by law).
- The food product is diverted to animal feed.
- The food product is diverted to non-food use (e.g. vegetable oil to biofuels, food grade guar gum to the paper or textile industry).
- The food product is disposed of as waste.

Of the categories listed above, taking no specific action or re-introduction of food products following removal of contamination are potentially controversial from a consumer perspective, but this will be influenced by the way in which the issue is communicated.

4.4 Estimating exposure from food production systems

The exposure to an individual from a given amount of chemical contamination following an incident can vary widely, depending on the chemicals involved and the spread of the contamination. Following a contamination incident, the overall exposure of individuals would depend on the amount and type of food consumed and the concentration of chemical(s) within the different types of food.

An exposure assessment would need to be performed in conjunction with relevant authorities (e.g. FSA) to determine the potential exposure to a population who have been exposed or are at risk of exposure to contaminated food. The subsequent risk assessment would need to consider susceptible members of the population (e.g. children, immune suppressed individuals) and variations between people’s diets (e.g. vegetarians).

The exposure information can be compared with the safety guidelines or with the level found by the hazard characterisation to have effects. The aim is to consider whether harm could result at the estimated exposure levels and how serious any effects might be. It needs to consider uncertainties in the exposure and whether effects may occur at intakes above the safety guidelines. Risk characterisation provides the basis for making decisions on whether there is a need to manage the risk by reducing exposure[4].

4.5 Constructing a recovery strategy for food production systems

Selecting an appropriate recovery strategy is a multistage process and an overview of the decision framework is given in the flowchart in Figure 4.1. It should be noted that the decision framework is not a substitute for expert specialist advice but provides a framework for requesting, recording and evaluating the advice (Steps 1 to 3). The selection of the most appropriate subset of recovery options is a 6-step process, involving the elimination of inappropriate options through the use of a series of selection figures, look-up tables or checklists. The 6-step process is summarised in Figure 4.2. The selection diagrams (Figures 4.3 to 4.13) are relevant for fresh and processed food within that category (i.e. Meat is relevant to animals (livestock) before they are culled and subsequently processed).

Step 1 describes the initial identification of the chemical and the nature and extent of the incident. Step 2 of the framework utilises the decision tree Figure 4.1 and identifies the food production system and appropriate options (Figures 4.3 to 4.13). Steps 3 to 5 then provide a methodology for eliminating options that are unsuitable or ineffective by evaluating their characteristics. From the remaining options, a recovery strategy can be determined (Step 6). A template table is provided (Table 4.9) that could be used to help record the decisions made during the recovery option elimination process. Implementation of the recovery strategy then follows, and if monitoring confirms that acceptable levels have been reached then it is possible to return to normality. If monitoring indicates that acceptable levels have not been reached, then the user returns to the decision tree in Step 2.

The final step is to document the incident and evaluate the response, including the effectiveness of the handbook. Further details of the steps are given in the following sections.

The Food Production decision framework does not include a strategy for performing a risk assessment or for designing or implementing a monitoring strategy following a chemical incident. This falls outside the scope of the UK Recovery Handbook for Chemical Incidents.

Figure 4.1 should be interpreted in the following way:

	Indicates a decision point
	Indicates a step in the decision framework where action is required
	Indicates implementation of recovery options need to be considered
	Indicates a termination point

Where further information or guidance is available on the topic described in the ‘box’ in the decision tree, the link to the information is indicated in blue. This information should be read in conjunction with the decision tree (Figure 4.1).

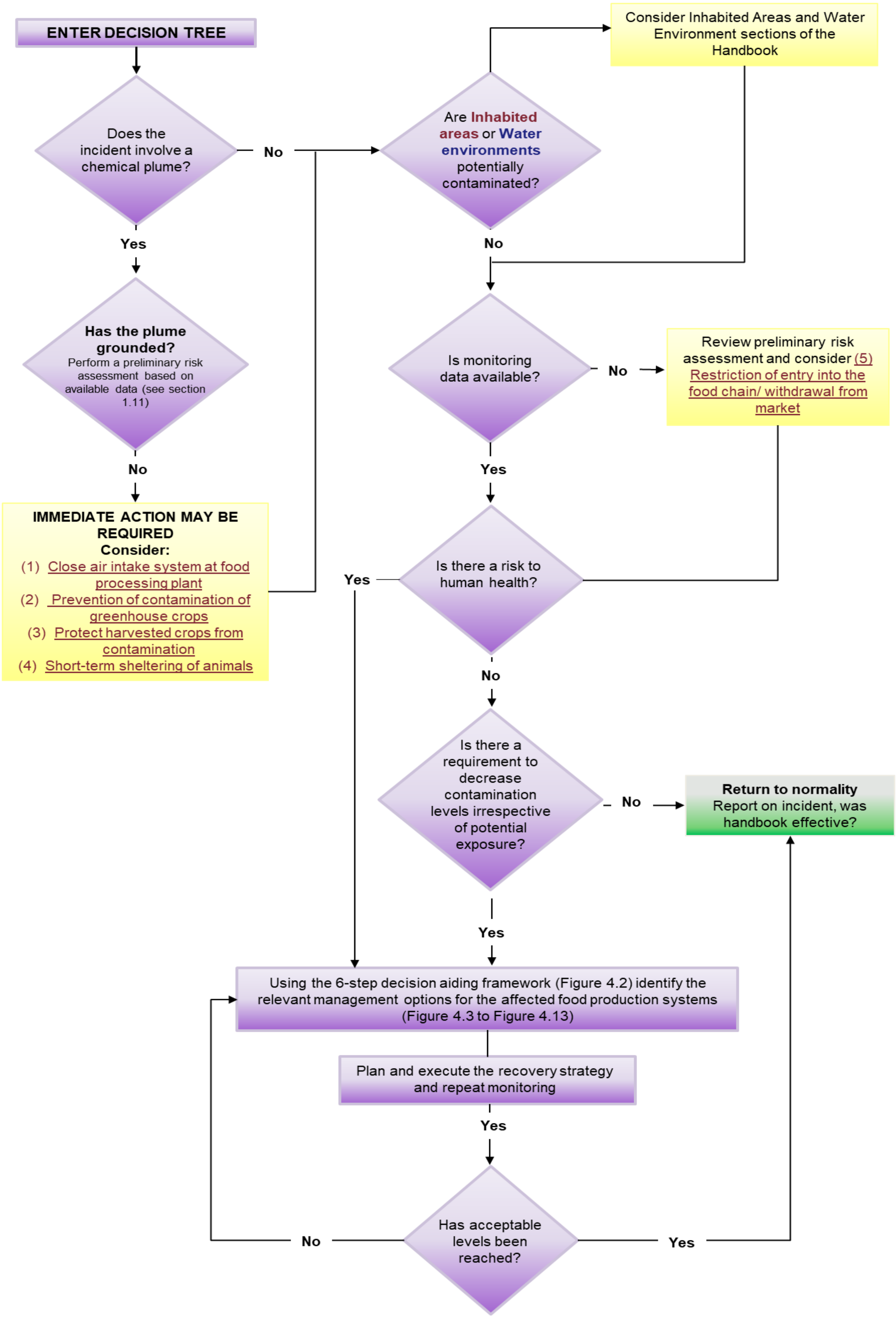


Figure 4.1: Decision Tree - Food Production Systems

Step 1: Obtain relevant information regarding the incident

Determine physiochemical properties of contaminant, identify affected food production system(s) and obtain expert advice

Refer to: Table 4.5

↓

Step 2: Consult flow chart (*Fig 4.1*) and decision trees for food production systems

Identify potentially applicable recovery options
Consult Inhabited areas and Water environments sections of handbook (if applicable)

Refer to: Fig. 4.3–4.13

↓

Step 3: Determine the effectiveness of recovery options

A: Eliminate options based on physiochemical properties
B: Eliminate options based on effectiveness

Refer to: Tables 4.5-4.6

↓

Step 4: Review key considerations and constraints

Eliminate further options according to other considerations (public health, waste, social, technical, cost and time)

Refer to: Tables 4.7-4.8

↓

Step 5: Consult recovery options sheets

Eliminate further options following a detailed analysis of options on a site and incident specific basis

Refer to: Section 5

↓

Step 6: Compare remaining recovery options

Based on Steps 1-5, select and combine options for managing each phase

Refer to: Table 4.9

↓

Implement recovery strategy

↓

Was recovery strategy effective?

Yes
Return to normality and report

No
Return to Step 2

Figure 4.1 Key considerations for implementing a recovery strategy (food production systems)

4.5.1 Step 1: Obtain relevant information regarding the incident

When a chemical incident occurs, the initial steps are to identify the chemical(s) involved and seek technical (chemical) expertise. Information on the physiochemical properties of the chemical of concern should then be collected e.g. toxicity, water solubility and persistency amongst others. The handbook has identified a subset of physicochemical and toxicological properties that should be considered, which are outlined in Table 4.5 and Table 1.3 (Section 1). These properties will then be used to eliminate options in Step 3 of the decision-making process. Only when this information is available can an appropriate recovery strategy be developed.

Particular attention must be taken when an incident involves a mixture of chemicals as it is not only useful to look at the individual chemicals but of utmost importance is to assess the potential interactions between the chemicals themselves. This will have a direct influence on the recovery options selected. Implementation of an option should ideally not cause further damage or unnecessary complications.

Table 4.5 Important physicochemical properties

Physical characteristic	Description	Interpretation	Chemical	
			Value	Interpretation
Physical form (solid/liquid gas)	**Gases** and vapours spread out in the environment until they are equally distributed throughout the space available to them. **Liquids** will flow with gravity when released and must therefore be safely contained to stabilise the incident and prevent further risk to persons, property and the environment. **Solids** need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion			
Partition coefficient between water and octanol (**K_{OW})**	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = **K_{OW}**) > 1,000: Likely to bioaccumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bioaccumulating < 500: Unlikely to bioaccumulate (hydrophilic)- Low.	**High K_{OW}** Likely to be; Bio-accumulated: Sorbed in soil or sediments. Unlikely to be: Mobile	**Low K_{OW}** Likely to be: Mobile Soluble Biodegraded Unlikely to be: Bio-accumulated	
Biological half life	How long chemical will persist in animals (e.g. milk/sheep). Will give indication of how long recovery options relating to may be effective (e.g. manipulation of culling).			
Uptake by plants / crops	Potential for a chemical to transfer to grass /crops/plants and hence potentially contaminate food chain			
Potential for chelation / absorption from gut	Whether a chemical can have its removal enhanced from livestock by using chelating agents or absorbent materials (e.g. clay minerals)			

Table 4.5 Important physicochemical properties

Physical characteristic	Description	Interpretation		Chemical	
				Value	Interpretation
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. Higher volatility would result in a higher vapour pressure. Interpretation (Units = Pascals) < 1.3 x 10^{-4}: Unlikely to volatilise Between 1.3 x 10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	**High VP** Likely to: Be an inhalational risk Evaporate quickly	**Low VP** Unlikely to be: An inhalational risk		
Persistence	The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.	**Short persistence**: Hours to days **Moderate Persistence:** Weeks to months **Long Persistence:** Months to Years			
Water solubility	The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread by flowing water. Water based decontamination of surfaces may be more effective if a chemical is water soluble; removal options or active decontamination may be more appropriate for non-water-soluble chemicals Interpretation: Units ppm (mg/l) <10: Negligible solubility Between 10 and 1000: Increasing likelihood of solubilising >1000: Likely to solubilise	**High Solubility,** Likely to be mobile: Unlikely to be; Volatilised or persistent	**Low solubility** Likely to be; Immobilised by adsorption and persistent Unlikely to be; Mobile		
Soil sorption	Measures how readily a chemical is adsorbed to organic surfaces in the soil matrix. Some soils have very limited abilities to sorb chemicals e.g. sandy soils or ones with low clay or organic matter contents. Gives an indication of likely persistence in soil. Interpretation (Units = K_{OC}) > 10,000: Likely to adsorb Between 1,000 and 10,000: Increasing likelihood of adsorbing < 1,000: Unlikely to adsorb	**High K_{OC}** Likely to be; adsorbed or accumulated Unlikely to be; Mobile	**Low K_{OC}** Likely to be; Mobile Unlikely to be; Adsorbed or accumulated		

Table 4.5 Important physicochemical properties

Physical characteristic	Description	Interpretation	Chemical	
			Value	Interpretation
Boiling point	Boiling point is the temperature at which a liquid's vapour pressure equals atmospheric pressure and the liquid starts to turn to vapour. Low boiling point substances tend to be either gases or very volatile liquids at ambient temperature			
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.			
Toxicity	Sum of adverse effects of the degree of danger posed by a substance to living organisms. It is expressed generally as a dose response relationship involving the quantity of substance to which the organisms are exposed and the route of exposure skin (absorption), mouth (ingestion), or respiratory tract (inhalation).			

4.5.2 Step 2: Consult decision trees/diagrams for food production systems

Consult flowchart (Figure 4.1) which provides an overview of the decision-making process. Consult the decision diagrams (Figure 4.3 to Figure 4.13) to identify which recovery options are applicable for protection (actions taken to protect the food chain), restoration (return production system back to normal) and fate of affected produce (including waste disposal) that should be considered for the affected food production systems. This step will identify the recovery options that could be applicable for each food production system under consideration.

The remediation of affected food production systems infrastructure (i.e. machinery, warehouses, production lines and farm buildings) are covered in the Inhabited areas (Section 6) of the handbook. The remediation of affected Water environments is covered in the Water environments (Section 8). Where there may be cross-over between sections of the handbook (Inhabited Areas/ Water Environments) these are highlighted in Figures 4.3 - 4.13.

This step is essentially an ‘inclusive’ step, identifying the full list of potential recovery options. Elimination of options is carried out in Steps 3 to 5.

Decision diagrams are presented for the following production systems:

- Cereals (Figure 4.3)
- Fruit and vegetables (Figure 4.4)
- Milk (Figure 4.5)
- Meat (Figure 4.6)
- Eggs (Figure 4.7)
- Honey (Figure 4.8)
- Freshwater and marine fish and shellfish (Figure 4.9)
- Foraged/ domestically grown foods and game (Figure 4.10)
- Animal feed/ silage (Figure 4.11)
- Animal by products (e.g. slurry) (Figure 4.12)
- Breeding (non-food) animals (Figure 4.13)

Figure 4.3 Cereals

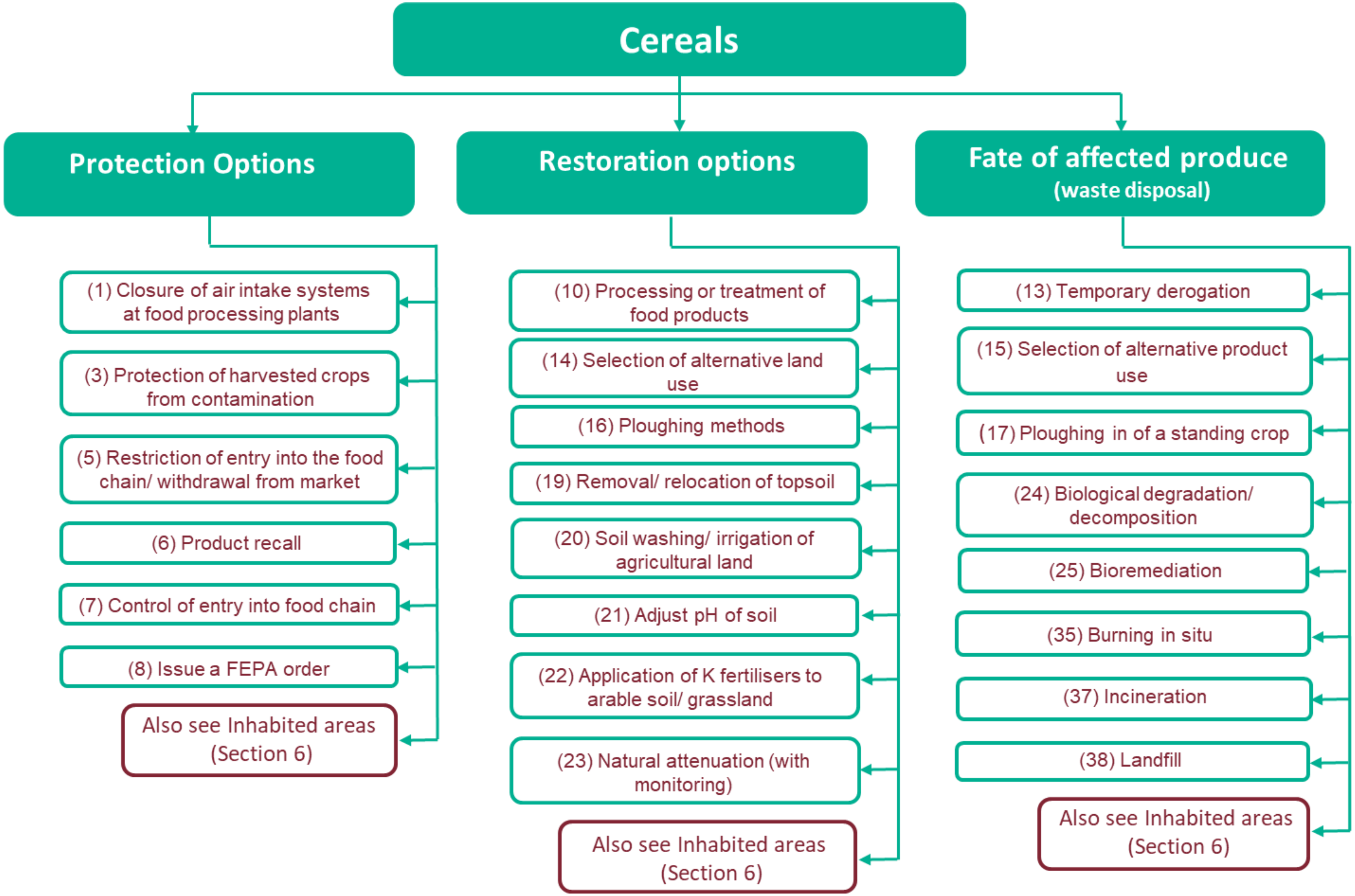


Figure 4.4 Fruit and vegetables

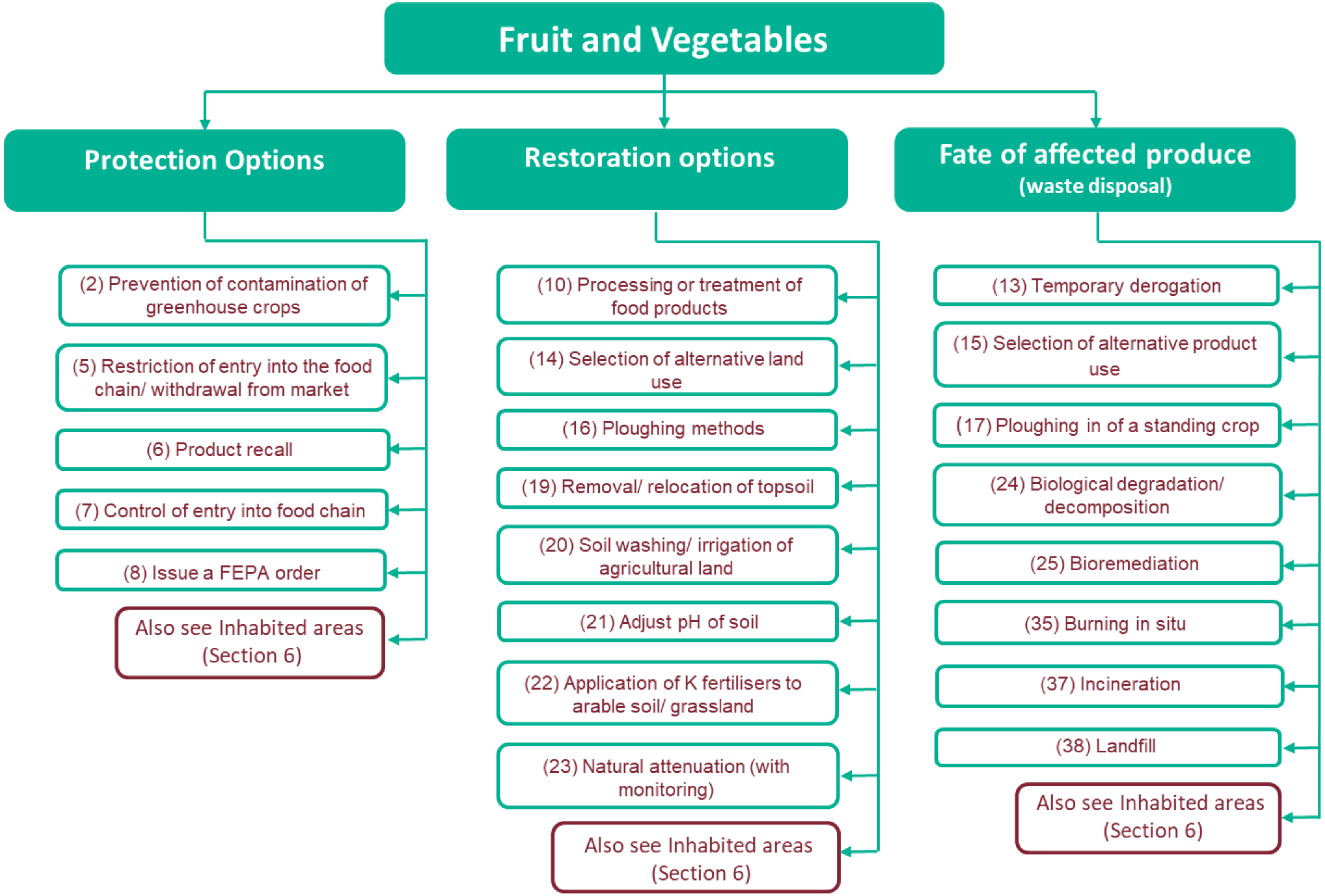


Figure 4.5 Milk production

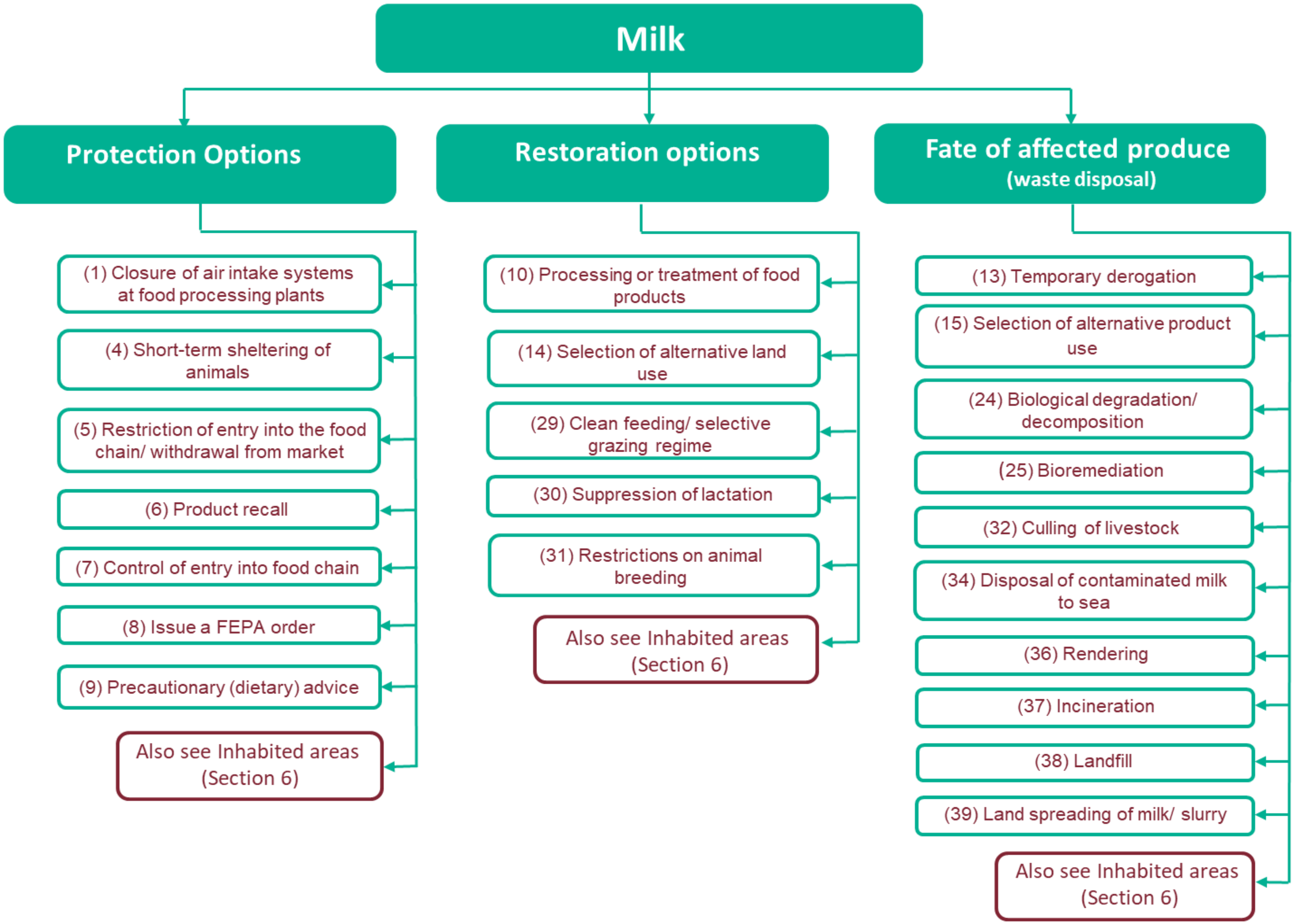


Figure 4.6 Meat

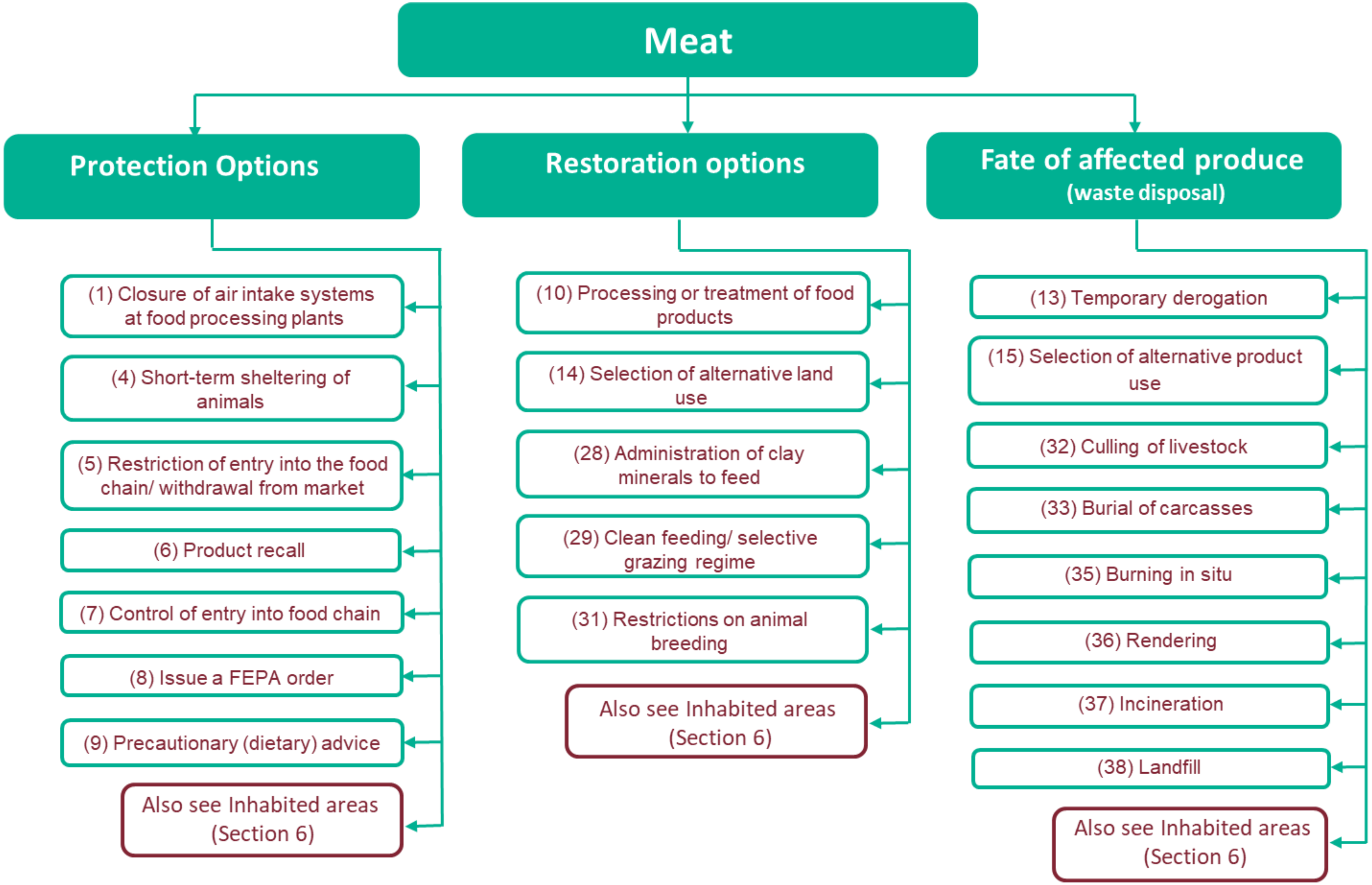


Figure 4.7 Eggs

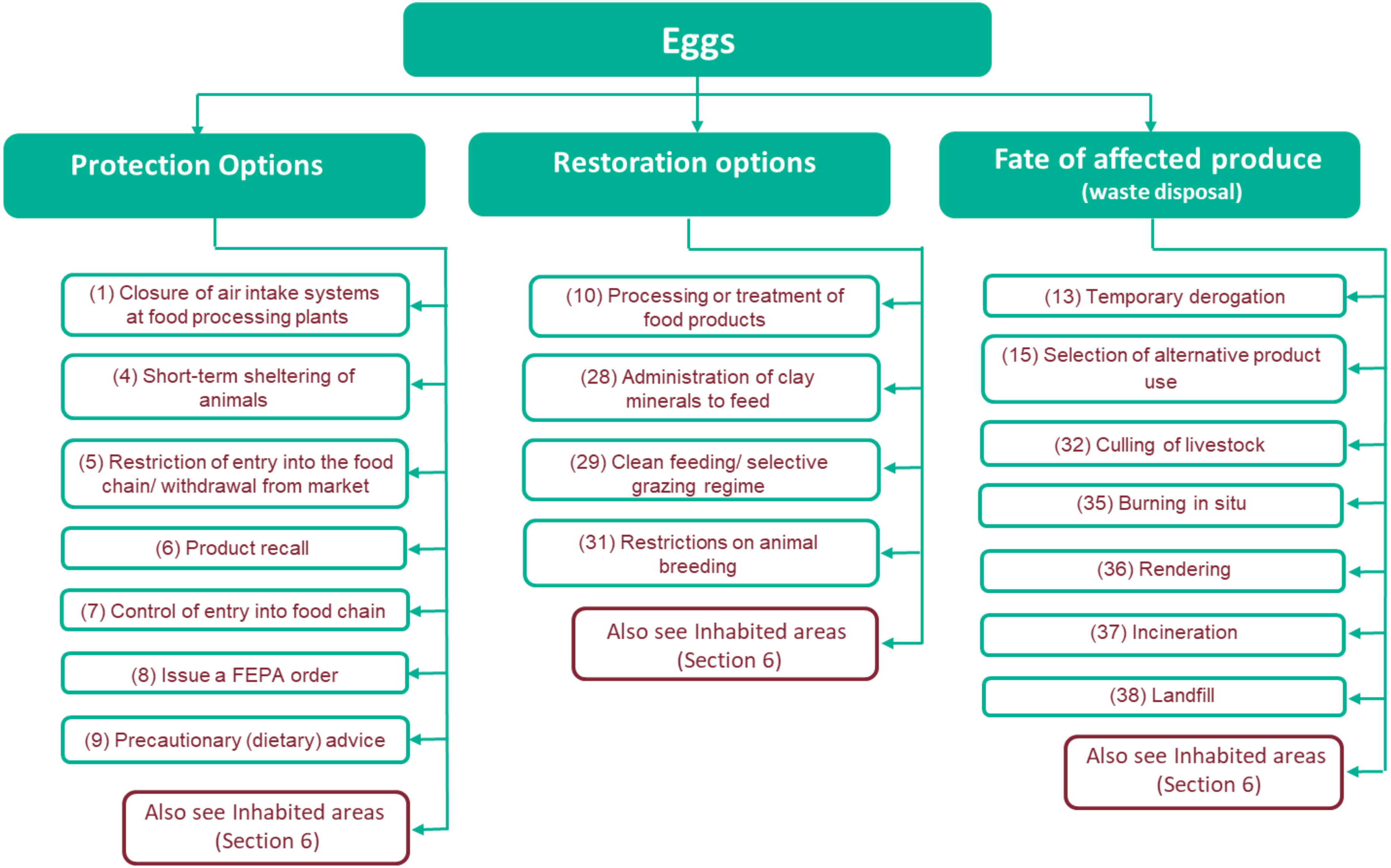


Figure 4.8 Honey

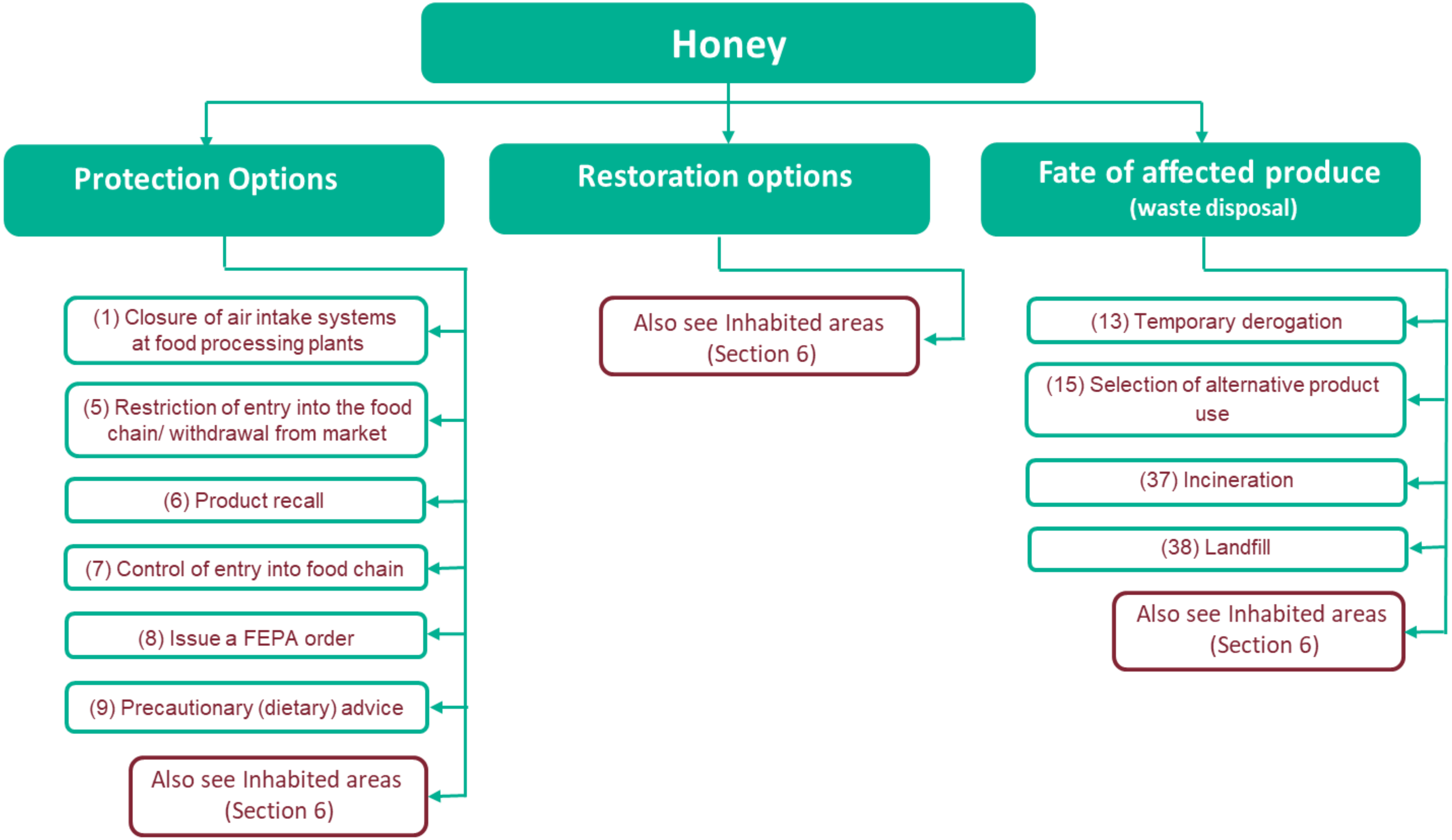


Figure 4.9 Freshwater and marine shellfish

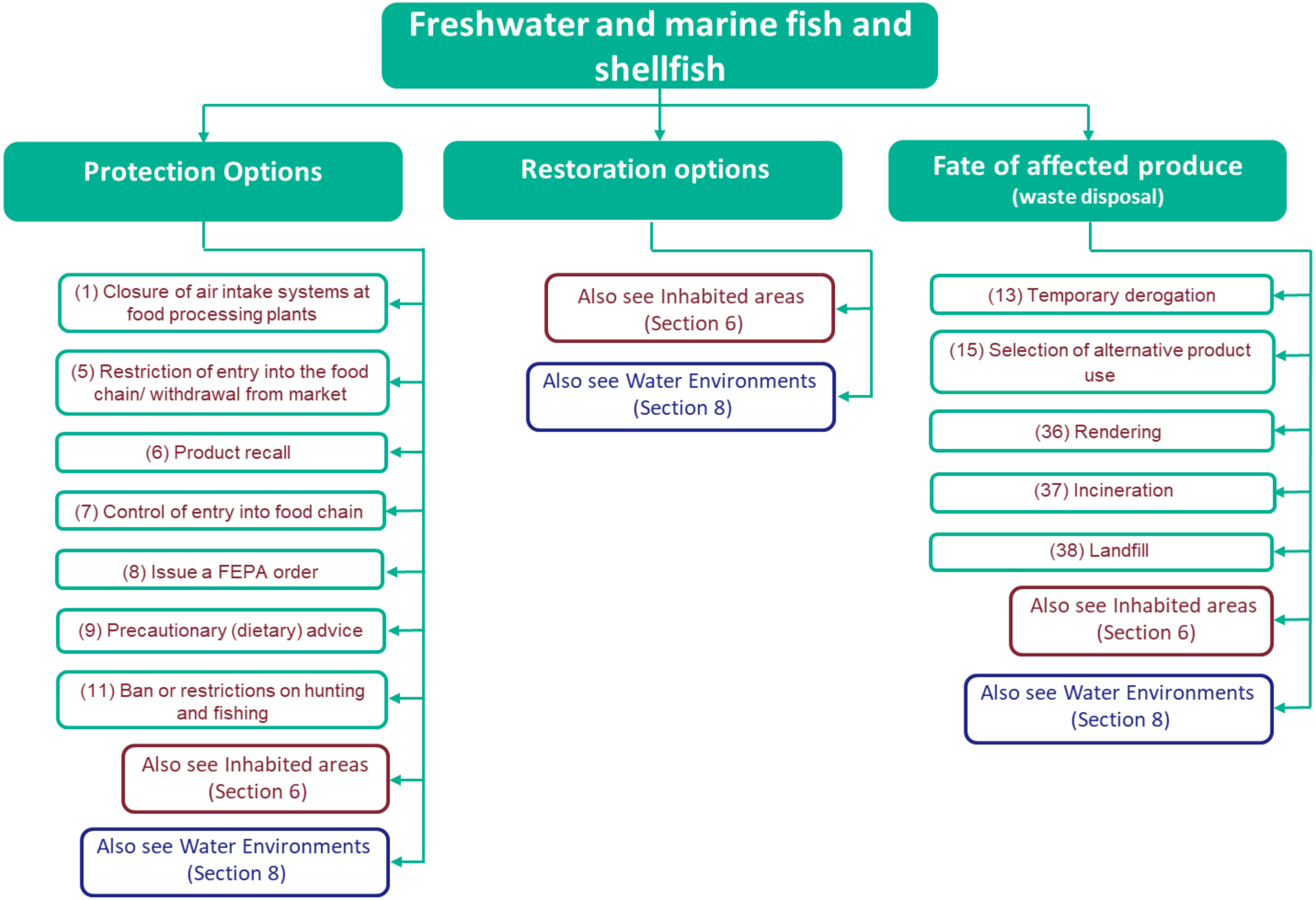


Figure 4.10 Foraged/ domestically grown goods and game

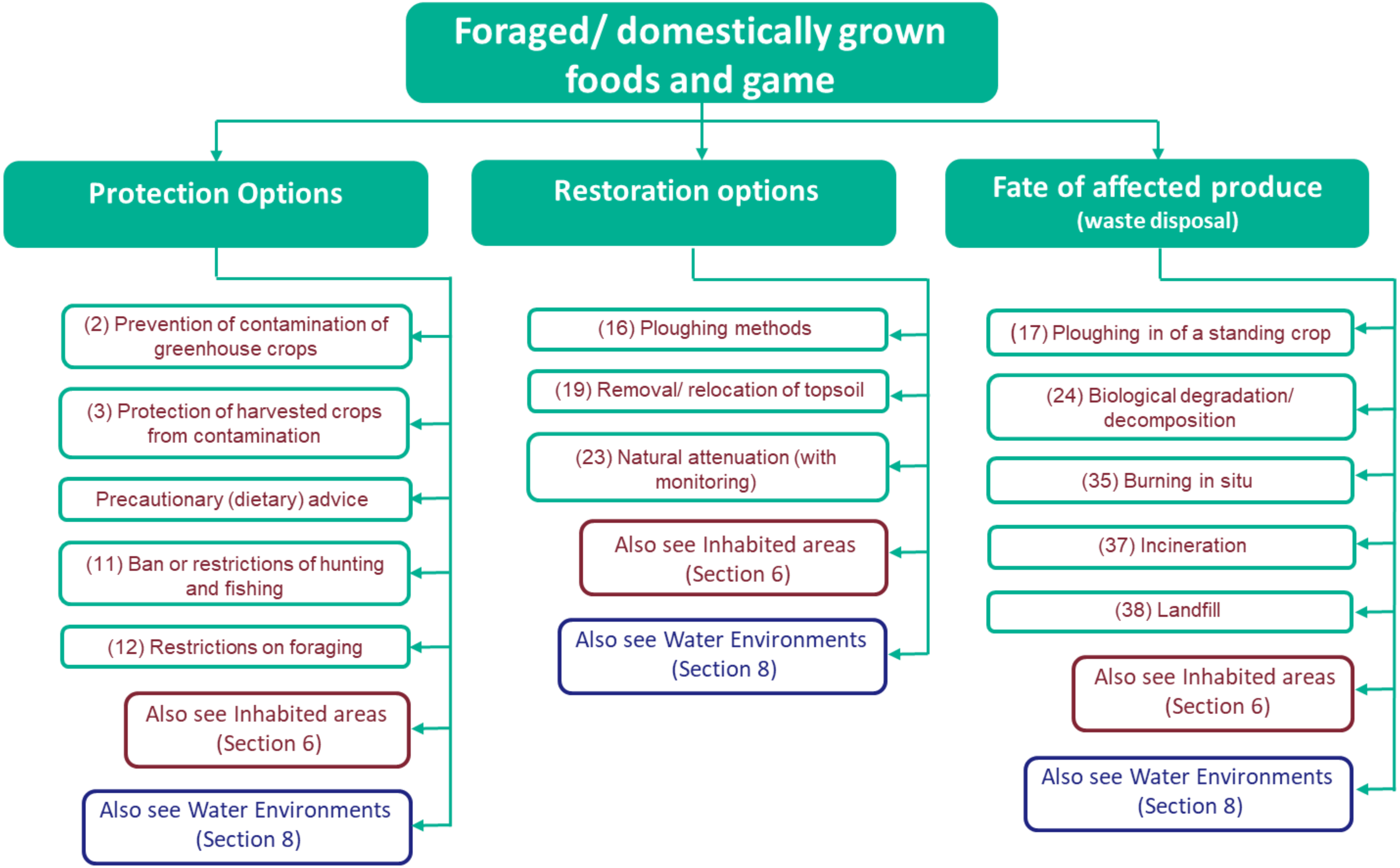


Figure 4.11 Animal Feed/ Silage

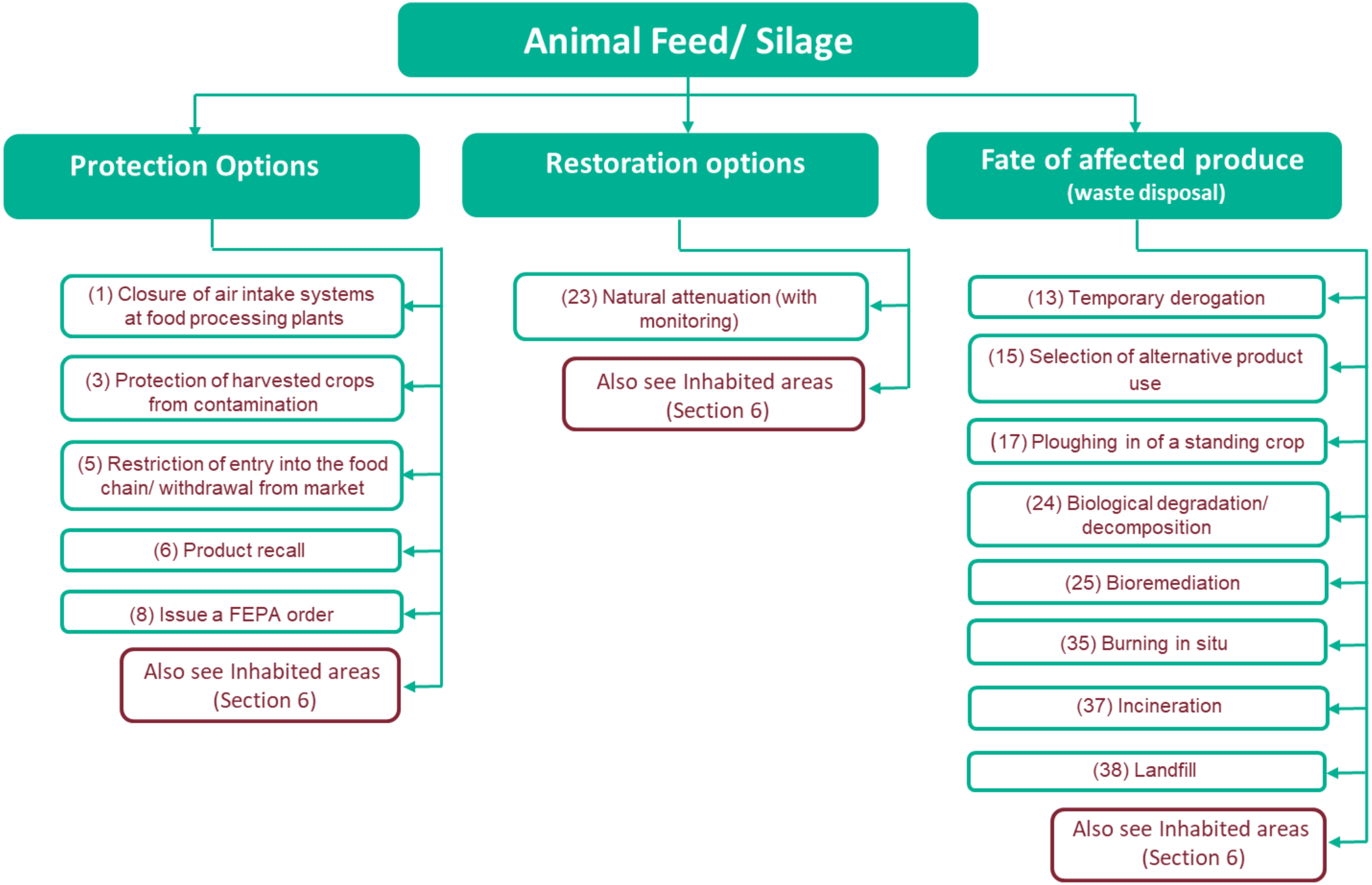


Figure 4.12 Animal by-products (i.e. slurry)

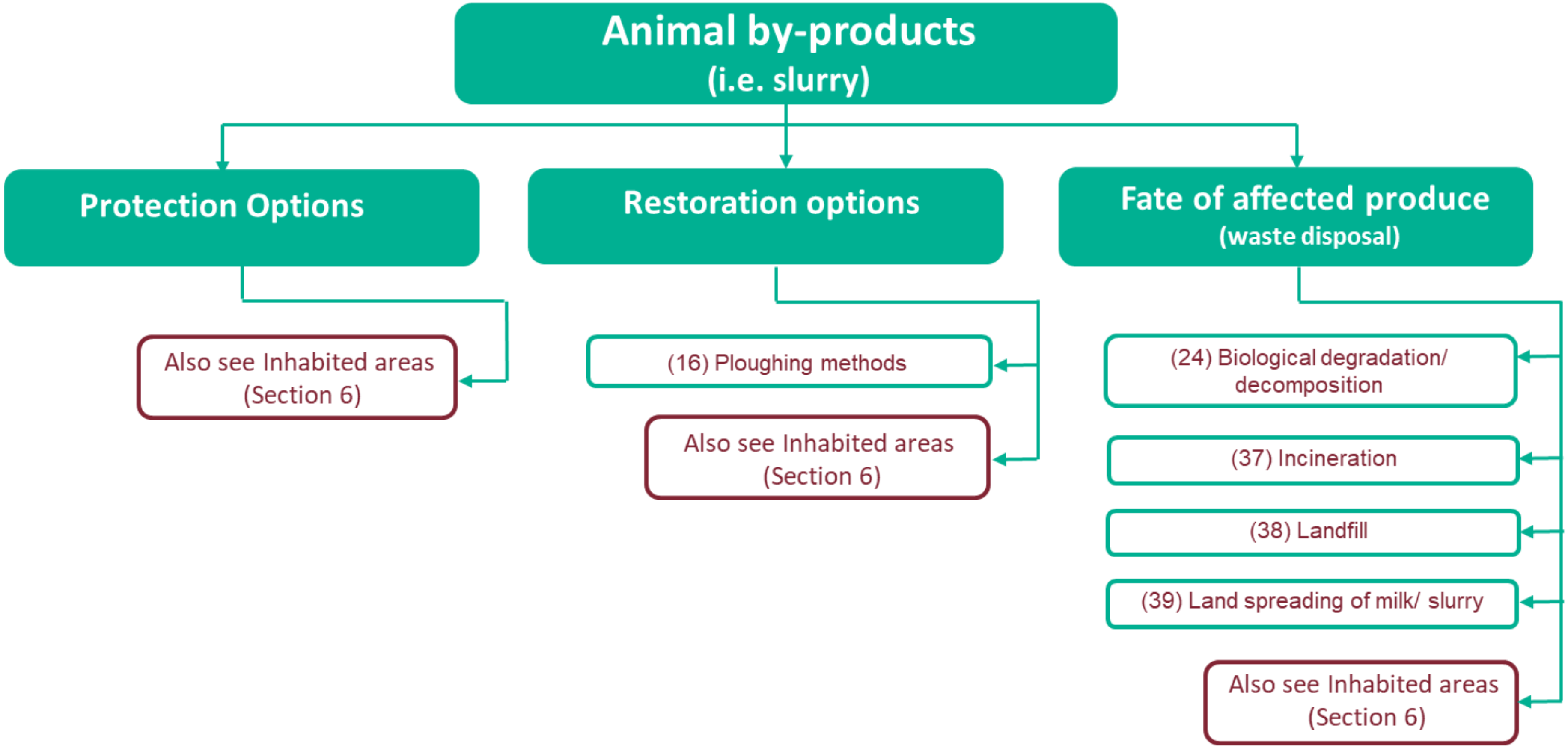
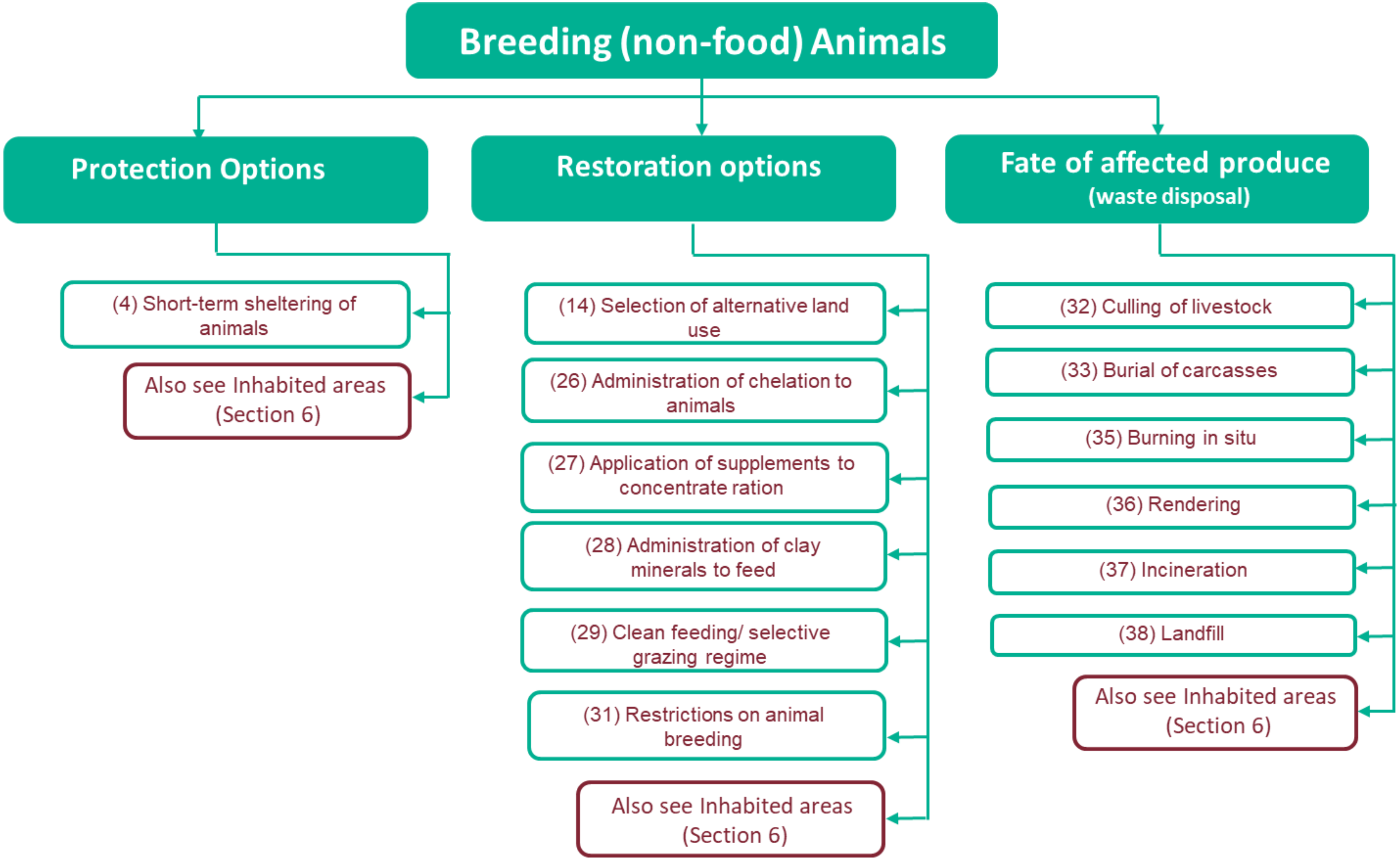


Figure 4.13 Breeding (non-food) animals



4.5.3 Step 3: Review effectiveness of recovery options

A: Elimination of recovery options based on physicochemical properties only

Working through Figure 4.3 to Figure 4.13 has identified potential recovery options that may be applicable for the following categories of food production systems:

- Cereals
- Fruit and vegetables
- Milk
- Meat
- Eggs
- Honey
- Freshwater and marine fish and shellfish
- Foraged/ domestically grown foods and game
- Animal feed/ silage
- Animal by-products (e.g. slurry)
- Breeding (non-food) animals

At this stage expert advice (e.g. PHE/ FSA) should be sought to determine and interpret the physicochemical properties of the chemical(s), using data identified in Table 4.5 (Step 1) to assist in eliminating recovery options. For example, if information obtained in Table 4.5 indicates that a chemical has a long biological half-life, the recovery option (23) Natural attenuation (with monitoring) could be eliminated at this stage.

Particular attention must be taken when an incident involves a mixture of chemicals as it is not only important to look at the individual chemicals, but also to assess the potential interactions between chemicals themselves.

PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is openly available at:

https://www.gov.uk/government/collections/chemical-hazards-compendium

B: Elimination of options based on effectiveness

Determining which recovery options may be further eliminated can be achieved by considering the effectiveness of the recovery option in more detail (Table 4.6).

The colour-coding in Table 4.6 gives an indication of whether options would fall into “up to 100% effective”, “potentially effective” or “limited effectiveness”. The classification used in the selection tables is intended to be a generic guide and is **not chemical specific**. The greyscale colour coding in Table 4.6 is based on an evaluation of the evidence base, stakeholder experience, advice or ongoing decontamination research within the UK. Therefore, Table 4.6 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (see Table 4.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. FSA/ PHE).

A recovery option should only be eliminated if it is deemed to be ineffective (black) for the affected food production system. All other recovery options should be retained. However, if the option is ‘potentially effective’ (grey) it should be recognised that there may be potential technical difficulties in implementing the option, or it may be that the option would only partially remove any residual contamination. The implementation of “protective" recovery options (e.g. (6) Product recall) are not influenced by the type of contamination so cannot be eliminated at this stage.

Therefore, options are applicable if:

- There is direct evidence that it would be effective for the chemical (known applicability)
- The mechanism of action is such that it would be highly likely to be effective for the chemical (probable applicability)

An option is taken as not being applicable if one or more of the following criteria are met:

- There is direct evidence that the option would not be applicable to the chemical.
- The chemical’s properties are such that the option would not be expected to have any effect.
- The hazard posed by the chemical would not be reduced.
- The time taken to implement the recovery option would be longer than the chemical’s persistence in the environment.
- There is a risk that implementing the recovery option should make the hazard worse (i.e. volatilization).
- Implementation of this option would place operatives at an unacceptable risk.

If it is not possible to readily eliminate a recovery option at this stage, then it should be retained for consideration in Step 4.

Table 4.6 Overview of recovery option effectiveness * colour coding is based on evaluation of the evidence base and stakeholder input.

	Potential increased worker exposure	Effectiveness
Protection options (actions taken to protect the food chain)		
(1) Close air intake system at food processing plant		
(2) Prevention of contamination of greenhouse crops		
(3) Protect harvested crops from contamination		
(4) Short-term sheltering of animals		
(5) Restriction on entry of food into the food chain/ withdrawal from market		
(6) Product recall		
(7) Control of entry into food chain		
(8) Issue a FEPA order		
(9) Precautionary (dietary) advice		
(11) Ban or restrictions on hunting and fishing		
(12) Restrictions on foraging		
Restoration (getting the production system back to normal)		
(10) Processing or treatment of food products		
(14) Selection of alternative product use		
(16) Ploughing methods		
(18) Land improvement (for 'natural' pasture)		
(19) Removal/ relocation of topsoil		
(20) Soil washing / irrigation of agricultural land		
(21) Adjust pH of soil		
(22) Application of potassium fertilisers to arable soils and grassland		
(23) Natural attenuation (with monitoring) (do no recovery)		
(26) Administration of chelation to animals		
(27) Application of supplements to concentrate ration		
(28) Administration of clay minerals to feed		
(29) Clean feeding/ selective grazing regime		
(30) Suppression of lactation		
(31) Restrictions on animal breeding		
Fate of affected product (waste disposal)		
(13) Temporary derogation		
(15) Selection of alternative product use		
(17) Ploughing in of a standing crop		
(24) Biological degradation/ decomposition		
(25) Bioremediation		
(32) Culling of livestock		
(33) Burial of carcasses		
(34) Disposal of contaminated milk to sea		
(35) Burning in-situ		
(36) Rendering		
(37) Incineration		
(38) Landfill		
(39) Land spreading of milk and/ or slurry		

Effectiveness	**Up-to 100% effective**	**Moderately effective**	**Limited effectiveness**
Potential for increased worker exposure	**Unlikely**	**Moderate risk**	**High risk**

4.5.4 Step 4: Review key considerations and constraints

Step 3 has identified potential recovery options that could be applicable to the affected food production systems. Recovery options invariably have other considerations or constraints associated with their implementation. A detailed description of these constraints is provided in the recovery option sheets (Section 5).

To further assist in eliminating unsuitable options some of the key considerations for each option are described in Table 4.7 and summarised in Table 4.8 for public health, waste, social, technical, cost and time issues for each option. These tables can be used in conjunction with the recovery option sheets (Section 5) to reduce the subset of options that may require more in-depth review.

The colour coding in Table 4.7 and Table 4.8 is based on an evaluation of the evidence base, stakeholder experience and advice or ongoing decontamination research within the UK. The colour-coding gives an indication of whether options have “none or minor”, “moderate” or “important/ key” constraints or considerations associated with their implementation. The classification used in the selection tables is intended to be a generic guide and is not chemical specific. Therefore, Table 4.7 and Table 4.8 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (see Table 4.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. FSA/ PHE).

The numbers in the brackets in Table 4.7 and Table 4.8 refers to the recovery option number. If an important (key) constraint is identified it does not indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis (Step 5).

Table 4.7 Overview of considerations for recovery options (Food production systems)

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
Protection options (actions taken to protect the food chain)		
(1) Close air intake systems at food processing plant	**Time -** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between chemical contamination release and notification.	**Technical -** Access to machinery and controls.
Practical experience		
(2) Prevention of contamination of greenhouse crops	**Time -** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between chemical contamination release and notification.	
Practical experience		
(3) Protect harvested crops from contamination	**Technical -** Availability of covering materials and means to secure it. **Time -** A decision needs to be made quickly as this recovery options should be implemented in the early phase. Time between notification and release of contamination occurring. **Public health-** Exposure of farm workers while covering crops	**Cost -** May be high, considering; equipment; personnel and volume of the affected crop area that protection.
Practical experience		
(4) Short-term sheltering of animals	**Technical -** Availability of suitable housing with water supply; distance between pastures and shelters and availability of stored feed. **Time -** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between chemical contamination release and notification. **Public health-** Exposure of farm workers while moving animals.	**Cost -** May be high, considering; equipment; infrastructure (i.e. farm buildings) personnel and number of animals requiring sheltering.
Practical experience		
(5) Restriction of entry into the food chain / withdrawal from market	**Waste -** There may be significant amounts of contaminated food products (i.e. milk, meat, eggs and crops) that will require a suitable disposal route and may require disposal and/or storage under a waste transfer licence. Long term restrictions (e.g. FEPA order) may also lead to culling and disposal of livestock	
Practical experience	Incident: Seveso Italy (1976) [4]. Incident: Cyanide Grapes (1989) [5].	
(6) Product recall	**Waste -** There may be significant amounts of contaminated recalled food products (i.e. milk, meat, eggs and crops) that will require a suitable disposal route and may require disposal and/or storage under a waste transfer licence.	**Social -** Contacting members of the public
Practical experience	Incident: Dioxins in pork (2008) [6]. Incident: Nicotine ground beef (2002) [7].	

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(7) Control of entry into food chain	**Technical -** If immediately culling, availability of abattoir or on-farm culling equipment, and ability to gather free-ranging animals quickly. If prolonged time before culling, availability of additional feed and implications for animal welfare. **Cost -** May be high, considering; equipment; personnel; number of affected livestock and waste disposal.	**Waste -** No waste is directly produced as a result of this option, however, long term restrictions (e.g. FEPA order) may also lead to culling and disposal of livestock.
Practical experience		
(8) Issue a FEPA order	**Social:** Economic loss occurring as a result of restrictions being imposed.	None
Practical experience	Incident: Empress oil spill (1996) [23].	
(9) Precautionary (dietary) advice	**Time –** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between noting chemical contamination and toxicity in livestock (i.e. chickens following lead exposure) could result in contaminated produce being eaten by members of the public.	**Public Health -** There is a risk that some members of the public may already have been exposed prior to the advice being issued. **Social -** This is an advice option and is difficult to enforce. Food safety legislation does not apply to home grown produce.
Practical experience	Incident: Lead and chickens (2010) [9]. Incident: Secondary beach contamination from gasworks (2001) [8].	
(11) Ban or restrictions on hunting and fishing	**Social-** Difficulties with enforceability and policing	**Time -** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between noting chemical contamination and toxicity in game or fish and could result in contamination being consumed by members of the public. This option is also affected by season and may have to be implemented annually (from early – long term).
Practical experience	Incident: Minimata Japan (1956) [10]. Incident: Seveso Italy (1976) [4].	
(12) Restrictions on foraging	**Social-** Difficulties with enforceability and policing	**Time -** A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified and could result in contaminated wild foods being consumed by members of the public. This option is also affected by season and may have to be implemented annually (from early – long term).
Practical experience		
Restoration options (getting the production system back to normal)		
(10) Processing or treatment of food products e.g. fat-soluble chemicals can be extracted from milk during the skimming process. The end product (skimmed milk) is suitable normal use and the fat extract then requires disposal.	**Technical -** Availability, capability and capacity of facilities to process contaminated foods. **Waste -** There may be significant amounts of contaminated food products (i.e. crops) and production processes that will require a suitable disposal route and may require disposal and/or storage under a waste transfer licence.	**Cost -** May be high, considering; equipment; personnel; type of contaminated food product and waste disposal.
Practical experience		

	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(14) Selection of alternative land use		**Social -** Land blighted **Technical -** Restrictions imposed by environmental protection scheme. It depends on what the site will be used for (i.e. golf course or parkland).
Practical experience	Incident: Geochemical lead poisoning in lambs (2011) [11]. Incident: Seveso Italy (1976) [4].	
(16) Ploughing methods	None	**Technical -** Depends on the nature of the chemical contaminant, persistence and degradation products. Restrictions may be imposed by environmental protection schemes. Not applicable if crop is present or if soil is very wet, sandy, frozen or stony. **Cost -** May be high, considering; equipment; personnel; and size of the affected area. **Time -** Should be implemented in the early – medium phase to be effective.
Practical experience		
(18) Land improvement (for 'natural' pasture)	None	**Technical -** Depends on the nature of the chemical contaminant, persistence and degradation products. Restrictions may be imposed by environmental protection schemes. Not applicable after first rainfall.
Practical experience		
(19) Removal/ relocation of topsoil	Waste There may be significant amounts of contaminated soil that will require a suitable disposal route and may require disposal under a waste transfer licence. **Cost -** May be high, considering; equipment; personnel; size of the affected area and volume of topsoil requiring disposal.	**Social -** Resistance to topsoil removal (together with associated flora and fauna) and to aesthetic consequences of garden or allotment changes. Stigma associated with affected area.
Practical experience	Incident: Broomfield tip, Wigan (2002) [12]. Incident: Heavy Metal Contamination of Agricultural Soil (Itaia Itai disease, 1940's) [13].	
(20) Soil washing / irrigation of agricultural land		**Public health -** Risk of contamination of groundwater and water supplies
Practical experience	Incident: Heavy Metal Contamination of Agricultural Soil (Itaia Itai disease) 1940's [13]	
(21) Adjust pH of soil	**Technical -** Depends on the nature of the chemical contaminant, persistence and degradation products. Restrictions may be imposed by environmental protection schemes. This option is carried out with ploughing, so may not be applicable for very wet, dry, frozen or steep areas.	**Cost -** May be high, considering; equipment; personnel and size of the affected area.
Practical experience	Incident: Heavy Metal Contamination of Agricultural Soil (Itaia Itai disease) 1940's [13]	

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(22) Application of potassium fertilisers to arable soils and grassland	**Technical -** Depends on the nature of the chemical contaminant, persistence and degradation products. Restrictions may be imposed by environmental protection schemes. This option is carried out with ploughing, so may not be applicable for very wet, dry, frozen or steep areas. This option is only applicable if the soil has a low (potassium) status.	**Cost -** May be high, considering; equipment; personnel and size of the affected area.
Practical experience		
(23) Natural attenuation (with monitoring)	None	**Public health -** Potential for leaching of chemicals into groundwater **Social –** This option may be perceived as doing “nothing” by the public, which has negative implications and may be unacceptable to members of the public.
Practical experience	Incident: MSC Napoli (2008) [14]. Incident: Secondary Beach contamination from gasworks (2001) [8].	
(26) Administration of chelation to animals	**Technical -** Depends on the nature of the chemical contaminant, persistence bioavailability. This option is also limited by the availability of chelating agents and skilled personnel to administer the treatment. **Cost -** May be high, considering; equipment; consumables (chelating agent); personnel and number of affected animals.	**Waste -** Limited, contaminated slurry would contain chelating agent and contaminant **Social -** Acceptability to farmers or herders, food industry and consumers. Possible animal welfare issues.
Practical experience	Incident: Lead Toxicity in calves, Blackburn (2011) [15].	
(27) Application of supplements to concentrate ration	None	**Waste -** Limited, animal slurry would contain contaminant **Technical -** Depends on the nature of the chemical contaminant, persistence bioavailability. This option is also limited by the availability of calcium or copper supplements, or pelleted concentrates with enriched levels of calcium or copper. **Cost -** May be high, considering; number of affected animals and potential cost of modifying feed.
Practical experience		
(28) Administration of clay minerals to feed	**Technical -** Depends on the nature of the chemical contaminant, persistence bioavailability. This option is also limited by the availability of clay minerals or infrastructure (i.e. feed manufacturing plants) to add clay minerals to feed. (clay mineral needs to be compliant with animal feed legislation)	**Waste -** Limited, animal slurry may contain clay minerals. **Cost -** May be high, considering; number of affected animals and potential cost of modifying feed.
Practical experience		

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(29) Clean feeding/ selective grazing regime.	None	**Technical –** Depends on the availability of suitable housing with water, power supply, straw for bedding, ventilation and alternative clean feeds. **Waste -** Slurry or manure produced while livestock are fenced in or housed. **Time -** A decision needs to be made quickly as this option would need to be implemented in the early – medium phase of an incident for this option to be effective. **Cost –** May be high, considering; number of affected animals; consumables (i.e. fencing); personnel and consumables. **Social -** Selective grazing regime depends on the willingness of farmers at receiving farms to accept contaminated livestock, and to participate. Also, stigma, impact on public confidence and disruption.
Practical experience		
(30) Suppression of lactation	None	**Waste -** There may be significant volumes of contaminated milk produced until milk production ceases. Contaminated milk will require a suitable disposal route and may require storage and/or disposal under a waste transfer licence. **Social -** Farmer's resistance and opposition of the public due to the perception that hormones may damage the environment. **Time -** A decision needs to be made quickly as this option would need to be implemented in the early – medium phase of an incident for this option to be effective.
Practical experience		
(31) Restrictions on animal breeding	**Technical -** Depends on the nature of the chemical contaminant, persistence bioavailability, and the length of time animals would be subject to modified husbandry. **Cost –** May be high, considering; number of affected animals; consumables (i.e. feeding) and infrastructure (i.e. housing). For example, feeding and housing a dairy herd that are not used for milk production would be very expensive.	
Practical experience	Incident: Seveso Italy (1976) [4].	
Fate of affected produce (waste disposal)		
(13) Temporary derogation	None	None
Practical experience		

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(15) Selection of alternative product use	**Technical -** Depends on the nature of the chemical contaminant, and marketing for alternative products and know how. **Waste -** There may be significant amounts of contaminated food products (i.e. crops) and by-products from processing that will require a suitable disposal route and may require disposal and/or storage under a waste transfer licence. For example, condensed fat from skimmed milk may require rendering and incineration, contaminated by-products for example the refining of rapeseed and sugar beet to bio-diesel and bio-ethanol, may be generated in processing plants.	
Practical experience		
(17) Ploughing in of a standing crop	**Technical-** May affect future land use as the contamination is not being removed.	None
Practical experience		
(24) Biological degradation/ decomposition	**Waste -** There may be significant amounts of contaminated end products or by-products from biological degradation or decomposition that will require a suitable disposal route and may require disposal and/or storage under a waste transfer licence. Disposal routes and aerial emissions could lead to the spread of low levels of contamination in the environment.	**Technical -** This option may be up-to 95% effective, but depends on the nature of the chemical contamination and volume of material involved. This option is also affected by the suitability of land for composting in-situ and availability of commercial facilities and capacity in the area. **Cost –** May be high, considering; volume of affected food products; personnel costs; equipment (hiring machinery); potential compensation issues and landfill tax.
Practical experience		
(25) Bioremediation	Technical- The feasibility of this option depends on the nature of the chemical contamination, volume of material involved and the availability of a method.	**Public health -** Risk of odour and health complaints from nearby populations **Cost –** May be high, considering; volume of affected food products; personnel costs; equipment (hiring machinery); potential compensation issues and landfill tax
Practical experience	Incident: Contaminated land Manchester (2009) [16]. Incident: Hauxton remediation site (2003) [17].	
(32) Culling of livestock	**Waste –** There may be significant amounts of condemned livestock carcasses that will require further action (i.e. rendering, incineration and landfill). **Social -** Major disruptions to food business and farmers. Culling requires the consent of the owner, and there may be resistance of the public and impact on the farming community and cost.	**Public Health –** There is the potential for increased worker exposure (i.e. driver and operators at the abattoir, farm or knackers-yard. **Time -** A decision needs to be made quickly as this option would need to be implemented in the early – medium phase of an incident for this option to be effective.
Practical experience	Incident: Lead and chickens (2010) [18]. Incident: Michigan PPB incident (1973) [19].	

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(33) Burial of carcasses	**Technical -** Availability and suitability of land for engineering a purpose built burial pit. There are strict controls on the burial of carcasses. This option does not remove the chemical contamination – but removes the affected livestock from the food-chain. **Public Health –** There is the potential for negative impacts on people's health such as stress, worry and anxiety. **Waste-** If burial does not take place in a properly engineered site, leachate could escape creating an additional public health issue. **Social -** Acceptability with the public in the locality of the burial site. **Cost –** May be high, considering; number of animal carcasses requiring burial; personnel; equipment (hiring machinery); and potential compensation issues.	
Practical experience	Incident: Michigan PPB incident (1973) [19].	
(34) Disposal of contaminated milk to sea	**Technical -** Identification of long sea outfalls with capacity to discharge milk, authorisation to discharge milk to sea and transportation and offloading at discharge points. **Cost -** May be high, considering; the volume of milk requiring disposal; personnel; equipment and potential compensation issues.	**Social -** Acceptability with the public.
Practical experience		
(35) Burning in-situ	**Public Health -** Negative impact on the public health of susceptible groups (children, elderly or pregnant women). Adults and children with respiratory or cardiovascular problems are also to be at higher risk of experiencing complications with existing chronic conditions. **Waste -** There may be significant amounts of contaminated pyre ash and there is a risk that this waste disposal method could lead to low levels of contamination in the environment. **Social -** Acceptability with the general public. Visually highly emotive. Perception of risk, land subsequently being blighted. **Technical -** Suitability of land, associated land blight afterwards, transportation, and disposal of remaining pyre ash to land fill. This removes the contaminant from the food-chain, but doesn't remove the contamination.	**Cost -** May be high, considering; quantities of crops of number of animals/ livestock requiring disposal; personnel; equipment and potential compensation issues.
Practical experience		

	Major (key) considerations for selected recovery options	**Moderate considerations** for selected recovery options
(36) Rendering	**Waste-** The products of rendering will need further disposal.	**Public Health -** Potential for the general public to develop concerns over health effects, with smell/ odour complaints. **Technical -** This option may be up-to 95% effective, but depends on the nature of the chemical contamination and volume of material involved. This option is also affected by the suitability of material (i.e. livestock or solid wastes) for rendering and the availability of commercial facilities and capacity in the area. **Cost –** May be high, considering; volume of affected food products (including livestock); personnel costs; equipment (hiring machinery).
Practical experience	Incident: Dioxins in pork (2008) [6].	
(37) Incineration	None	**Social -** There could be local opposition near to an incineration plant due to public perception that chemical contamination will be released to the atmosphere. Acceptability with the general public and concerns over health effects should also be considered. **Technical -** This option may be up-to 95% effective, but depends on the nature of the chemical contamination and volume of material involved and the availability of commercial facilities and capacity in the area. Large municipal waste incinerators can process 300-500,000 tpa and could therefore take a large volume of waste. **Cost –** Incineration costs are high (but controlled)
Practical experience	Incident: ESS pursuit, mustard contamination (2010) 20. Incident: Nagano, Japan Paddy rice fields (2006) 21.	
(38) Landfill	**Waste –** For hazardous waste there is limited capacity and transport requirements may be significant.	**Public Health -** Acceptability with the general public and concerns over health effects. **Cost –** Incineration costs are high (but controlled)
Practical experience	Incident: Michigan PPB incident (1973) [19]. Incident: Love canal USA (1978) [22].	
(39) Land spreading of milk and/ or slurry	None	**Public Health -** Acceptability with the general public and concerns over health effects, with the potential for smell/ odour complaints. **Social -** Odour nuisance. **Technical –** There may be significant volumes of contaminated milk that requires disposal of through this method. There is a risk that this waste disposal method could lead to low levels of contamination in the environment. The suitability of this option is influenced by the land available for land spreading (not waterlogged, frozen, in nitrate sensitive area). Capacity of slurry tank to store milk at times when land not suitable for spreading.
Practical experience		

Table 4.8 Overview of recovery option considerations *colour coding is based on evaluation of evidence base and stakeholder input.

Recovery option	Public Health	Waste	Social	Technical	Cost	Time
Protection options (actions taken to protect the food chain)						
(1) Close air intake system at food processing plant						
(2) Prevention of contamination of greenhouse crops						
(3) Protect harvested crops from contamination						
(4) Short-term sheltering of animals						
(5) Restriction on entry of food into the food chain						
(6) Product recall						
(7) Control of entry into food chain						
(8) Issue a FEPA order						
(9) Precautionary (dietary) advice						
(11) Ban or restrictions on hunting and fishing						
(12) Restrictions on foraging						
Restoration (getting the production system back to normal)						
(10) Processing or treatment of food products						
(14) Selection of alternative product use						
(16) Ploughing methods						
(18) Land improvement (for 'natural' pasture)						
(19) Removal/ relocation of topsoil						
(20) Soil washing / irrigation of agricultural land						
(21) Adjust pH of soil						
(22) Application of potassium fertilisers to arable soils and grassland						
(23) Natural attenuation (with monitoring) (do no recovery)						
(26) Administration of chelation to animals						
(27) Application of supplements to concentrate ration						
(28) Administration of clay minerals to feed						
(29) Clean feeding/ selective grazing regime						
(30) Suppression of lactation						
(31) Restrictions on animal breeding						
Fate of affected produce (waste disposal)						
(13) Temporary derogation						
(15) Selection of alternative product use						
(24) Biological degradation/ decomposition						
(25) Bioremediation						
(32) Culling of livestock						
(33) Burial of carcasses						
(34) Disposal of contaminated milk to sea						
(35) Burning in-situ						
(36) Rendering						
(37) Incineration						
(38) Landfill						
(39) Land spreading of milk and/ or slurry						
Considerations/ constraints	**None or minor**		**Moderate**		**Important (key)**	
Time – when to implement recovery option	**No restrictions on time**		**Weeks to months/years**		**Hours – days**	

4.5.5 Step 5: Consult recovery option sheets

Refer to individual recovery options sheets (Section 5) for all remaining options that have been identified in the selection process and note other relevant constraints. This step involves a detailed analysis of all remaining options by careful consideration of the information on the relevant recovery options. This step can only be completed on an incident specific basis and in close consultation with local stakeholders to take into account local circumstances.

4.5.6 Step 6: Compare the remaining recovery options

Once options have been eliminated from the selection tables, if appropriate, the next step is to identify all the remaining options that could be considered for the type of food production system affected. These options need to be evaluated on a site and chemical incident specific basis using detailed information provided in terms, for example, exposure reductions, resource requirements, costs and amounts of waste generated, which may help to identify options that are not worth pursuing.

To aid with this selection strategy, a table could be designed to compare the remaining recovery options. Table 4.9 gives an example of a template that could be used for such a purpose.

Once a recovery strategy has been implemented then the remaining steps are to monitor to determine if the recovery strategy has been effective, and to report on the incident and the response, including the effectiveness of the Handbook (see Figure 4.1). These steps are outside the scope of the Handbook and are not discussed further.

Table 4.9: Further analysis of identified recovery options

Option number	Recovery option name	Step 1 Obtain information regarding the incident (refer to Table 4.5)	Step 2 Identify preliminary options for affected food production system (refer to Figure's 4.3 – 4.13).	Step 3 – Determine effectiveness of recovery options. Eliminate options on: A: Physicochemical properties B: Effectiveness of option (refer to Tables 4.5 and 4.6)	Step 4 - Review key considerations and constraints (refer to Tables 4.7 and 4.8)	Step 5 - Consult recovery option sheets (Section 5).	Option applicable?	Reason for elimination?

4.6 References

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5 Recovery options for food production systems

(1) Closure of air intake systems to minimise contamination of food processing plants and foodstuffs within them
(2) Prevention of contamination of greenhouse crops
(3) Protection of harvested crops from contamination
(4) Short-term sheltering of animals
(5) Restriction of entry into food chain/ withdrawal from market
(6) Product recall
(7) Control of entry into food chain
(8) Issue of a FEPA order
(9) Precautionary (dietary) advice
(10) Processing or treatment of food products
(11) Ban or restrictions on hunting and fishing
(12) Restrictions on foraging
(13) Temporary derogation
(14) Selection of alternative land use
(15) Selection of alternative product use
(16) Ploughing methods
(17) Ploughing in of a standing crop
(18) Land improvement (for ‘natural’ pasture)
(19) Removal/relocation of topsoil
(20) Soil washing/irrigation of agricultural land
(21) Adjust pH of soil
(22) Application of potassium fertilisers to arable soils and grassland
(23) Natural attenuation (with monitoring)
(24) Biological degradation/decomposition
(25) Bioremediation
(26) Administration of chelation to animals
(27) Application of supplements to concentrate ration
(28) Administration of clay minerals to feed
(29) Clean feeding/selective grazing regime
(30) Suppression of lactation
(31) Restrictions on animal breeding
(32) Culling of livestock
(33) Burial of carcasses
(34) Disposal of contaminated milk to sea
(35) Burning in-situ
(36) Rendering
(37) Incineration
(38) Landfill
(39) Land spreading of milk and/or slurry

(1) Closure of air intake systems to minimise contamination of food processing plants and foodstuffs within them

Objective	To reduce: • Contamination of foodstuffs from unfiltered air used in processing (1) • Contamination of food processing facilities (2). In the following text these objectives are referred to as (1) and (2) where comments are specific.
Other benefits	Maintain the credibility of safe food production systems to consumers (1, 2). Reduce inhalation of contaminated indoor air in industrial buildings and exposure workers in contaminated industrial plants after the passage of a chemical plume (2).
Recovery option description	In food industries, relatively large volumes of air are used for drying, roasting and pneumatic transport of food products. Outdoor air may be used directly or after purification with filters (e.g. EU filter categories 3 to 10). Due to large air volumes, sufficient filtering is not always possible. Contamination of foodstuffs can be prevented by halting those processes at risk before and during the passage of a chemical plume. For protection of facilities in general, intake rates of air into buildings can be reduced to a minimum or stopped. This is a “**self-help**” measure if carried out by facility owners.
Key information requirements	Is a chemical plume involved?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**.
Target	Industrial food processes: milling, roasting, drying, dairy or meat plants, bakery and catering industries etc. Predominantly targeted at food processes involving powdered foodstuffs All facilities of food processing industry (2).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could be dispersed via a plume. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is necessary. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium Important physicochemical properties would include vapour pressure, physical form
Scale of application	**Any** (potentially large scale)
Exposure pathway prevention	Deposition (from air to foodstuffs). Ingestion (1), inhalation and dermal (skin) contact (2).
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between closure of air intake systems to minimise contamination is **critical** and this may limit the feasibility of this option.
Considerations	
Public health considerations	If properly communicated and implemented by competent operators, no negative side-effects are expected from shutting the processing facility (1).
Legal implications and obligations	Requirement to consider appropriate chemical protection if there is a risk of operators being exposed to contaminated air (i.e. if time were short). Instructions for shutdown of a process or ventilation system must be followed. Responsibilities regarding compensation may need to be defined. For more information on legislation please see Appendix A
Social implications	Resistance of operators to carry out procedure. Resistance of food production workers to enter the affected area to retrieve food products. As the measure is preventative, with little risk to consumers, it is likely to help maintain public confidence in the safety of food products and promote trust in authorities.
Environmental considerations	None

(1) Closure of air intake systems to minimise contamination of food processing plants and foodstuffs within them

Ethical considerations	As this measure is precautionary authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary. Redistribution of exposure from consumers to operators or owners. Informed consent, if there is a risk that operators may be exposed to a chemically contaminated plume (if they have to go outside to close the air intakes).
Effectiveness	
Recovery option effectiveness	For batch processes that are completed and stopped before passage of the plume the effectiveness should be close to 100% assuming that processing is not restarted until air concentrations are reduced to close to background levels (1). Prevention of contamination of industrial plants through closure of air intakes will result in substantial reductions. However, this will not result in air tight buildings, so effectiveness cannot be expected to be 100% (2).
Technical factors influencing effectiveness of recovery option	Incomplete or erroneous timing may substantially reduce the effectiveness of this measure, as the time to close air intake systems and deposition is critical to minimise contamination. Sufficient time is needed to stop any existing processing prior to passage of the plume (1). The ability or possibility to make plants air-tight will vary (2). Closing air intakes of an industrial plant can be complex. Changes in wind direction at the time of the incident may deem this option unnecessary. Availability of suitably trained personnel Depending on the time and labour required, operators may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with public sheltering advice or evacuation. It should be in a contingency plan. A review of different types of food processing plants could reveal potential risks from complete closure of air-intake systems (2) at specialised technical facilities.
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	None
Consumables	None for the actual implementation of the measure. After passage of the plume the air filters may need to be replaced and disposed of.
Skills, personnel and operator time	Capabilities will exist on site. Competent persons would need to be available and may have to be called on to implement the recovery option out of hours.
Safety precautions	Operators may need to wear appropriate chemical protection if they must go outside in order to close vents (risk of being exposed to contaminated air) To maintain an uncontaminated status, staff will need instruction and occupational monitoring may be required (2).
Other limitations/factors influencing costs	Delayed implementation may result if the protocol for implementing this measure is not sufficiently well known to the key persons in advance. Only competent staff members with the right to stop a process in an actual threat situation may be able to implement the measure (unless otherwise stated in emergency plans prepared for a particular site). Requirement for well-informed pre-warning may make this measure more applicable to sites far away from the source. A decision on implementation will have to consider the (potentially unknown) technical consequences of a sudden shutdown of some industrial processes.
Waste	
Amount and type	Significant quantities of waste are not expected to be generated by this measure (1), and there may be a reduction in the amount of unfit food to be disposed of. Filters in air ventilation systems may require disposal.
Possible transport, treatment, disposal and storage routes	N/A

(1) Closure of air intake systems to minimise contamination of food processing plants and foodstuffs within them

Factors influencing waste issues (i.e. cost)	Potential for spoilage of food products if processes are shutdown.

Exposure

Averted exposure	Contamination of food products and processing equipment
Potential increased worker exposure	Potential risk of exposure if operators must go outside in order to close vents, there may also be additional exposures associated with disposal of contaminated air filters.

Other considerations

Agricultural impact	None
Compensation issues	There may be requests for compensation for loss of earnings and production if; • Production is lost as a consequence of unnecessary shutdown; • Plant subsequently fails because of shutdown; • Large quantities of food are contaminated in the event that the information provided regarding the timing of the recovery option was incorrect. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk .
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. This recovery option would have to be implemented prior to the arrival of a contaminated plume, therefore rapid and comprehensive instructions to plant operators would be required. Depending upon time of day, information on risks would need to be communicated to workers prior to their leaving the workplace for home. Clear and readily available instructions should be provided in the identified processing plants' existing emergency plans/ handbook. Information must be updated regularly to ensure operators are not exposed to a contaminated plume. The cost of communicating the recovery option and its objectives to operators and the industry should also be considered; multiple channels may be necessary (e.g. advisory centre, leaflets, internet).

Additional information

Practical experience	This option is fairly routine in the event of a local fire. Food contamination from processed air containing harmful microbes or heavy metals has been considered by the food industry.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Implementation of this recovery option avoids contamination of the food production plant as well as food products. Closure of air intake systems could lead to lost production and compensation issues would need to be identified in the event of an incident or false alarm
Document History	

(2) Prevention of contamination of greenhouse crops

Objective	To stop contaminated air or water entering greenhouses and/or polytunnels thus preventing or minimising the contamination of crops and growing media within them.
Other benefits	Reduces the amount of potentially contaminated food. Avoids contamination of growing medium.
Recovery option description	Switch off ventilation systems during passage of chemical plume and close all windows, doors and vents. The recovery option is **precautionary**. It is most useful if implemented before the passage of a chemical plume but could still be implemented after the plume has passed to minimise impact. Normal operation should be able to resume soon after the passage of the plume. Water plants with clean water i.e. water not directly contaminated in incident
Key information requirements	Is a chemical plume involved?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**.
Target	Greenhouse and/or polytunnel crops.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are could be dispersed via a plume and **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium Important physicochemical properties would include vapour pressure, physical form
Scale of application	**Any** (Potentially large scale).
Exposure pathway prevention	Direct contamination of crops, and later soil to plants.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between notification and contamination occurring is **critical** and this may limit the feasibility of this option.

Considerations

Public health considerations	Depending on the time before arrival of the plume, operators may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with public sheltering advice or evacuation.
Legal implications and obligations	Requirement to consider chemical protection if there is a risk of personnel being exposed to contaminated air-masses. The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. For more information on legislation please see Appendix A
Social implications	This recovery option may help maintain public confidence regarding the quality of food products and trust in authorities. Depending on the nature of the chemical involved (i.e. persistence in environment) there could be disruptions in farming practice.
Environmental considerations	None.
Ethical considerations	As this measure is precautionary authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary. Self-help if carried out by owners.

Effectiveness

(2) Prevention of contamination of greenhouse crops

Recovery option effectiveness	Potentially up to 100%
Technical factors influencing effectiveness of recovery option	The effectiveness of this option will depend on; Properties of chemical(s) involved – only applicable to chemicals dispersed in a plume Incomplete or erroneous timing may substantially reduce the effectiveness of this measure, as the covering of crops and deposition is critical to minimise contamination. Compliance of farmers or operators to carry out procedure. Type and condition of greenhouse and/or polytunnel. Availability of alternative water supplies if rainwater normally collected although this method of irrigation is unlikely to be used by large scale producers or in southern climates due to the limited volumes of water likely to be collected. If it was to be collected again after contamination the roof would have to be cleaned or a suitable period would need to have elapsed between incident and collection in the case of short lived chemicals.
Feasibility and intervention costs	
Specific equipment	None.
Utilities and infrastructure	Alternative water supply if collected rainwater normally used.
Consumables	None.
Skills, personnel and operator time	Skills are present within horticultural community. Personnel may have to implement the recovery option out-of-hours.
Safety precautions	Ensure operators are removed prior to contamination or passage of a chemically contaminated plume (effective system of communication must be in place).
Other limitations/factors influencing costs	Requirement for well-informed pre-warning may make this measure more applicable to sites remote from the source.
Waste	
Amount and type	Significant quantities of waste are not expected to be generated by this measure. However, potentially contaminated rainwater should not subsequently be used to irrigate greenhouse crops.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	Potentially transport and disposal of rainwater. Crops may require disposal if damaged – but contamination level should be minimal.
Exposure	
Averted exposure	Contamination of crops
Potential increased worker exposure	Exposure to operators should be minimal as long as the procedures are completed before the arrival of a chemical plume.
Other considerations	
Agricultural impact	Potential spoilage of crop due to lack of ventilation.
Compensation issues	There may be requests for compensation for loss of earnings and production if; • Crops spoilt or damaged as a consequence of this measure. • Large quantities of food are contaminated in the event that the information provided regarding the timing of the recovery option was incorrect. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

(2) Prevention of contamination of greenhouse crops

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. This recovery option would have to be implemented prior to the arrival of a contaminated plume, therefore rapid and comprehensive instructions to plant/ horticultural operators would be required. Depending upon time of day, information on risks would need to be communicated to workers prior to their leaving the workplace for home. Clear and readily available instructions should be provided in the identified processing plants' existing emergency plans/ handbook. Information must be updated regularly to ensure operators are not exposed to a contaminated plume and that the recovery option is not applied post contamination. The cost of communicating the recovery option and its objectives to those likely affected (e.g. gardeners and commercial producers) should be considered; multiple channels may be necessary (e.g. advisory centre, leaflets, internet). Provision of information to consumers on the rationale of the recovery option and evidence of its effectiveness would be important.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	The time between notification and contamination occurring is critical and this may limit the feasibility of this option. Avoids contamination of the greenhouse as well as the products inside. Closure of ventilation systems could lead to lost production if sustained for a lengthy period of time. It is not clear who would pay compensation for the close down if it was a false alarm. Re-assurance monitoring may be required for crops entering the food-chain for public confidence. Notification to switch off ventilation systems would need to coincide with public announcement about the incident
Document History	

(3) Protection of harvested crops from contamination

Objective	To prevent the contamination of crops which have been harvested prior to contamination and those stored outside waiting processing (e.g. sugar beet).
Other benefits	Public confidence in food products.
Recovery option description	Covering of hay, silage (stored in clamps) and fodder crops (e.g. beets) stored on farms with plastic sheets or waterproof tarpaulin. The recovery option is precautionary, and only useful if implemented before the passage of a chemical plume. Normal operation may be resumed soon after the passage of the plume.
Key information requirements	Is a chemical plume involved?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**.
Target	Predominantly animal forage and fodder crops although also applicable to other harvested crops where appropriate (e.g. silo's full of grain exposed to smoke).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are could be dispersed via a plume and **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium Important physicochemical properties would include vapour pressure, physical form
Scale of application	**Any**. Potentially large scale but depends on the time available between notification and arrival of the plume and availability of resources or materials.
Exposure pathway prevention	Direct contamination.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between notification and contamination occurring is **critical** and this may limit the feasibility of this option.

Considerations

Public health considerations	None.
Legal implications and obligations	Requirement to consider chemical protection if there is a risk of farmers being exposed to contaminated air and subsequently when removing contaminated covering. For more information on legislation please see Appendix A
Social implications	Compliance or resistance of farmers or operators to carry out procedure. Compliance of supporting industries, for example entering the affected area to collect crops. This recovery option may help maintain public confidence regarding the quality of food products and trust in authorities. Depending on the nature of the chemical involved (i.e. persistence in environment) there could be disruptions in farming practice.
Environmental considerations	Would be difficult to implement in high winds. Some crops may spoil if covered for prolonged periods in hot weather. There may be issues associated with disposal of waste plastics.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act. As this measure is **precautionary** authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary. Redistribution of exposure from consumers to operators or owners. Self-help if carried out by farmers. Informed consent, there is a risk that operators may be exposed to a contaminated plume.

(3) Protection of harvested crops from contamination

Effectiveness

Recovery option effectiveness	Potentially up-to 100% effective.
Technical factors influencing effectiveness of recovery option	The effectiveness of this option will depend on properties of chemical(s) involved – only applicable to chemicals dispersed in a plume. Incomplete or erroneous timing may substantially reduce the effectiveness of this measure, as protecting harvested crops from contamination and deposition is critical to minimise contamination. Farmers may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with advice for public sheltering or evacuation. Availability of covering materials. Farmers may have to implement the recovery option out of hours. Degree to which covering diverges from usual practice. If contaminated water runs off protective sheet onto crop upon removal, then effectiveness will be reduced.

Feasibility and intervention costs

Specific equipment	Covering and securing materials.
Utilities and infrastructure	None
Consumables	Plastic sheeting
Skills, personnel and operator time	Skills are present within farming and horticultural community. Personnel may have to implement the recovery option out-of-hours.
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). If this option is implemented as a '**self-help'** option personal protective equipment (PPE) may be required.
Other limitations/factors influencing costs	Amount and nature of crop to be covered. Existing storage method for crop (e.g. fodder likely to be under cover with one or more open walls).

Waste

Amount and type	Contaminated covering materials. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Depending on the nature of the chemical, waste may be classified as dangerous in transport (e.g. asbestos) and subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Existing organised routes of disposal of agricultural plastic wastes, such as silage bale wrapping, will be inappropriate where recycling is the aim of the existing schemes.
Factors influencing waste issues (i.e. cost)	Transport and disposal of covering materials. Crops may require disposal if damaged. Maybe reduction in amount of food to be disposed of. Covering material is unlikely to be biodegradable. Landfill operators are reluctant to accept large quantities of plastic waste as it works its way to the surface and causes drainage problems. There are limits on hazardous wastes that can be disposed of to landfill.

Exposure

Averted exposure	Contamination of crops

(3) Protection of harvested crops from contamination

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers or farming personnel use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely operator exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the implementation of reactive liquids as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included. Additional exposures to people applying coverings should be minimal as long as the procedures are completed before the arrival of a plume. Exposure to persons handling contaminated coverings should be considered.

Other considerations

Agricultural impact	Risk of spoilage of some crops if covered for prolonged periods. If forage or fodder to be sold from the farm market, value may be reduced.
Compensation issues	There may be requests for compensation for loss of earnings and production if; • Crops spoilt or damaged as a consequence of this measure. • Large quantities of food are contaminated in the event that the information provided regarding the timing of the recovery option was incorrect. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. This recovery option would have to be implemented prior to the arrival of a contaminated plume, therefore rapid and comprehensive instructions to plant/ horticultural operators would be required. Depending upon time of day, information on risks would need to be communicated to workers prior to their leaving the workplace for home. Cost of communicating the recovery option and its objectives to farmers; multiple channels may be necessary (e.g. media broadcasts, advisory centres, leaflets, and internet). Information must be provided quickly and updated regularly to ensure farmers are not exposed to a contaminated plume and that recovery option is not applied post contamination. The short time available may preclude extensive consultation, thus making it difficult to satisfy conditions of informed consent from operators. Advice on handling waste. Provision of information to consumers on the rationale of the recovery option and evidence of its effectiveness would be important. Whilst the recovery option is likely to help maintain consumer confidence, it may be necessary for monitoring of foodstuffs to ensure acceptability of produce.

Additional information

Practical experience	Farmers will have experience of covering crops after harvest (e.g. silage clamps) or to protect from weather.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	The time between notification and deposition is critical and this may limit the feasibility of this option. Hay bales may be covered already or in Dutch barns. Similarly, silage may be in clamps. If harvested crops have not been gathered this would need to be done before covering and therefore require additional time. There could be a secondary waste issue from covering material
Document History	

(4) Short-term sheltering of animals

Objective	To avoid or limit contamination of food products derived from grazing animals (by reducing the ingestion of contaminated feed during and soon after the grounding of a chemical plume).
Other benefits	Minimise the volume of contaminated milk requiring disposal. Will reduce exposure of farm animals especially to chemicals with a short persistency. Public confidence in food products may increase. Animal welfare benefits
Recovery option description	Short-term housing of grazing animals prior to incident and feeding with stored feedstuffs. The long-term clean feeding or housing of livestock is dealt with in a separate Recovery option. It is possible that this recovery option may coincide with the evacuation of the human population. If so farmers (or suitable emergency workers) will need to return at regular intervals to tend stock (until the evacuated population are allowed to return or, if evacuation is likely to be for a prolonged period, a decision is made to remove or cull the animals. For extreme emergency situations requiring the immediate evacuation of the public, this recovery option will not be possible.
Key information requirements	Is a chemical plume involved?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with (29) Clean feeding/ selective grazing regime.
Target	Grazing animals. Any animals outdoors at the time of the relevant incident
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are could be dispersed via a plume and **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include vapour pressure, physical form
Scale of application	**Any** (potentially large scale depending on farming practices).
Exposure pathway prevention	Direct contamination and ingestion by animals. Ingestion of contaminated products.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between notification and contamination (i.e. animals are at risk of exposure) is **critical** and this may limit the feasibility of this option.
Considerations	
Public health considerations	None
Legal implications and obligations	Requirement to consider chemical protection if there is a risk of farmers being exposed to contaminated air-masses. Animal welfare regulations. Regulations on the recovery of agricultural discharges; e.g. the recovery option will result in the production of manure and/or slurry on which there may be legal restrictions with regard to when it can be spread to land. For more information on legislation please see Appendix A

(4) Short-term sheltering of animals

Social implications	Compliance of supporting industries, for example entering the affected area to collect milk or deliver feed. Acceptability of produce to food industry or consumers – need for monitoring data on foodstuffs. increase confidence that the problem of contamination is being effectively managed; There may be a of confidence if no recovery option applied. Disruption or adjustment of farming and related industrial activities, and people's image or perception of 'countryside'. Depending on the nature of the chemical involved (i.e. persistence in environment) there could be disruptions in farming practice (i.e. restricting future grazing), or stigma associated with the affected area.
Environmental considerations	Housing of livestock produces large volumes of manure and/or slurry; that must be disposed of appropriately to avoid pollution (this is normal practice to avoid pollution from nitrates). Storage capacity on farm for manure and/or slurry.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act. As this measure is **precautionary** authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary. Redistribution of exposure from consumers to operators or owners. Self-help if carried out by farmers. Informed consent, there is a risk that operators may be exposed to a contaminated plume. Ethical issues will depend on whether the recovery option is introduced as mandatory, or as advice to farmers (whilst the considerations will be the same, the weight of the various aspects will change).
Effectiveness	
Recovery option effectiveness	Up to 100% dependent upon chemical composition, housing type, and water and feed supplies.
Technical factors influencing effectiveness of recovery option	Incomplete or erroneous timing of the recovery option may substantially reduce its effectiveness. Compliance of farmers or operators to carry out procedure. They may be reluctant to be outside while there is a risk of contamination. This is likely to be exacerbated if the measure coincides with advice for public sheltering or evacuation. Distance between pastures and shelters. Degree to which recovery option diverges from usual practice. Type of housing will determine exposure to airborne chemicals (e.g. some housing, especially in southern European countries, is likely to be of a more open construction and therefore inhalation of chemicals will still occur). Availability of forage – combined implementation with protection of harvested crops may aid in this. Unlikely to be sufficient local housing and conserved foodstuffs in systems using summer grazing regimes remote from farmsteads (may limit practicability of this measure in extensive Mediterranean systems). Water sources may be contaminated – especially relevant to farms with local water supplies. Roughage is generally exhausted at the end of winter (concentrates will normally still be available). Whilst the recovery option is likely to help maintain consumer confidence in foodstuffs, it may be necessary for monitoring to ensure acceptability and for reassurance purposes.
Feasibility and intervention costs	
Specific equipment	Equipment to remove manure or slurry – may not be required in emergency phase.
Utilities and infrastructure	Suitable housing with water supply, and power if required. Storage capacity for extra manure or slurry.
Consumables	Stored feed must be available. Bedding (straw etc.) if used.
Skills, personnel and operator time	Farmers would possess the necessary skills as housing animals is normal practice. Farmers may have to implement the recovery option out of hours, This recovery option may result in extra work for farmer looking after housed animals and subsequently disposing of manure and/or slurry.

(4) Short-term sheltering of animals

Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Time for which animal sheltering is required. Availability of feed locally. In near field situations, especially where population may have been evacuated, health monitoring of animals may be required even if only for reassurance purposes. Roads must not be blocked by moving animals when people need to be evacuated.
Waste	
Amount and type	No contaminated waste expected although manure and/or slurry will need to be disposed of when the emergency has passed. Reduced amount of food waste.
Possible transport, treatment, disposal and storage routes	Use of normal slurry or manure disposal routes is unlikely to be a problem given short term nature of recovery option.
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated meat / milk products
Potential increased worker exposure	No additional exposure during the operation if farmers or operators return to shelter before arrival of contamination. Potential exposure if this recovery option is combined with population evacuation for those who will have to come back regularly to milk and feed animals.
Other considerations	
Agricultural impact	Normally changes from grazing to conserved feeds would be progressive. In an emergency situation diet would have to be changed rapidly this may lead to reduced productivity and negative health effects in the affected animals. Animal welfare issues associated with housing animals in emergency facilities (i.e. may not be as well prepared as when normally housed) and if housed in summer when temperature or poor ventilation may be a problem.
Compensation issues	There may be requests for compensation for loss of earnings and production by the farmer for replacement feed (and bedding) and for additional work or labour. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. This recovery option would have to be implemented prior to the arrival of a contaminated plume, therefore rapid and comprehensive instructions to farmers would be required. Information must be provided quickly and updated regularly to ensure farmers are not exposed to a chemically contaminated plume and that this option is not applied post contamination. Advice to farmers on handling contaminated waste (manure and/or slurry).
Additional information	
Practical experience	

(4) Short-term sheltering of animals

Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Farmers should be able to gather dairy animals relatively quickly (in about 1 hour). There could be animal welfare issues as animals if adapting or introducing alternative stored feeds very quickly. The availability of alternative feed will depend on the time of year with the period from March-May likely to have fewest options for alternative feedstuffs
Document History	

(5) Restriction of entry into food chain/withdrawal from market

Objective	To prevent consumers from eating contaminated food by removing contaminated food from the food chain.
Other benefits	Maintenance of confidence in food products.
Recovery option description	Livestock, milk, meat, eggs and crops, and derived products, when determined as unsafe or that could contain potentially harmful levels of contaminants or where there is a breach of a regulatory limit are withheld or withdrawn from sale.
Key information requirements	Nature and level of contamination. Relevant regulatory limits Risk assessments
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should be considered in conjunction with; (6) Product recall; (7) Control of entry into food chain and (8) Issue of a FEPA order. Waste disposal of contaminated foodstuffs or animals may also need to be considered, including; (17) Ploughing in of a standing crop; (24) Biological treatment/degradation; (32) Culling of livestock; (35) Burning in situ; (36) Rendering; (37) Incineration; (38) Landfill; and (39) Land spreading of milk or slurry
Target	Livestock, milk, meat, eggs and crops and derived products.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate the food chain and **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include: persistence, partition coefficient, biological half life
Scale of application	**Any**
Exposure pathway prevention	Ingestion of contaminated food.
Time of application	**No restrictions on time.** There are no restrictions on time with implementing this recovery option (hours to years), although it should be considered as soon as a risk is recognised.

Considerations

Public health considerations	No issues unless there is a delay in implementing this option and contaminated food products enter the food chain.
Legal implications and obligations	Under general food law Regulation (EC) 178/2002: Article 14 places a legal obligation on food businesses not to place unsafe food on the market. Under Article 19, they must withdraw food from the market as soon as they have reason to believe it does not comply with food safety requirements. Under Article 18, they must be able to trace where they have obtained or supplied food, ingredients or food-producing animals and whom they have supplied. There may be legal constraints on the disposal options for the withdrawn foodstuffs (see waste disposal Recovery Options). Where food implicated in the incident has been supplied to other EU Member States or third countries, there may be pressure to replicate actions taken elsewhere (especially within the EU), even where these are considered excessive. For this reason, decisions need to be taken and communicated quickly. This is of particular importance where a decision is made NOT to take action. For more information on legislation please see Appendix A

(5) Restriction of entry into food chain/withdrawal from market

Social implications	Retail trade or producers' may be reluctant to implement this recovery option. Potential to cause alarm within communities. Usually it is when the public become aware of a withdrawal that some food businesses make a decision to recall products to reinforce trust and promote consumer confidence. Policing the recovery option and averting fraudulent trading. Potential for generating mistrust of food production systems or conversely, possible increase in public confidence that the problem of contamination is being effectively managed. There may be a negative social and psychological impact (or stigma) associated with food produced from the affected area.
Environmental considerations	The fate of withdrawn foodstuffs and appropriate waste disposal routes of food products that are withdrawn from the market must be considered when implementing this recovery option.
Ethical considerations	As this measure is **precautionary** authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary.
Effectiveness	
Recovery option effectiveness	Highly effective (up to 100%) at removing commercially produced food that is contaminated above safe or permissible levels from food chain.
Technical factors influencing effectiveness of recovery option	Mode of implementation of the recovery option (i.e. how will affected food products be withdrawn?). Difficulties in monitoring for specific chemicals. e.g. minimum 2-week turnaround time for dioxin analysis Difficulties tracing contaminated food that has been significantly distributed (e.g. abroad; into a wide range of products)
Feasibility and intervention costs	
Specific equipment	None. Withdrawal of contaminated food (or food that is suspected to be contaminated) can be implemented without specific equipment. Monitoring may be required to demonstrate that food complies with acceptable levels or is of low risk to the consumer.
Utilities and infrastructure	Additional containers and temporary storage capacity may be needed to ensure that quarantined and unaffected batches of foodstuffs will not be mixed.
Consumables	None.
Skills, personnel and operator time	Logistical experts to ensure maintenance of the food supply especially in early phase. Personnel will also be required to enforce this option and potentially to source alternative sources of food.
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). If quarantined food is highly contaminated, normal storage facilities, even if separate from other storage, may be inadequate and additional safety measures may be needed to prevent the spread of contamination.
Other limitations/factors influencing costs	The scale and complexity of the affected part of the food chain may affect the practicability of withdrawal so the extent of the withdrawal must be balanced with the risk. Storage costs may also need to be considered if large quantities of waste will require disposal. Time and distances involved in travelling to areas under restrictions for monitoring purposes. Time and distances involved in sourcing alternative source of food.
Waste	
Amount and type	Depending on scale of incident, it is possible that significant quantities of contaminated waste (i.e. food products, slurry from contaminated live animals) will be generated (including, milk, meat, eggs, crops and derived products). Contaminated waste may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. Long-term restrictions may also lead to cull and disposal of livestock.

(5) Restriction of entry into food chain/withdrawal from market

Possible transport, treatment, disposal and storage routes	Milk may be land-spread, processed, biologically treated or disposed of to sea. Livestock carcasses may be disposed of directly by rendering and incineration or burial. Alternatively, the carcass may be rendered, and the products of rendering disposed of appropriately (i.e. dioxins would go into the tallow (fat) whereas heavy metals and water soluble chemicals would be in the MBM). Crops may be ploughed in, composted, processed, digested, land filled or incinerated.
Factors influencing waste issues (i.e. cost)	Dependent on subsequent disposal route selected for withdrawn foodstuffs and quantities of waste produced. Area under restrictions and duration of restrictions. Acceptability of, and compliance with, waste disposal practice. Local availability of suitable disposal routes. Legal constraints on the fate of withdrawn foodstuffs.
Exposure	
Averted exposure	Ingestion of contaminated food products
Potential increased worker exposure	None directly, but subsequent recovery of large quantities of waste crops, animal carcasses and milk may incur additional exposure. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers must comply with the Health and Safety at Work Act to ensure that recovery workers or farming personnel use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the implementation of reactive liquids as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	
Agricultural impact	None.
Compensation issues	There may be requests for compensation: **Farmer:** For loss of earnings following restrictions on products **Industry:** For the difference in costs compared to normal practice. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some production or retail companies, so good stakeholder dialogue will be essential. Dissemination of information about the recovery option, its rationale and possible alternatives i.e. information explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels will be required. Good communication with members of public is essential to prevent alarm within communities
Additional information	
Practical experience	Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32 Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report-Health Protection Agency. 2010 (17); pg6 Centres for Disease Control and Prevention. Nicotine Poisoning After Ingestion of Contaminated Ground Beef Michigan. Morbidity and Mortality Weekly Report 2003 (52): 413-416.

(5) Restriction of entry into food chain/withdrawal from market

Key references	Guidance Notes for Food Business Operators on Food Safety, Traceability, Product Withdrawal and Recall (2002) Food Standards Agency Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015..
Comments	It is generally accepted that there has to be agreed limits above which food is withdrawn from market. It is important to harmonise these limits between Member States. There must be recognition that food withdrawal notices have associated waste disposal problems. Nevertheless, it must also be understood that exceedance of a limit does not automatically indicate a health concern as many limits are set to reduce long-term exposure and provide a legal basis for enforcement action.
Document History	

(6) Product recall

Objective	To prevent consumers from eating contaminated food that they have already purchased.
Other benefits	Maintenance of confidence in food businesses and brands.
Recovery option description	Recall involves advice to the public not to consume specific products but to dispose of them or return them to the retail outlet where they were purchased (normally for a refund). Food business operators must recall products when risk assessment indicates a public health concern and withdrawal alone does not provide sufficient level of protection. Product recall would normally be carried out in conjunction with a product withdrawal/restriction from the food chain (Recovery option 5). Food businesses and retailers may also choose to initiate a recall when they consider this necessary to maintain public confidence. Consumers should be informed effectively and accurately of the reason for the recall of the product and consideration given to those who may already have consumed affected products (i.e. to avoid unnecessary anxiety and whether or not they should seek medical advice) .
Key information requirements	Details of implicated products, including any brand names, descriptions, origin, dates of manufacture, batch numbers i.e. any information that will enable consumers, retailers and enforcement officers to identify and distinguish affected from unaffected products.
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry of food into the food chain/ withdrawal from market Waste disposal of affected produce would also need to be considered, relevant options include; (36) Rendering; (37) Incineration; (38) Landfill and (39) Land spreading of and/or slurry.
Target	People who have purchased the affected products.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are could contaminate the food chain and pose a risk to public health. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium Important physicochemical properties would include: persistence, partition coefficient, biological half life
Scale of application	**Any.**
Exposure pathway prevention	Ingestion of contaminated food products.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between contamination and recall is **important** and this may limit the feasibility of this option.

Considerations

Public health considerations	None. However, the public information and communication strategy would have to be carefully considered as this option considers food that has already been purchased for consumption and people may have already eaten the affected food.
Legal implications and obligations	Under general food law Regulation (EC) 178/2002 Article 19.1 places the obligation on food businesses to recall products where necessary to protect public health. Article 18.3 obliges food business operators to maintain records of the businesses to whom they supply their products. The basis for enforcement under 178/2002 is risk to health. As risk assessments tend to be subjective by nature, it is possible that the need for a recall may be challenged by the food business operator. There will be legal constraints on the fate of the recalled foodstuffs (see waste disposal Recovery Options below). For more information on legislation please see Appendix A

(6) Product recall

Social implications	Individuals complying with instruction to return food Issue may be trust (or lack of) in the institutions or experts advising against consumption. Effects to consumers e.g. price increases and food shortages in extreme incidents. If extensive, recall of food products may lead to market shortages and disruption of farming and the food processing industry particularly in early phase of Implementation There may be public anxiety for those who have already consumed recalled products Perceived contamination of all food products (and loss of confidence). Operators could be put out of business with knock-on effects on other businesses. Potential for generating mistrust of food production systems or, conversely, possible increase in public confidence that the problem of contamination is being effectively managed. Negative social and psychological impact regarding contaminated food.
Environmental considerations	None. However, the public information and communication strategy would have to be carefully considered as this option considers food that has already been purchased for consumption and people may have already eaten the affected food.
Ethical considerations	Under general food law Regulation (EC) 178/2002 Article 19.1 places the obligation on food businesses to recall products where necessary to protect public health. Article 18.3 obliges food business operators to maintain records of the businesses to whom they supply their products. The basis for enforcement under 178/2002 is risk to health. As risk assessments tend to be subjective by nature, it is possible that the need for a recall may be challenged by the food business operator. There will be legal constraints on the fate of the recalled foodstuffs (see waste disposal Recovery Options below). For more information on legislation please see Appendix A
Effectiveness	
Recovery option effectiveness	Compliance with the recommendation not to eat certain foodstuffs and returning/ disposing of contaminated food products very unlikely to be 100% effective at reducing exposure, and will never be possible to verify in practice. Some implicated food may already have been consumed. Indeed some incidents come to light as a result of adverse effects from consumption. Additionally there would be no certainty that the message reaches all purchasers of affected batches.
Technical factors influencing effectiveness of recovery option	Selection of suitable communication channels and clarity of information. Difficulties tracing contaminated food that has been significantly distributed (e.g. abroad) Willingness of population to accept this type of intervention, and the extent to which advice is followed (possible language and literacy issues). There may be negative consequences for food producing companies, who may therefore challenge the basis for the recall. When the population has trust in the institutions or experts advising against consumption, the recovery option is likely to have more positive than negative social consequences (e.g. trust, personal control and informed choice).
Feasibility and intervention costs	
Specific equipment	No specialist equipment is required to implement this option; however containers and temporary storage facilities may be needed for recalled food.
Utilities and infrastructure	For a large scale recall, specific facilities (i.e. temporary storage prior to waste disposal) may be required. Appropriate lines of communication are of paramount importance in implementing this option.
Consumables	Dependant on communication method
Skills, personnel and operator time	Communication skills
Safety precautions	None
Other limitations/factors influencing costs	None

(6) Product recall

Waste

Amount and type	Depending on scale of the recall, it is likely that significant quantities of contaminated food products may require disposal. Contaminated waste may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Depending on scale of incident can result in large quantities of recalled food requiring transport, storage and disposal Milk may be land-spread, processed, biologically treated or disposed of to sea. Animal products may be disposed of directly by rendering and incineration or landfill. Fruit and vegetables could be composted, processed, digested, land filled or incinerated.
Factors influencing waste issues (i.e. cost)	Dependent on: disposal route selected for recalled foodstuffs and quantities of waste produced, acceptability of, and compliance with, waste disposal practice, local availability of suitable disposal routes, chemical composition of contaminated food, legal constraints on the fate of recalled foodstuffs.

Exposure

Averted exposure	Ingestion of contaminated food products
Potential increased worker exposure	None

Other considerations

Agricultural impact	None
Compensation issues	There may be requests for compensation; **Food industry** • For difference in costs compared to normal practices. • Refund or replacement costs. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some production or retail companies, so good stakeholder dialogue will be essential. Dissemination of information about the recovery option, its rationale and possible alternatives i.e. information explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels will be required to all of the food businesses concerned. Good communication with members of public is essential to prevent alarm within communities, with consistent information about the recall and the reasons for it. All possible means of communication to consumers should be considered. These may include food business, Local Authority and Food Standards Agency websites, special interest groups (e.g. for contaminated infant formula or baby food, organisations such as NCT, Royal College of Midwives), point-of-sale notices, newspaper and magazine adverts, television and radio (local and/or national), direct mailing (where possible and relevant).

Additional information

Practical experience	Product recalls are very common (see the Alerts section of the Food Standards Agency website at http://www.food.gov.uk/enforcement/alerts/

(6) Product recall

Key references	Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32 Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report-Health Protection Agency. 2010 (17); pg6 Centres for Disease Control and Prevention. Nicotine Poisoning After Ingestion of Contaminated Ground Beef Michigan. Morbidity and Mortality Weekly Report 2003 (52): 413-416.
Comments	
Document History	

(7) Control of entry into food chain

Objective	To limit the entry of contaminated food into the food chain, this includes crops, meat, milk and eggs.
Other benefits	Avoids the need for food-producing animals to be culled for disposal.
Recovery option description	In the early to medium (weeks to months) phase of the incident, a decision may need to be made regarding the manipulation of slaughter times to reduce concentrations in meat as a consequence of natural degradation of short-lived chemicals, or losses (with or without metabolism) from the tissues (biological half-life) by withholding animals and products (i.e. eggs, milk from dairy herds) from the food chain until contamination levels are acceptably low, combined with provision of uncontaminated feeds (allowing the affected animal time to clean up 'naturally' as levels in environment reduce. Milk and egg production are good excretion routes for some chemical contaminants). For some contamination scenarios, e.g. heavy metals, it might also be possible to allow meat but not offal to enter the food chain.
Key information requirements	For a policy of immediate culling (for disposal), slaughter (if for entry into the food chain) or harvest to be adopted, there must be contingency plans in place to cope with the legal and practical logistics of transporting large numbers food produce (crops or animals) at short notice.
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should be considered in conjunction with waste disposal options such as (32) Culling of livestock; (33) Burial of carcasses; (35) Burning in-situ; (36) Rendering; (37) Incineration and (38) Landfill.
Target	Livestock.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are could bio-accumulate or **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties: biological half-life, partition coefficient
Scale of application	**Any**
Exposure pathway prevention	Prevention of contaminated food from entering the food chain (i.e. ingestion of contaminated crops/ animal products).
Time of application	**No restrictions on time.** There are no restrictions on time with implementing this option (hours to years), although it should be considered as soon as a risk is recognised.

Considerations

Public health considerations	None.
Legal implications and obligations	Animal welfare issues may need to be considered. For more information on legislation please see Appendix A
Social implications	Farmer or herder resistance to the recovery option. May impact on public confidence eg :loss of confidence that farm produce and derivative products from affected areas is 'safe' (may i.e. result in loss of employment in local 'cottage' industries or growth of a black market); loss of image of a food-producing region may also be a concern (e.g. as with the NI dioxin incident).
Environmental considerations	None expected.

(7) Control of entry into food chain

Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). As this measure is **precautionary** authorities may lose public trust if with hindsight measures are proved to have been unnecessary. Animal welfare must not be compromised by extra time spent at, or waiting to be sent to slaughterhouses prior to slaughter or in travelling long distances to remote slaughterhouses. Early slaughtering involving removal of young livestock from lactating dams may have animal welfare implications (e.g. mastitis).

Effectiveness

Recovery option effectiveness	Up-to 100% effective
Technical factors influencing effectiveness of recovery option	Can vary dependant on chemical involved and whether slaughtering (if for entry into the food chain) or harvesting crops is brought forward or delayed. Timing of harvest/ slaughter compared to contamination occurring. Physicochemical properties Chemical concentrations in feed provided over fattening period. Differences in chemical concentrations of grazed herbage. Compliance with the recovery option.

Feasibility and intervention costs

Specific equipment	Abattoir or slaughtering equipment on farm for immediate slaughtering. Tractor/ farm machinery to facilitate harvest.
Utilities and infrastructure	Sampling and monitoring equipment to determine contamination levels in affected food produce. Clean pasture Animal housing Storage capacity for harvested crops
Consumables	Additional feed for prolonged rearing if the decision is to prolong the fattening period rather than implement immediate slaughter. Cartridges for captive bolts etc.
Skills, personnel and operator time	Farmer or herder to harvest crops or arrange immediate slaughtering (including gathering of free ranging animals) or prolonged rearing period. Additional effort may be required to gather animals at times different to normal practice. Slaughtering would be carried out by licensed operatives with necessary skills, but may result in additional work by abattoir operators or on-farm operatives.
Safety precautions	General precautions for animal handling.
Other limitations/factors influencing costs	Immediate slaughtering will depend on the capacity of local slaughterhouses to cope with large numbers of animals presented for slaughtering shortly after incident. Attention must be paid to any drugs which have been administered to the animals; there are prescribed periods before which drug residues may be at unacceptable levels (up to 60 days post administration). The increase in animal numbers on the farm could cause logistical problems with regard to accommodation and also have implications for animal welfare and stocking rate or herd size agreements. Scale of revised slaughtering programme and length of prolonged rearing. Shortage of clean feed. Age of animal following delay to slaughtering. Time of year: If animals are grazing, less animal feed required.

Waste

Amount and type	Depending on the number of affected animals, and how they are managed (i.e. if animals are kept on clean feed awaiting compliance) there may be significant amounts of by-products requiring disposal (milk, eggs, slurry etc).

(7) Control of entry into food chain

Possible transport, treatment, disposal and storage routes	Contaminated animal by-products (milk, eggs, slurry etc) may require transport, storage and disposal. Milk may be land-spread, processed, biologically treated or disposed of to sea. Animal products may be disposed of directly by rendering and incineration or landfill.
Factors influencing waste issues (i.e. cost)	Contamination levels of by-products (milk, eggs, slurry) may influence waste disposal options and subsequent costs.
Exposure	
Averted exposure	Contaminated food products entering the food chain.
Potential increased worker exposure	**Farmers/herders**: Possible that farmers may be exposed to chemical contamination whilst gathering animals (if contaminated externally)
Other considerations	
Agricultural impact	Altering slaughter periods may have a consequence for annual cycles of farming or herding activity e.g. with respect to availability of manpower, provision of feed over longer periods etc.
Compensation issues	There may be requests for compensation; **Farmer/herder:** • Immediate slaughtering • Lower slaughter weight of young animals if the slaughtering is performed earlier than usual. Meat from such animals is likely to have a lower fat content and hence poorer flavour. Furthermore, the conventional jointing of carcasses may not be feasible and bulk slaughtering of animals is likely to reduce market value. **Planned delay in slaughter time** • Poorer meat quality if the slaughter is performed later than usual. • it is likely that a greater than normal proportion of the carcass would have to be used for low grade meat products, such as mince, sausages and pies, than for prime cuts. • Lower price for fur or pelt if the slaughter is performed at a time when the quality is poorer. • Additional feed over prolonged rearing period if necessary. • Additional labour Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some farmers, so good stakeholder dialogue will be essential. Dialogue with farmers or herders is necessary to ensure understanding of the reasons and conduct of slaughter, and to identify means of ameliorating negative consequences of recovery option on other farming and related activities. Effective communication would be especially important if used as an early phase precautionary measure.
Additional information	
Practical experience	Withholding from the food chain is common practice for on-farm incidents, especially those involving lead (normally 3 months but can vary according to source and level)
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	

(7) Control of entry into food chain

Document History

(8) Issue of a FEPA order

Objective	To prevent the production in or movement of food or food-producing animals from a defined geographical area
Other benefits	None.
Recovery option description	In the aftermath of a chemical incident, the FSA may issue an order under the Food and Environment Protection Act (FEPA) 1985 to prohibit production or movement or food or agricultural produce within or out of a designated geographical area. It can apply to all forms of agricultural production but can also be imposed over a defined marine area to prevent the collection of fish and shellfish. A FEPA order could be issued, for example, following a large-scale oil spill or chemical incident. However, FEPA orders would only be applicable to commercially produced food and there is no power to prevent people growing and eating food domestically (e.g. from allotments/ gardens).
Key information requirements	The level of risk to health (there must be a hazard to health for a FEPA order to be issued) The potential for contamination to spread within an area or through the food chain The size and number of farms or food businesses in the area affected The precise geographical boundaries of the designated area.
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option is likely to be considered in conjunction with (5) Restriction on entry into food chain/ withdrawal from market and (6) Product recall. It is likely to be necessary if voluntary measures are considered inadequate, affected food businesses are uncooperative, the risk to health is very significant, there is a possibility of unintentional introduction of contaminated food into the food chain or if the impact is likely to be very long term. This recovery option should be considered in conjunction with fate of affected produce options such as; (32) Culling of livestock; (17) ploughing in of standing crop Waste disposal options will also include; (33) Burial of carcasses; (35) Burning in-situ; (36) Rendering; (37) Incineration; and (38) Landfill.
Target	Anyone producing food within a designated geographical area that has been subject to contamination.
Targeted chemicals and important physicochemical properties	This recovery option is applicable for all chemicals that are could contaminate a food production system. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable option. Expert guidance should be sought on an incident and site-specific basis but the Food Standards Agency has the authority to issue the FEPA order and must therefore confirm that there is a food safety risk. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Any**
Exposure pathway prevention	Entry of contaminated food into the food chain Consumption of contaminated food
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any time but must be implemented as soon as a food safety risk comes to light. A FEPA order can remain in place indefinitely.

Considerations

Public health considerations	None.
Legal implications and obligations	Seek expert advice and guidance. The FSA can issue a FEPA order on behalf of the Secretary of State for Agriculture. A FEPA order has provisions for prohibiting the gathering and picking of wild plants (e.g. fungi) and hunting wild game and fish. Refer to Appendix A for more information

(8) Issue of a FEPA order

Social implications	There will be an impact on farmers/ food businesses. Changed perception of natural resources because of feeling that they are damaged or polluted. Loss of traditional activities e.g. gathering wild food, however, advice could maintain this as opposed to the alternative (food restrictions). Potential loss of home produced and or wild foodstuffs may have most negative impact on poorer population groups.
Environmental considerations	None.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act. As this measure is **precautionary** authorities are unlikely to lose public trust even if with hindsight measures are proved to have been unnecessary.
Effectiveness	
Recovery option effectiveness	Up to 100% effective if implemented soon after contamination occurs or is discovered. Difficult to enforce on people consuming domestically produced food.
Technical factors influencing effectiveness of recovery option	None.
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	N/A
Consumables	N/A
Skills, personnel and operator time	N/A
Safety precautions	None
Other limitations/factors influencing costs	None
Waste	
Amount and type	None directly but may lead to large quantities of food waste.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated foods
Potential increased worker exposure	N/A
Other considerations	

(8) Issue of a FEPA order

Agricultural impact	Will lead to prevention of use of agricultural land for a period of time.
Compensation issues	Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some farmers, so good stakeholder dialogue will be essential. Dialogue with farmers or herders is necessary to ensure understanding of the reasons for the issue of a FEPA order, and to identify means of ameliorating negative consequences of this recovery option on other farming and related activities. Effective communication would be especially important if this option was used as a se precautionary measure.

Additional information

Practical experience	Sea empress oil spill resulting in closing of fisheries in surrounding area.
Key references	Moller TH, Dicks B. Fishing and harvesting bans in oil spill response. International Oil Spill conference. #0095 Leonard DRP, Law RJ, Kelly CA. Responding to the sea empress oil spill. IA EA-SM-354/86.
Comments	
Document History	

(9) Precautionary (dietary) advice

Objective	Avoid any risk to health from the consumption of contaminated food.
Other benefits	Help people maintain their way of life. Reduces the need for disposal Enables informed choice
Recovery option description	Provision of advice and information to consumers in general (e.g. allotment holders, kitchen garden producers, hunters and foragers) on the risks associated with the consumption of contaminated produce and ways to restrict their dietary intake of chemicals. This would include: The issuing of guidance on which foodstuffs can be eaten without restrictions, those which should only be consumed occasionally, and those which should be avoided completely. Advice can also include methods for safe preparation (e.g. wash/ scrub/ peel) The provision of advice on additional recovery options that can be carried out to either reduce contamination levels in produce or provide reassurance that produce is safe to eat. Much of the information, advice and guidance would come from the local authority (advised by the FSA) and be communicated via local media, leaflets and through the press (i.e. newspapers and magazines). This is a **self-help** measure, and improves personal control and ability to make informed choices.
Key information requirements	What is the level of chemical contamination?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**.
Target	Consumers
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that can contaminate the food chain. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties that should be considered include; partition coefficient and persistence
Scale of application	**Any.**
Exposure pathway prevention	Ingestion of contaminants at a potentially harmful level.
Time of application	**No restrictions on time.** For as long as selected foodstuffs have increased chemical concentrations (hours to years). In the early phase it is more likely to be advised to avoid certain foods completely

Considerations

Public health considerations	None.
Legal implications and obligations	Seek expert advice and guidance (i.e. FSA). For more information on legislation please see Appendix A
Social implications	When the population has trust in the institutions or experts advising dietary restrictions, this measure is likely to have more positive than negative social consequences (e.g. trust, personal control and informed choice). For socially isolated or independent rural populations, e.g. crofting communities a key issue may be trust (or lack of trust) in the institutions or experts advising dietary restrictions. Loss of traditional activities e.g. gathering wild food, however, advice could maintain this as opposed to the alternative (food restrictions). Potential loss of home produced and or wild foodstuffs may have most negative impact on poorer population groups.
Environmental considerations	None

(9) Precautionary (dietary) advice

Ethical considerations	None.
Effectiveness	
Recovery option effectiveness	Compliance with the recommendations should be 100% effective at reducing exposure to a safe level
Technical factors influencing effectiveness of recovery option	Foodstuffs and methods of preparation. Willingness of affected population to accept the advice to avoid or limit consumption of certain foods. This may depend on the extent to which the food has a cultural and economic significance in the population. Replacement foods may be required. Loss of traditional activities e.g. gathering free food
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	None
Consumables	Printing and distributing leaflets
Skills, personnel and operator time	The time used for providing information, advice and guidance will depend on the communication method (press releases, television interviews, public meetings, magazine articles, letters, leaflets, internet, telephone, fax etc.) Communication skills (including the ability to explain the relevant risks in lay terms)
Safety precautions	N/A
Other limitations/factors influencing costs	Scale of incident.
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated foods
Potential increased worker exposure	N/A
Other considerations	
Agricultural impact	None
Compensation issues	Compensation may be considered in special cases, such as populations for whom wild or home produced foods have a cultural or economic significance. Possible liability issues in the case of unforeseen health effects Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

(9) Precautionary (dietary) advice

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. The methods of communication may need to be flexible (i.e. local radio, news, newspapers and magazines) to ensure the information reaches the target audience. It is essential that advice is kept simple and comprehensible.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(10) Processing or treatment of food products

Objective	To remove or significantly reduce chemical contamination within food products so that it can still be sold
Other benefits	Reduces amount of waste food products requiring disposal
Recovery option description	This option requires food to be processed to remove the chemical contamination. Processing could be standard practice or modified accordingly to increase the amount of contamination that is removed. This option requires further research but suggestions from stakeholders include: • Skimming of milk before consumption (remove chemicals which would be present in fat of milk) • Processing of contaminated meat and cereal for inclusion in pet food • Chemical treatment of milk to reduce / remove contamination Implementation of this option in the UK would require an evaluation of economic considerations (e.g. major food shortage) and consultation with the food production industry. This option was not deemed acceptable following a radiation incident (see comments field below).
Key information requirements	What is the chemical contaminant and at what level is it present?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market
Target	Contaminated food products
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals (but less likely as toxicity increases). However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties : Partition coefficient, solubility
Scale of application	**Small**
Exposure pathway prevention	N/A
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented from the early (days – hours) to late (months - years) stages of a chemical incident, as long as the food in question remains fit for use after processing but would need to be considered as soon as the contamination comes to light

Considerations

Public health considerations	None.
Legal implications and obligations	Article 3 of Commission Regulation 1881/2006 (as amended) prohibits dilution of non-compliant food with other food. It is likely that such a prohibition would be extended to contaminants not currently regulated under 1881/2006 if a risk assessment indicated a health concern. For more information on legislation please see Appendix A
Social implications	Acceptability to consumers, food processors. Social acceptability of consuming food products that were previously contaminated
Environmental considerations	None.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act.

(10)	Processing or treatment of food products
Effectiveness	
Recovery option effectiveness	Up to 100% if implemented correctly
Technical factors influencing effectiveness of recovery option	Physicochemical properties of the chemical(s) involved Availability , capability and capacity of facilities for processing
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance as specialist equipment is likely to be required to implement this option.
Utilities and infrastructure	Power supply, water.
Consumables	Food processing materials.
Skills, personnel and operator time	Training may be required if food processing practices are changed significantly
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. food processing personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Would vary dependant on the contamination and process used.
Waste	
Amount and type	Would vary dependant on the contamination and process used. Disposal routes would have to be identified for any non-usable by-products.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated food products
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. food processing personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	

(10) Processing or treatment of food products

Agricultural impact	None
Compensation issues	None.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. The methods of communication may need to be flexible (i.e. local radio, news, newspapers and magazines) to ensure the information reaches the target audience. It is essential that advice is kept simple and comprehensible. The main communication need would be a clear record of the action taken and the evidence that it would not compromise food safety, agreed between the food business(es) concerned and the Competent Authority

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	For any incident after which processing to decontaminate might be a recovery option, the issues should be considered objectively (e.g. dairies may be unwilling to accept contaminated milk into their processing plants). Insurance companies should also be consulted as they may be within their rights not to compensate where a decision not to reprocess has no public health basis.
Document History	

(11)	Ban or restrictions on hunting and fishing
Objective	To prevent the consumption of contaminated meat and fish by banning or restricting hunting or fishing to certain times during the season, where relevant.
Other benefits	Traditional hunting for game can be preserved; the amount of condemned meat will be reduced.
Recovery option description	Hunting and fishing (coarse or salmon species) are typically restricted to certain periods of the year. However, competition anglers who comply with “catch and return” are not at risk. Poachers are at risk, but are less likely to observe a ban in any case. Hunting could continue as long as the prey is kept out of the food chain.
Key information requirements	What is the chemical contaminant and where has the contamination occurred?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (9) Precautionary (dietary) advice and (12) Restrictions on foraging
Target	Farmers, land owners, gamekeepers, hunters (i.e. those involved in the hunting of waterfowl, wildfowl, game fowl, ground game, deer). Anglers: Salmon family (e.g. salmon, trout) and Freshwater (i.e. coarse) Fish (e.g. pike, perch, tench).
Targeted chemicals and important physicochemical properties	This recovery option would only be applicable to chemicals with the potential to bio-accumulate or pose a short-term risk in game and fish that would warrant a temporary ban. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties that should be considered include; biological half-life and partition coefficient.
Scale of application	**Any**
Exposure pathway prevention	Ingestion of contaminated fish and meat.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented from the early (days – hours) to late (months - years) stages of a chemical incident, but should be considered as soon as the contamination comes to light.
Considerations	
Public health considerations	None.
Legal implications and obligations	A FEPA order has provisions for prohibiting the gathering and picking of wild plants (e.g. fungi), and hunting wild game and fish. (Need to check what powers exist covering public/common land c.f. private land. For more information on legislation please see Appendix A
Social implications	Resistance from hunters. Acceptability of reducing the hunting season. If implemented successfully (i.e. hunters avoid the contaminated areas) there are possible negative consequences for the community or owner (for private hunting lands) or ecosystems.

(11)	Ban or restrictions on hunting and fishing
Environmental considerations	Impact on ecosystem (due to lack of game management), population dynamics, breeding, mortality or birth rate, competition etc. The continuous management of large game species through hunting licenses is of utmost importance to keep the number of animals at a sustainable level. It is therefore important to keep hunting (culling) under all circumstances even if the meat does not enter the food chain. Close hunting seasons exist to allow time for breeding and for populations to recover from previous hunting or fishing seasons. **Hunting – Close season**: varies with species and location but is typically 1 February to 31 Aug for game birds and wildfowl. **Fishing – Close season**: varies with species and location but is typically 15 March to 15 June for coarse fish and salmon species in Rivers in England and Wales. If contamination levels in the affected species were such that the overall length of the hunting or fishing season was significantly reduced or completely excluded in a year, then a recovery programme would have to be considered. For example; culling species normally hunted if over populated, removing fish from waters if over stocked and the meat or fish prevented from entering the food chain. The Environment Agency carries out regular surveys on principal rivers to determine fish populations. Thus, if the fishing season had to be reduced significantly or excluded then these checks will be an important method of establishing whether a management programme is required.
Ethical considerations	None.
Effectiveness	
Recovery option effectiveness	Will reduce likelihood of consumption of contaminated meat of hunted species and freshwater fish.
Technical factors influencing effectiveness of recovery option	Success of communicating information regarding the restrictions to hunters or anglers. Individual willingness to comply with restrictions. The hunting of rabbits and pigeons is not restricted to seasonal hunting (they may be hunted at any time of the year). There are restrictions on hunting hare on moorland and enclosed land, furthermore hare cannot be sold between 1 March and 31 July. There is no legal close season for marine species caught in UK waters. Possibility of continued exposure.
Feasibility and intervention costs	
Specific equipment	Seek exert advice and guidance as specialist monitoring equipment may be required. Typical hunting equipment if management programme is required. Surveying equipment (electrofishing techniques) to establish fish populations.
Utilities and infrastructure	None.
Consumables	Production of leaflets and notices to inform anglers, farmers, gamekeepers and hunters. For hunting: distribution of this information via associations or societies to their members or via firearms registration certificates from police, in associations or societies magazines, firearm dealers etc. For anglers: distribution of this information via associations or societies to their members or via those providing rod licences and fishing permits
Skills, personnel and operator time	Depends on communication method e.g. design and distribution of leaflets. Communication lines to inform those about restriction and 'policing' to ensure compliance.
Safety precautions	If hunting season is shortened then there may be an increased number of hunters visiting forests during a shorter season which may have an adverse effect on their safety.
Other limitations/factors influencing costs	Infrastructure available for communication and exchange of information during processing of information, decision-making and Implementation of recovery option. Reduced financing of game management due to cancellation of hunting licences.
Waste	
Amount and type	None. However, waste in the form of contaminated carcasses would only be produced if hunting or fishing season is significantly reduced in length or excluded completely and a recovery programme is initiated that involves culling to maintain stocks at appropriate levels.

(11)	Ban or restrictions on hunting and fishing
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated fish and meat.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act. The only potential risk posed is by workers putting up warning signs in affected areas.
Other considerations	
Agricultural impact	May cause an increase in the numbers of herbivores which may have impact on grassland, forestry and other environments. Increase in predator numbers may have impact on farm animal husbandry. Possible increased grazing on agricultural lands if hunting season delayed, especially if extended over winter when food sources may be low.
Compensation issues	here may be requests for compensation for • The payments for unused hunting or fishing licences must be returned, if hunting or fishing season significantly reduced or excluded or for cancelled hunting parties. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. The methods of communication may need to be flexible (i.e. local radio, news, newspapers and magazines) to ensure the information reaches the target audience. It is essential that advice is kept simple and comprehensible.
Additional information	
Practical experience	This recovery option was implemented following the Seveso (dioxin) incident in Italy, 1976.
Key references	Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32 Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	It may be that delaying the start of the hunting season or cancelling the season altogether would be an acceptable option.
Document History	

(12)	Restrictions on foraging
Objective	To reduce consumption of contaminated self-gathered wild or free foods (i.e. nuts, mushrooms fruits and berries)
Other benefits	Limit exposure from surface contamination on wild or free foods.
Recovery option description	Advice against gathering of wild or free food products such as; nuts, mushrooms, honey, fruits and berries will reduce exposure by preventing the consumption of these foodstuffs.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **protection option** and should be linked to **remediation** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (9) Precautionary (dietary) advice; and (11) Ban or restrictions on hunting and fishing.
Target	People who gather and/or consume wild or free foods. Foodstuffs such as fruits, berries, herbs, honey, edible flowers, aquatic plants, nuts, mushrooms.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties that should be considered include; biological half-life and partition coefficient.
Scale of application	**Any**
Exposure pathway prevention	Ingestion of contaminated foodstuffs.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented from the early (days – hours) to late (months - years) stages of a chemical incident, but should be put in place as soon as a health concern comes to light.
Considerations	
Public health considerations	None.
Legal implications and obligations	This option is voluntary and has no legal basis for enforcement. (On the other hand, a FEPA order has provisions for prohibiting the gathering and picking of wild plants and hunting wild game and fish). Land ownership may be an issue. For more information on legislation please see Appendix A
Social implications	Public or stakeholder resistance to the recovery option. Recovery option may be met with disappointment from local populations for whom collection of wild food has a cultural and economic significance. There may be issues with regard to blight. Disruption to people's image of countryside as "clean". Negative social and psychological impacts caused by, for example, the loss of traditional activities and loss of cheap food sources. The willingness of affected populations to observe restrictions will change over long time periods.
Environmental considerations	
Ethical considerations	Negative for liberty and autonomy.
Effectiveness	

(12)	Restrictions on foraging
Recovery option effectiveness	Effectiveness will be 100% if restrictions are complied with. However it is difficult to enforce compliance with this option. The effectiveness of this option could be improved if gatherers and locations of wild or free foods are known in community, which could then be targeted by leaflets and posters warning about the contamination hazard.
Technical factors influencing effectiveness of recovery option	**Long-term (e.g. arsenic or heavy metals)** Success of communicating the restrictions to gatherers. Availability of contaminated foodstuffs for gathering may vary by year, season and location. Individual willingness to submit to restrictions, particularly over long time periods.
Feasibility and intervention costs	
Specific equipment	Seek exert advice and guidance as specialist monitoring equipment may be required for authorities to regularly check levels of contamination in wild or free foods.
Utilities and infrastructure	Communication lines to inform those about restriction.
Consumables	Dependent on communication method. Production of leaflets circulated to gatherers via local groups. Production and erection of signs in areas known to be used by gatherers (similar to Foot and Mouth Disease procedures). Information and advice distributed via specialist associations or societies i.e. ramblers.
Skills, personnel and operator time	Time associated with the erection of signs in areas known to be used by gatherers. Time associated with distribution of leaflets circulated to gatherers.
Safety precautions	None.
Other limitations/factors influencing costs	Methods used to ensure compliance. Degree of policing and monitoring required.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated foodstuffs.
Potential increased worker exposure	N/A
Other considerations	
Agricultural impact	Possible increased utilisation of agricultural grasslands or crops by ‘uncontrolled’ game species.
Compensation issues	There may be requests for compensation for loss of earnings by commercial enterprises affected by the bans or restrictions on foraging. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in

(12)	Restrictions on foraging
	other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. The methods of communication may need to be flexible (i.e. local radio, news, newspapers and magazines) to ensure the information reaches the target audience. It is essential that advice is kept simple and comprehensible. Media interest is likely to be high compared to some other recovery options.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(13)	Temporary derogation
Objective	Raising Intervention limits or otherwise relaxing controls to allow sale or use of potentially non-compliant foodstuffs.
Other benefits	Regulatory authorities (i.e. FSA) may grant a derogation to certain products of importance to minority groups (but not cheesemakers). Prevents excessive amounts of food waste; avoids widespread withdrawals and recalls where the risk to health is deemed low.
Recovery option description	Raising Intervention limits in foodstuffs either because of a chemical incident and the temporary derogation or relaxation of controls would be to avoid a large amount of enforcement activity when the health risk is considered low. This recovery option is likely to be controversial, so a good communication strategy will be essential. In extreme circumstances authorities may take the decision to allow levels of chemicals above the maximum contaminant (or residue) level to enter the food chain. This would have to be a decision taken after an appropriate risk assessment to the potentially effected population and may need to be implemented in conjunction with other **precautionary measures** such as advice to sensitive groups. This recovery option is only likely to only be considered in limited circumstances (e.g. food shortage or excessive demand on resources), and would need to take into account relevant EU legislation and would in most cases require agreement from the Commission.
Key information requirements	What is the chemical contaminant, and at what level is it expected to be present in food?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (29) Clean feeding/ selective grazing regime
Target	Producers, enforcement bodies and the Commission.
Targeted chemicals and important physicochemical properties	This recovery option is could be considered for any contaminants regulated in food, but is **not applicable to acutely toxic** chemicals. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include partition coefficient.
Scale of application	**Any**
Exposure pathway prevention	N/A
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	Care would have to be taken to ensure that sensitive groups were not put at unacceptable risk.
Legal implications and obligations	Legal formalities could be quite complex, especially if required at EU level. Informal relaxation of controls would not have a legal basis so action still possible by enforcement bodies. For more information on legislation please see Appendix A
Social implications	Public or producers resistance to recovery option. The impact on consumer confidence should be considered.
Environmental considerations	Avoidance of waste.

(13) Temporary derogation

Ethical considerations	Information to consumers. Potential risk of recovery option being used as an alternative to option that reduces exposure to chemical contamination.
Effectiveness	
Recovery option effectiveness	Will not reduce exposure of public to contaminated food products but should ensure that any exposure is not a risk to health.
Technical factors influencing effectiveness of recovery option	Public or producers' perception and understanding of risks - likely to be closely linked to good communication and dialogue, with a clear message that regulatory limits are not the same as safety limits.
Feasibility and intervention costs	
Specific equipment	None.
Utilities and infrastructure	N/A
Consumables	N/A
Skills, personnel and operator time	N/A
Safety precautions	None.
Other limitations/factors influencing costs	None.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	None.
Potential increased worker exposure	N/A
Other considerations	
Agricultural impact	May make it possible to maintain on-going agricultural practices.
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for reduced market value of foodstuffs. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and

(13) Temporary derogation

	international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dissemination of information about the recovery option, its rationale and possible alternatives, i.e. explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels, and reasons for increase. This recovery option is potentially contentious will require excellent stakeholder dialogue, including producers, farmers and regulatory enforcement bodies.

Additional information

Practical experience	Where appropriate, notifications are raised through the Rapid Alert System for Food and Feed (RASFF) and if appropriate temporary derogations are agreed. This recovery option has been used informally in a number of incidents, e.g. the Irish Pork (dioxins) incident, in which controls were not applied to products containing <20% Irish pork. A formal and long-standing derogation exists for certain fish taken from the Baltic Sea.
Key references	Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report-Health Protection Agency. 2010 (17); pg6. Article 1 of Commission Regulations (EC) No 1259/2011 amending regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non dioxin-like PCBs in foodstuffs.
Comments	Unlikely to be possible without stakeholder consultation (producers, retailers and regulatory enforcement bodies).
Document History	This is a new recovery option.

(14)	Selection of alternative land use
Objective	To change agricultural land use so that it can still be used for productive activities.
Other benefits	Keeps land in use and provides income to farmer.
Recovery option description	Contaminated land may be used for non-food production, such as flax for fibre and linseed oil; rapeseed for bio-diesel; sugar beet for bio-ethanol (possibly also animal feed); perennial grasses or coppice for bio-fuel. Land unsuitable for grazing may still be acceptable for edible crops. In some circumstances, land may be used for forestry, or given over to recreational use (e.g. golf courses)
Key information requirements	What is the chemical involved?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. May also be linked to (23) Natural attenuation (with monitoring) as a change in use until contamination has reduced to safe levels.
Target	Farmland.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent chemicals. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This option is not applicable for chemicals at concentrations that would prevent the growth of crops, be at risk of significant uptake and/or remain a hazard to livestock.
Scale of application	**Any**
Exposure pathway prevention	Soil to plant. Soil to animal Plant to animal. Ingestion of contaminated crops, meat or milk.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	Need to consider whether, if public access permitted, residual contamination would be a hazard.
Legal implications and obligations	Seek expert advice and guidance. For more information on legislation please see Appendix A
Social implications	Perception that land remains contaminated Disruption or adjustment of farming and related industrial activities or maintenance of farming and associated communities, and effects on people's livelihoods (e.g. farmers) Stigma or disruption to peoples' image or perception of 'countryside'. Possible loss of confidence in products. Increased confidence that contamination is being effectively managed.
Environmental considerations	The agricultural characteristics of the affected land – this will determine the crops and practices that the land can support. Implementing this recovery option by bring about changes in the local ecosystem (i.e. field).
Ethical considerations	None.
Effectiveness	

(14) Selection of alternative land use

Recovery option effectiveness	This recovery option does not remove contamination but is a method for re-appropriating land use.
Technical factors influencing effectiveness of recovery option	Expertise in growing alternative crops and supporting different livestock. Acceptability of alternative crops or livestock to farmers. Ease of substitution of non-edible crops for farmer and associated industries. Proof for profitability of suggested production in advance of investments.

Feasibility and intervention costs

Specific equipment	Sowing or harvesting equipment for alternative crop type.
Utilities and infrastructure	N/A
Consumables	Seed stock of alternative crop (availability may be limited). Stock of alternative livestock. Animal feed.
Skills, personnel and operator time	Expertise in cultivation of alternative crop or livestock. Specific tasks may include; Sowing or harvesting of alternative crop. Looking after new livestock. Transportation of crop or livestock to processing plant.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farming personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example, respiratory protection should potentially be considered for farmers if very dry conditions.
Other limitations/factors influencing costs	Crop type. Livestock type. If new equipment is required. Training.

Waste

Amount and type	Depends on the non-food crop selected and production process.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A

Exposure

Averted exposure	Ingestion of contaminated crops, meat or milk.
Potential increased worker exposure	Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are (i.e. transporting crops or livestock for processing): • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

(14) Selection of alternative land use

Agricultural impact	Change in crop type. Fertiliser requirements, nutrient cycling.
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Changes in land use on the farm; • Requirements for additional manpower; • Training and equipment; • Potential less economic use of land. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dissemination of information about the recovery option, its rationale and possible alternatives, i.e. explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels, and reasons for increase. This recovery option is would need to be discussed in detail with the farmers/ landowners to agree to implement this option as it could **not** be imposed on them. Information would also need to be disseminated to farmers about replacing food crops with non-food crop or livestock.

Additional information

Practical experience	This recovery option was implemented after the Seveso (dioxins) incident Italy (1976).
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32
Comments	
Document History	

(15) Selection of alternative product use

Objective	To identify alternative uses for products originally intended for the food and/or feed chain. .
Other benefits	Reduces amount of waste food products requiring disposal.
Recovery option description	Contaminated crops may be used for non-food production. Examples: Non-compliant guar gum redirected to non-food applications (about 40% of global guar gum production goes to non-food applications). Some contaminated products (e.g. crops/ meats) may be acceptable as ingredients for pet food. Vegetable oil intended for human food could also be redirected to bio-fuel. Animal feed ingredients may be diverted for other uses (e.g. vegetable oils for bio-fuels). However need to give consideration of bio-fuels by-products that can then go back into the food chain (e.g. glycerine / mineral salts). Not all crops or animal products will have an alternative use. The effects that the chemical contamination will have on the non-food product produced would also need to be considered.
Key information requirements	Potential non-food uses; potential markets; costs involved.
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**.
Target	Any food or feed products.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals; however it is dependent on the proposed alternative product use. The physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include vapour pressure, physical form
Scale of application	**Any.**
Exposure pathway prevention	Ingestion of contaminated food products.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident Depending on the scale, time would be required to source alternative markets, assess any necessary reprocessing operations (cost, effectiveness of technique). For perishable foods, action would need to be taken while these remained suitable for the proposed alternative use.
Considerations	
Public health considerations	None.
Legal implications and obligations	Seek expert advice and guidance as there is legislation for alternative product (e.g. Bio-fuel regulations). Monitoring by enforcement bodies may be required to ensure affected products do not re-enter the food chain. For more information on legislation please see Appendix A
Social implications	None.
Environmental considerations	Potentially beneficial if product is reused rather than discarded.
Ethical considerations	None.
Effectiveness	

(15)	Selection of alternative product use
Recovery option effectiveness	The main reason for selecting this option would be economic and therefore the effectiveness of this option will depend on the accuracy of cost calculations.
Technical factors influencing effectiveness of recovery option	Acceptability to processors and regulators of using contaminated crops or animal products to make non-food products. Proof of technical feasibility.
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance, as this option will depend on the affected product and processing technique used.
Utilities and infrastructure	Power supply. Storage and possibly processing facilities for chosen crop or animal product.
Consumables	Processing materials.
Skills, personnel and operator time	Training may be required if processing practises are changed significantly
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. production personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Use of this option will be very much cost-driven. The selection (and subsequent processing) of contaminated products for alternative product use should be cheaper than waste disposal alone to make this option feasible. Costs should be considered, for example if it is necessary to pay a processing plant to get the food into a suitable condition for a non-food use, this would have to be included the cost model.
Waste	
Amount and type	Depends on the production process. Contaminated by-products from for example the refining of rapeseed and sugar beet to bio-diesel and bio-ethanol, may be generated in processing plants.
Possible transport, treatment, disposal and storage routes	On-site treatment plants or sewage treatment works for processing by-products.
Factors influencing waste issues (i.e. cost)	Incineration/landfill capacity
Exposure	
Averted exposure	Ingestion of contaminated food products.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. processing plant operative) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. processing plant operative) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	None.

(15)	Selection of alternative product use
Compensation issues	None.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dissemination of information about the recovery option, its rationale and possible alternatives, i.e. explaining the risks associated with the levels of contamination, the uncertainty and the variance of levels, and reasons for increase. This recovery option is would need to be discussed in detail with the food businesses concerned, in conjunction with prospective customers and enforcement bodies.
Additional information	
Practical experience	This recovery option makes use of existing commercial processes.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(16)	Ploughing methods
Objective	To reduce the risk of contaminant uptake by crops or animals by burial and/or dilution
Other benefits	Does not produce any waste
Recovery option description	**Shallow / deep ploughing**: If no crop is present an ordinary single-furrow mouldboard plough can be used to invert the top layer of the soil profile. Much of the contamination originally at the surface will be buried deep in the vertical profile, which (i) will reduce chemical uptake by plant roots depending on their specific rooting behaviour; and (ii) reduce exposure from the contaminants. **Skim and Burial ploughing:** If no crop is present, a specialist plough with 2 ploughshares can be used to skim off a thin layer of contaminated topsoil (*ca*. 5 cm; adjustable) and bury it at a depth of about 45cm. The deeper soil layer (*ca*. 5-50cm) is lifted by the other ploughshare and placed at the top without inverting the 5-45cm horizon. Direct exposure and root uptake from the contaminants are reduced and effect on soil fertility minimised. Would need to be supported by an appropriate monitoring strategy to ensure effectiveness
Key information requirements	Equipment availability Geographical information systems providing information on soil types, topography of area What are the root depths
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (14) Selection of alternative land use and (19) Removal/ relocation of topsoil.
Target	Pasture or fallow arable land.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals a low mobility in soil. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include persistence, water solubility, adsorption to soil.
Scale of application	**Any.** Large where ploughing is possible. However, there may be a delay obtaining skim and burial ploughs. Areas suitable for ploughing could be identified using geographical information systems (GIS) and information on soil type and slope.
Exposure pathway prevention	Soil to plant transfer (may be reducing rather than preventing) Soil to animal transfer
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident. Normal ploughs are often readily available on farms; however, there may be a delay obtaining the more specialist skim and burial ploughs Ideally should be carried out as early as possible although timing is not so critical for persistent chemicals with low soil mobility.
Considerations	
Public health considerations	Contamination of soil at depth may restrict subsequent uses (e.g. tourism).
Legal implications and obligations	Ploughing may be restricted under some environmental protection schemes. For more information on legislation please see Appendix A
Social implications	Ploughing with associated removal of flora and fauna raises wildlife issues that are likely to be contested; Perception that contamination is not being removed and is just being “buried”. Changed relationship to the countryside and potential loss of amenity resulting from changes in people’s perception of land as ‘natural’ to being ‘unnatural’ or in some way damaged. May impact on public confidence.

(16)	Ploughing methods
Environmental considerations	Changes to landscape and other environmental effects. The measure would not be acceptable in regions with thin top-soils as soil fertility and structure would be detrimentally affected. The risks of implementing this option would need to be assessed, for example this option may bring contamination closer to groundwater sources, which could lead to the transfer of chemicals to other areas and affect other populations. Seek expert advice and guidance as soil biodiversity could be affected, particularly for soil dwelling organisms. Long term changes in physical characteristics and structure of the surface horizon e.g. enhanced mineralisation of organic matter, change of nutrient loading and soil erosion.
Ethical considerations	None.
Effectiveness	
Recovery option effectiveness	Moderately effective, does not remove contamination from environment but can be an effective method of reducing source or weakening pathway.
Technical factors influencing effectiveness of recovery option	Properties of chemical (s) involved Soil type Sandy soils are friable and may crumble during ploughing and inversion may be incomplete. Soils which are excessively wet, dry or frozen cannot be ploughed without damaging soil structure. Depth of soil profile can influence ploughing depth Use of machinery: difficult on land with >16º slope cannot be ploughed. High water ground level. Intended subsequent cultivation, for example, some winter wheat varieties can have >2m deep root systems.
Feasibility and intervention costs	
Specific equipment	Plough Skim and burial plough (may be limited availability of this equipment). Tractor (Deep ploughing and skim and burial ploughing likely to require powerful tractors e.g. 76-90 kW).May need to be hired. Appropriate monitoring equipment to show effectiveness of option
Utilities and infrastructure	Potentially road networks for transporting skim and burial plough.
Consumables	Fuel (ca. 15 l ha^{-1}).
Skills, personnel and operator time	Farmers or agricultural workers are likely to possess the necessary skills but must be instructed carefully about the objectives. 1 operator per plough: 0.2 man-days ha^{-1}, i.e. 1.5 h ha^{-1}
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. agricultural workers/ farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection if very dry conditions.
Other limitations/factors influencing costs	Exposure limits for farmers or agricultural workers.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	N/A

(16) Ploughing methods

Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Contamination of crops and food animals
Potential increased worker exposure	Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. agricultural workers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Field drainage systems may be destroyed. Soil fertility may increase; especially if crops have taken some of the shallower nutrients out. Equally soil fertility could also be reduced – fertilisation may be required. Future restriction on land use (i.e. type of crops grown)
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Requirements for additional manpower to implement recovery option; • Training and equipment; • Loss of income for non-adherence to conservation schemes Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Farmers or operators may require information on this recovery option (i) for areas of land not normally ploughed; (ii) when ploughing is to be undertaken at non-standard times of the year. There is also a need for dialogue regarding selection of areas for treatment. Need dialogue between farmers, Environment Agency (as regulators), ecologists and public specialists because of potential for groundwater contamination. Dialogue regarding selection of areas considered suitable for application of this recovery option and to clarify the costs and benefits to farmers before decisions on implementation are made. Provision of information to operators on correct application of procedure and chemical hazards
Additional information	
Practical experience	This standard agricultural practice is acceptable to farmers, provided the incremental exposure to tractor drivers from the contamination is minimal. This is also a method for remediating chemically contaminated land.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Thorup-Kristensen K. Winter wheat roots grow twice as deep as spring wheat roots, is this important for N uptake and N leaching losses? Plant Soil. (2009) 322:101–114. Available [March 2012] at; http://orgprints.org/16121/2/16121.pdf
Comments	Deep ploughing should not be carried out repeatedly as effectiveness is likely to be significantly reduced (i.e. there is a risk contamination will be brought back up, which is especially relevant is chemicals are persistent).

(16) Ploughing methods

Document History

(17) Ploughing in of a standing crop

Objective	To dispose of a contaminated crop *in situ*.
Other benefits	Provides a source of organic matter and nutrients to the soil.
Recovery option description	This is the direct incorporation of crops at any stage of development up to maturity. Crops are destroyed and do not enter the food chain. Subsequent ploughing dilutes concentration of chemical in soil. Desiccation of the standing crop could be achieved if necessary by applying herbicides prior to ploughing, in order to reduce the volume of material that has to be incorporated into the soil. Crops can still be destroyed if depth of burial is less than 300mm.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market Alternative recovery options could include; normal harvesting; (23) Natural attenuation (with monitoring); (24) Biological degradation/ decomposition; (37) Incineration and (38) Landfill.
Target	Contaminated crops.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent chemicals with a low mobility in soil. Important physicochemical properties that should be considered include; adsorption to soil, persistence and water solubility. This recovery option is applicable to all chemicals that are could be dispersed via a plume. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Any**
Exposure pathway prevention	Soil – plant and ingestion of contaminated crops. It may not necessarily be the soil that is contaminated (e.g. if the crops have been irreversibly damaged by smoke. This would be a factor to consider in selecting the option.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident. However, to reduce the amount of biomass to be incorporated ploughing in is best carried out in the early phase (hours to days). On the other hand, if herbicide pre-treatment is considered necessary, this will cause a delay to the ploughing operation.
Considerations	
Public health considerations	None.
Legal implications and obligations	Potential implications if farms participate in environmental stewardship schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's). For more information on legislation please see Appendix A
Social implications	Possible blight on land.
Environmental considerations	Incorporated organic matter provides a source of nitrogen for mineralisation. Unless a cover crop is planted immediately, leaching of nitrates may occur. Incorporation of rape straw may cause slug problems. Other possible impacts include soil erosion, loss of wildlife habitat and the application of additional herbicide.
Ethical considerations	None.
Effectiveness	

(17) Ploughing in of a standing crop

Recovery option effectiveness	A standard mouldboard plough can achieve 90-95% incorporation of standing stripped straw on a range of soils from medium loams to heavy clays. Similar efficiencies would be expected for other crops. Ploughing in destroys crops and prevents them from entering the food chain.
Technical factors influencing effectiveness of recovery option	Ploughing in may not be appropriate for excessively wet or dry soils because it may damage the soil structure, and may not be possible at certain times of the year.
Feasibility and intervention costs	
Specific equipment	Tractor and tractor-driven mouldboard plough (widely available). Forage harvester and rotovators. Field crop sprayer for application of desiccants (should be readily available). Disc or skim coulters, trash boards, forage harvester, rotary cultivator.
Utilities and infrastructure	None.
Consumables	Fuel (ca. 15 l ha^{-1}), and if required desiccants such as glyphosate (ca. 6 l ha^{-1})
Skills, personnel and operator time	Farmers and agricultural workers would have the required skills, but must be instructed carefully about the objectives. One operator per plough. 4 h ha^{-1} mouldboard plough; 1 h ha^{-1} forage harvester; 2 h ha^{-1} rotovator; 0.3 h ha^{-1} field crop sprayer. Work rates vary depending on crop type and stage of maturity, herbicide application, soil type and conditions, field size and shape, topography and operator experience. Labour costs may be higher if it is necessary to provide additional protection for workers.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. agricultural workers/ farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	None.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated crops
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. agricultural workers/ farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. agricultural workers) exposure. They would, however, need to

(17) Ploughing in of a standing crop

	be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	Incomplete breakdown of incorporated crops may make subsequent cultivation difficult.
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Requirements for additional manpower to implement recovery option; • Loss of income from crop; • Loss of income for non-adherence to conservation schemes Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	This is an acceptable option provided soil conditions are suitable and nitrate loss is controlled by appropriate husbandry. Ploughing in of crop residues is a standard practice on arable farms, particularly for cereal straw.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(18)	Land improvement (for 'natural' pasture)
Objective	To reduce exposure of animals that are grazing on contaminated land.
Other benefits	Reduction in exposure from contaminated land.
Recovery option description	Land improvement involves ploughing, rolling, reseeding and the application of NPK fertilisers and lime. Application of a broad spectrum herbicide prior to ploughing may be considered to destroy the existing vegetation. In some cases, drainage may be required. If only certain areas are remediated, fencing may also be necessary to prevent livestock straying onto un-remediated land (such as contamination hotspots.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered as an alternative to (14) selection of alternative land use in conjunction with; (16) Ploughing methods
Target	This option applies to any grazing land that has been found to be or has become contaminated.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are persistent and is more likely to be applicable to those with low mobility in soil. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include persistence, water solubility and adsorption to soil.
Scale of application	**Medium/ large** i.e. when contamination is not so localised that fencing off alone is practicable.
Exposure pathway prevention	Reduction of exposure of animals to contaminants to an acceptable level with regard to food safety and animal welfare.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	None.
Legal implications and obligations	Potential implications if farms participate in environmental stewardship or organic farming schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's) Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. This option may be unacceptable to environmentalists if there is a risk to loss of biodiversity and there may be pressure to not implement this option. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	There may be a changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged, with knock-on effects for public use of amenity, and resistance to change the ecosystem and landscape. Resistance of farmer to change farming practice. Erection of fencing and gates may have a visual and amenity impact.

(18) Land improvement (for 'natural' pasture)

Environmental considerations	Areas of pasture with steep slopes and shallow soils mean that some areas cannot be ploughed or drained. Physical characteristics that determine if a soil can be cultivated are: • Slope < 12º: cultivation possible • Slope 12-16º: some limitations • Slope > 16º: unsuitable for cultivation (using normal farm machinery) • Depth < 0.3 m: unsuitable for ploughing • Depth 0.3-0.5 m: shallow ploughing only • Depth > 0.5 m: skim and burial or deep ploughing possible. At certain times of the year the ground is too wet for ploughing. All of the practises involved with this recovery option are part of normal agricultural activities and should comply with GAP. However, consideration should be given to the risk of that ploughing, application of herbicides and fertilisers and reseeding would change the ecology of the land and biodiversity may be lost. A significant increase in NPK application can lead to pollution of ground and surface waters. Also need to consider reactions of treatment chemicals with contaminants present. Contamination could be moved closer to the water table possibly resulting in enhanced contamination of ground water.
Ethical considerations	None.

Effectiveness

Recovery option effectiveness	Moderately effective, may not remove all contamination from environment.
Technical factors influencing effectiveness of recovery option	Soil type, nutrient status and pH; Plant species selected for reseeding. Application rates of NPK and lime. Implementation of drainage. Willingness and ability of farmers to adapt to a new land-use recovery regime.

Feasibility and intervention costs

Specific equipment	Tractor, mouldboard plough, sprayer, roller, fertiliser spreader, seeders and digger.
Utilities and infrastructure	Fertiliser or lime production facilities. Access to road network in remote areas. Spare land on (i.e. neighbouring farm or common land) which to graze livestock while improvements are carried out.
Consumables	Fuel, NPK fertilisers, lime, grass seed, herbicide (i.e. glyphosate if required). May also require consumables associated with fencing and drainage operations. Improvement of pastures is typically maintained on a rolling programme with NPK applied annually, lime every 5 years and land re-improved after 5-10 years.
Skills, personnel and operator time	Agricultural workers or farmers would possess the necessary skills as these are existing practices but must be instructed carefully about the objectives. The operator time will be variable, depending upon soil type and conditions, example values for improvement of upland pasture in the UK: 1.6 h ha^{-1} ploughing, 1.3 h ha^{-1} rolling, 0.7 h ha^{-1} broadcasting seed, 0.4 h ha^{-1} broadcasting fertiliser, installing fences and organising drainage.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. agricultural workers/ farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	Work rates vary depending on soil type and conditions, topography and operator experience. Requirements for drainage and fencing.

Waste

(18)	Land improvement (for 'natural' pasture)
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Animals to unsafe levels of contaminants.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. agricultural workers/ farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. agricultural workers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Land remains safe for food production (this recovery option is being implemented because the agricultural land has become contaminated and is therefore unsafe to use for food production). If improvement is carried out on a rolling programme there should be no significant loss of grazing. If the farm is organic, advice should be sought from the Soil Association about what remedial measures would be acceptable such as fertilisation or liming.
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Requirements for additional manpower to implement recovery option; • Loss of income for non-adherence to conservation schemes • For additional feeding stuffs if required whilst improvements are being carried out • Labour costs may be higher to compensate operators for exposure to chemicals Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Need for dialogue regarding selection of areas for treatment, between land owners or farmers, ecologists and public.
Additional information	
Practical experience	This option may have limited applicability in the uplands due to terrain.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	

(18) Land improvement (for ‘natural’ pasture)

Document History

(19)	Removal/ relocation of topsoil
Objective	To remove the source of contamination.
Other benefits	This recovery option will reduce chemical uptake by commercial (i.e. crops, including pasture) and non-commercial (i.e. kitchen gardens) produce. The Local Authority is the owner of allotments, and as such the LA would be responsible for making the final decision on actions for allotments (e.g. closure and sale to developers as in Town Ham, Gloucester). Limited waste if soil is relocated or reused in other area non-commercial areas (i.e. road landscaping, forestry, recreation (e.g. golf courses) all subject to public health concerns being satisfied).
Recovery option description	**Topsoil removal (for commercial sites)** **If crop is present** this option has to be preceded by harvest or the topsoil would have to be removed with the crop. **If no crop is present**, the top layer is removed using road construction equipment such as a bobcat or mini-bulldozer. In this way, much of the contamination is removed. When the amount of waste is taken into consideration recovery option may only be applicable on a relatively small scale. **Removal/ relocation of topsoil (non-commercial sites)** In kitchen gardens topsoil can be removed by spade and relocated or used for another purpose (i.e. flower bed). Occasionally, topsoil could be removed from gardens and disposed of to landfill sites or purpose-built repositories. Topsoil may also be removed from sections of allotments if a non-food production area is available.
Key information requirements	What is the chemical contamination?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should be considered in combination with waste disposal methods such as; (37) Incineration or (38) Landfill
Target	**Commercial sites** include; pasture or fallow arable land. **Non-commercial sites** include; areas used for non-commercial food production such as allotments or kitchen gardens.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are persistent and is more likely to be applicable to those with low mobility in soil. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include persistence, water solubility and adsorption to soil.
Scale of application	**Small** (amount of waste produced limits scale of application).
Exposure pathway prevention	Soil to plant transfer (some people keep chickens as well) Ingestion of contaminated food products.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident. However, in the case of allotments and domestic gardens, action would probably need to be rapid for social reasons.
Considerations	
Public health considerations	There is the potential for nuisance dust complaints if close to populations. There may also be concerns over the transportation of lorry loads of contaminated soil through inhabited areas.

(19)	Removal/ relocation of topsoil
Legal implications and obligations	The Local Authority is the owner of allotments, and as such the LA would be responsible for making the final decision on actions for allotments (e.g. closure and sale to developers as in Town Ham, Gloucester). **Non-commercial sites** Seek expert advice and guidance as there are contaminated land regulations that may apply. **Commercial sites** Potential implications if farms participate in environmental stewardship or organic farming schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's) Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	There may be suspicion over the Local Authority's motive for closing allotments. There may be wider concern about health implications of living on a contaminated plot, or stigma associated with affected areas. Disruption to farming and other related activities (e.g. tourism).
Environmental considerations	Soil biota may be affected. Loss of biodiversity. Large volumes of waste generated.
Ethical considerations	Potential redistribution of exposure to workers, as well as inequity due to redistribution of exposure to populations living close to waste disposal areas. Free informed consent of workers and members of the public.
Effectiveness	
Recovery option effectiveness	Up to 100% effective at removing contamination but will vary according to chemical involved. May be difficult to demonstrate 100% effectiveness as there is likely to be a variable contamination gradient in the soil (i.e. deciding how deep to go may be difficult)
Technical factors influencing effectiveness of recovery option	Chemical(s) properties Soil type and texture, and depth of removal that is required. Presence of vertical cracks in the soil. Operator skill ensuring contamination is not ploughed into clean surface during removal. Time between incident and implementation (for chemicals mobile in soil). As contaminated topsoil is being removed (not treated) and will probably have to be replaced with clean soil.
Feasibility and intervention costs	
Specific equipment	**Non-commercial sites (i.e. kitchen gardens)** Typical garden equipment (i.e. spade/ wheelbarrow) **Commercial sites** Bobcat mini bulldozer or bulldozer. Vehicle's to transport waste.
Utilities and infrastructure	Suitable disposal site. Roads to transport waste.
Consumables	Fuel for bobcat (ca 40 l ha^{-1}). Transporters.
Skills, personnel and operator time	Can be carried out by already skilled operators such as municipal workers and additional operators could be instructed within a day. Possible need for chemical protection training of workers. Typically some 50-100 h ha^{-1}, including loading to waste transport truck, but excluding waste transport and work at repository.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. recovery

(19) Removal/ relocation of topsoil

	workers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	There are risks of exposure to members of the public and recovery workers when implementing this option. Factors influencing costs include; Type of equipment. Soil type and conditions, field size and shape, topography and operator experience. Distances of contaminated site to equipment hire and to disposal site.
Waste	
Amount and type	Contaminated waste may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. **Non-commercial sites (i.e. kitchen gardens)** None if soil is relocated to other areas of allotment or kitchen garden not used for food production. If 5cm of topsoil is removed, 70kg m^{-2} of waste would be produced. **Commercial sites** Can result in tonnes of waste being produced if implemented over a large area
Possible transport, treatment, disposal and storage routes	Disposal to landfill sites or purpose built repositories. Waste topsoil could also be used for non-food-related landscaping (i.e. forestry, recreational areas, gold courses etc). Waste could also be subject to off-site treatment.
Factors influencing waste issues (i.e. cost)	Contamination level of waste. Volume of waste. Acceptability of waste disposal options (i.e. Landfill or re-use of contaminated top soil for non-food related used). Location of disposal site especially if outside affected area. **Non-commercial sites** If waste soil cannot be relocated to another area of the allotment or kitchen garden, it may have to be disposed of to landfill, which will result in subsequent transport and landfill costs. **Commercial sites** Transport to landfill site and subsequent landfill costs (including landfill tax). Siting and building of purpose-built repository. Cost can be significant for removal and disposal covering large areas.
Exposure	
Averted exposure	Ingestion of contaminated crops
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. recovery workers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. recovery workers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Soil fertility may be affected by the loss of top 5 cm of soil. Fertilisation may be required. The underlying soil may be compacted with implications for subsequent cultivation. Vegetation needs to be re-established.

(19)	Removal/ relocation of topsoil
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Loss of grazing areas and re-establishment of vegetation. • Cost of replacing contaminated topsoil • For additional feeding stuffs if required whilst improvements are being carried out Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information on correct application of procedure including chemical hazards. Need for dialogue regarding selection of areas for treatment. Dialogue with gardeners, local communities and farmers required concerning timing and selection of land to be remediated. Clarify the costs and benefits before decisions on the intervention are made.
Additional information	
Practical experience	Historically used in numerous chemical incidents (e.g. Seveso). Waste disposal facilities would be an important consideration due to potential large quantities of waste.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(20)	Soil washing/irrigation of agricultural land
Objective	A process which uses aqueous solutions (typically water) to dissolve and separate contaminants and/or contaminated soil particles from uncontaminated soil particles. This option also reduce uptake from crops and reduce livestock contamination.
Other benefits	
Recovery option description	Dependent on chemical properties (e.g. water solubility, soil mobility), watering of crops may increase leaching of chemicals from soil so there is less uptake by crops and to move contamination away from livestock. **Soil washing** is an *ex-situ* volume reduction/ waste minimisation treatment process, where the contaminated soil particles are separated from the bulk soil in a series of aqueous treatment steps. The separated contaminants then go to hazardous waste landfill or are further treated by other recovery methods such as, chemical, thermal or biological treatment. After the majority of contaminated soil has been removed, the bulk fraction remaining can be: • Recycled on site • Used on another site as fill • Disposed of relatively inexpensively as less hazardous material. Traditional water-based soil washing can be enhanced/ modified by using aqueous solutions such as acids, alkalis or surfactants which would selectively transfer contaminants on the soil into solution. The solution is then treated to remove contaminants. Soil can be treated on site enabling the clean fraction to be reused. Or alternatively material can be treated at a treatment centre which has no mobilisation cost, but does have a cost associated with transport to the treatment centre. **Soil flushing** is an *in-situ* process that uses aqueous solutions to dissolve and recover contamination from the ground. Commonly used additives include acids, alkalis, chelating agents, and surfactants. Infiltration and recover of the aqueous solutions can be carried out using galleries, sprayers, trenches or wells depending on the depth of contamination. Above ground the recovered solution is treated to remove the dissolved contamination and can be reused. For example, weak acidic solutions may be sprayed over an area of contamination and be allowed to infiltrate the ground. The low pH of the aqueous solution encourages the transfer of soil bound inorganic chemicals (i.e. metals) into solution. The solution is then pumped back to the surface via a borehole or intercepted by a trench. The recovered solution is then treated via an effluent treatment plant to concentrate and recover the inorganic chemicals (i.e. metals). The water may then be re-acidified and re-used or once acceptable standards have been reached, it may be discharged to the ground or to sewer. It is likely that this option would only be considered suitable where a field has a good drainage and collection system so that run-off could be collected and tankered away. It is unlikely that it would be acceptable to deliberately flood the contaminated area due to the associated risk to surface and ground water. A major constraint of this option is the leaching of chemicals to groundwater or surface waters if nearby.
Key information requirements	What is the chemical contaminant? Seek expert advice and guidance. The Environment Agency would be key to any decision impinging on potential surface or groundwater contamination. Good understanding of the site geology and hydrogeology is required. Nature of the soil (e.g. permeability as low permeability soils are difficult to treat) Soil composition (e.g. fine material content) Nature of contaminants (soil flushing process may produce more toxic or mobile compounds)
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**.
Target	Contaminated soil
Targeted chemicals and important physicochemical properties	This recovery option is applicable to a wide range of contaminants including both organic and non-organic compounds (including heavy metals), additionally the process can be designed to treat specific contaminants. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques.

(20)	Soil washing/irrigation of agricultural land
	Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include; persistence, water solubility and chemical toxicity (acute and chronic health impacts).
Scale of application	**Small/ medium**
Exposure pathway prevention	Soil to plant Soil to animal
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	There may be a risk of contamination of groundwater and hence water supplies. Dust from excavation works could have a potential health effect.
Legal implications and obligations	Need to consider potential contamination of waterways, as there is a risk of contamination of groundwater and hence water supplies and waterways. Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	Acceptability of diluting contamination in environment and not removing. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Dust and odour complaints from soil excavation for soil washing.
Environmental considerations	The procedure imposes environmental risk i.e. brings contamination closer to the groundwater which may lead to transfer of chemicals to other areas and affect other populations. There is also the potential risk of contamination of nearby waterways, groundwater or adjacent farms if area is flooded. Waste water from soil washing will generally require some form of run-off control to mitigate particulates in suspension prior to drainage/water discharge. Dust and particulate produced from excavation works may impact air quality. Chemicals injected into soil may affect soil pH, biological status, biodiversity and ecology. Long term changes in physical characteristics and structure of the surface horizon e.g. enhanced mineralisation of organic matter, change of nutrient loading and soil erosion. Changes in landscape. Soil fertility may be affected. Significant volatilisation is likely during excavation and material handling, this will require effective management. Addition of chemicals to the subsurface during soil flushing can mobilise some contaminants which can enter shallow ground water. There is the potential for the production of more toxic compounds. There is also potential for the process to significantly alter ambient aquifer pH.
Ethical considerations	Risk worsening situation by producing more toxic or mobile compounds. Soil flushing solution may contaminate shallow water tables.
Effectiveness	
Recovery option effectiveness	Dependent upon expectations, i.e. can be very successful as a management method where complete contaminant removal is not the required outcome
Technical factors influencing effectiveness of recovery option	The properties of the contaminant e.g. how easily it is mobilised/dissolved and toxic breakdown products. Soil properties e.g. its permeability, composition Consistency in effective implementation of option over a large area. Risk of chemical contamination of any nearby groundwater/surfaces, hydrogeology of the area needs to be considered.

(20) Soil washing/irrigation of agricultural land

Feasibility and intervention costs

Specific equipment	Water delivery (e.g. hosepipes, sprinklers, pumps) Sprayers, galleries, digging and drilling equipment, sampling equipment. Mobilisation costs can be high for soil washing. Often uneconomic to mobilise for small volumes on site. However given sufficient volumes can work out economically. There are significant power (energy) requirements for soil washing Excavation equipment for ex-situ soil washing.
Utilities and infrastructure	Effluent treatment plant and headworks.
Consumables	Water, treatment chemicals (possibly surfactants).
Skills, personnel and operator time	No specialist skills would be required to implement this option.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. recovery workers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	The costs of soil washing can be heavily influenced by the composition of the soil, i.e. percentage clay and slit content, or “fine” content in the material being treated. Typically more than 40% fine material may be considered too high. Treatability studies will be required to assess the potential effectiveness of soil washing. Other factors influencing costs are the size of the area and time (personnel costs).

Waste

Amount and type	Waste water from effluent treatment plant which will require a discharge license, for example process effluents, concentrated sludge, filters and free-contaminant from the effluent treatment plant. .
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	As a waste minimisation technique, contaminated residue will need to be treated further/disposed of. Secondary water treatment may be required for the process water (typically using activated charcoal).

Exposure

Averted exposure	Contamination of animals and crops
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ operative) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ operative) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	Process can also adversely affect organic matter and the biological status in the soil due to biodegradation, which can alter soil biodiversity. Sterilising effect of soil washing means time is required to re-build ecosystem functionality during and shortly after remediation.

(20)	Soil washing/irrigation of agricultural land
Compensation issues	Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information on correct application of procedure including chemical hazards. Need for dialogue regarding selection of areas for treatment. Dialogue with gardeners, local communities and farmers required concerning timing and selection of land to be remediated. Clarify the costs and benefits before decisions on the intervention are made.
Additional information	
Practical experience	
Key references	DEFRA research project final report: contaminated land remediation. CL:AIRE November 2010. EA Remediation Position Statements. 2007 Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(21)	Adjust pH of soil
Objective	To reduce the uptake of contaminants from soil into plants or to neutralise contamination
Other benefits	None
Recovery option description	Strong acids (e.g. sulphuric acid) could be counteracted by adding lime to soil. May also affect uptake of certain chemicals by plants depending on the soil conditions. Cadmium uptake can be reduced in paddy soils by raising the pH
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **waste disposal options**. This recovery option should also be considered in conjunction with; (16) Ploughing methods
Target	Agricultural land
Targeted chemicals and important physicochemical properties	The physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include partition coefficient, uptake by crops / plants
Scale of application	**Any.** However, widespread adjustment of soil pH could impact existing use and/or productivity. Areas can be identified using Geographical Information Systems (GIS) from readily available soil characteristic information.
Exposure pathway prevention	Soil to plant. Soil to animal.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	None if implemented correctly
Legal implications and obligations	Potential implications if farms participate in environmental stewardship or organic farming schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's) Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	Perception of a perception of additional chemical contamination from application of chemicals to adjust the pH of soil. Change of ecosystem, potential environmental risks on extensively managed land. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Liming may restrict subsequent use of the land (e.g. organic farming).
Environmental considerations	Lime is normally ploughed into the soil before the planting or sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Application may need to be restricted near watercourses and on flood plains – GIS could identify such areas. Minimal on intensively managed arable soils as lime is routinely applied at the rates proposed. Application can change nutrient status and thus plant and animal diversity – possible changes in landscape. Grasslands are often the habitat of endangered species and a change in nutrient status may be harmful to these species. Changes in bioavailability and mobility of nutrients and pollutants may lead to effects on water quality.

(21)	Adjust pH of soil
Ethical considerations	None.
Effectiveness	
Recovery option effectiveness	Seek expert advice and guidance. This recovery option does not physically remove contamination from the environment.
Technical factors influencing effectiveness of recovery option	Slope or stoniness of some grassland may make it unsuitable for a tractor and spreader. Difficult to apply lime/ calcium carbonate in windy conditions. Properties of chemical(s) involved Soil type and pH, cation exchange capacity, calcium status of soil. Type of lime applied (e.g. $CaCO_3$ can be more effective at changing soil pH). Whether rainfall follows lime application. Soil type, calcium carbonate/ silicate unlikely to work if soil acts as a strong buffer. Availability of appropriate monitoring equipment to support implementation of option
Feasibility and intervention costs	
Specific equipment	Tractor with spreading device (ideally 55-67 kW tractor with broadcast spreader (however, lower power tractor may be sufficient). Plough or harrow. Monitoring equipment and apparatus to support implementation.
Utilities and infrastructure	Lime / calcium production facilities or distribution network.
Consumables	Fuel (ca. 5 l ha^{-1}). Lime (1 - 8 tonnes CaO or $CaCO_3$ per ha). Calcium carbonate, calcium silicate.
Skills, personnel and operator time	Farmers would possess the necessary skills, as this is an existing practice. 1 operator ca. 0.25 hr ha^{-1} (excluding loading and transport of lime).
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	Controlled application on grasslands is needed to avoid detrimental increases in the intake of calcium by dairy cows. Repeated application may be required.
Waste	
Amount and type	None – assuming applied when no standing crop is present, or grassland receives a top-dressing.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Contamination of crops
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ operative) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible

(21)	Adjust pH of soil
	to estimate likely recovery worker (i.e. farmer/ operative) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Crop yield may be increased by solving acidity problems. General improvement in soil fertility. Agricultural impacts with respect to lime include; May prevent some diseases that attack crops; May induce manganese deficiency in oats. May restrict subsequent use of the land (e.g. organic farming).
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers for; • Applying soil treatment (i.e. lime) when not part of normal practice • Loss of grazing areas and re-establishment of vegetation. • Loss of income for non-compliance to environmental protection schemes. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information on correct application of procedure including chemical hazards. Need for dialogue regarding selection of areas for treatment. Dialogue with gardeners, local communities and farmers required concerning timing and selection of land to be remediated. Need for dialogue regarding selection of areas considered suitable for application of this recovery option especially between land owners or farmers, ecologists and expert organisations (i.e. Environment Agency) if recommended for areas not normally limed. Provision of information to farmers on appropriate application rates. Clarify the costs and benefits before decisions on the intervention are made.
Additional information	
Practical experience	Standard agricultural practice. Application of calcium carbonate/ silicate in rice paddy fields to reduce cadmium uptake
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(22)	Application of potassium fertilisers to arable soils and grassland
Objective	Reduce plant uptake of certain chemicals.
Other benefits	May improve condition of soil.
Recovery option description	Potassium fertilisers may be applied to soils of low potassium status to reduce plant uptake of certain chemicals. Potassium is applied singly or in conjunction with nitrate and phosphate fertilisers and is mixed in soil by harrowing or ploughing. Can also be applied as a top dressing to grassland.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with; (16) Ploughing methods
Target	Agricultural land.
Targeted chemicals and important physicochemical properties	Seek expert advice and guidance as without evidence this option should not be considered. The physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include persistence.
Scale of application	**Small/ Medium**
Exposure pathway prevention	Soil to plant. Plant to animal. Ingestion of contaminated crops/animals.
Time of application	There are **some restrictions on time** with this recovery option, it can be implemented at the early (hours – days) or medium (weeks – months) phase of a chemical incident.
Considerations	
Public health considerations	None.
Legal implications and obligations	Potential implications if farms participate in environmental stewardship or organic farming schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's) Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	Public or farmers resistance to recovery option. This depends on usual farm practice and the potential for ecosystem change or damage. If the area is, for example, a tourist area, there may be resistance to a change in the ecosystem. Changed relationship to the countryside and potential loss of amenity resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged.
Environmental considerations	Potassium fertilisers are normally ploughed into the soil before the planting or sowing of arable crops. It may not be possible to plough or harrow soils that are excessively wet, dry or frozen without damaging soil structure. Slope or stoniness of some land may make it unsuitable for a tractor and spreader. Application can change nutrient status and thus plant and animal diversity – possible changes in landscape although minimal likely impact on intensively managed arable soil as potassium fertilisers are routinely applied at the rates proposed. Changes in mobility of nutrients and pollutants may lead to effects on water quality.

(22)	Application of potassium fertilisers to arable soils and grassland
Ethical considerations	
Effectiveness	
Recovery option effectiveness	This recovery option does not remove contamination from the environment but can reduce levels in crops to be consumed.
Technical factors influencing effectiveness of recovery option	Reduction in exposure will be influenced by the properties of the chemical involved. Potassium status of the soil or soil solution. Farmers' compliance to recovery option, i.e. willingness to change farming practice.
Feasibility and intervention costs	
Specific equipment	All equipment should be available. Ideally 55-67 kW tractor with broadcast spreader (However, lower power tractor may be sufficient). Plough or harrow.
Utilities and infrastructure	None.
Consumables	Fuel (ca. 5 l ha^{-1}). Fertiliser as K_2O or KCl (100-200 kg K ha^{-1}), although larger applications have been made to great effect under specific scenarios previously.
Skills, personnel and operator time	Farmers would possess the necessary skills, as this is an existing practice. 1 operator (ca. 0.3 hr ha^{-1}) excluding transport and loading of potassium.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example consider respiratory protection and protective clothing if very dry conditions.
Other limitations/factors influencing costs	Repeated application may be required.
Waste	
Amount and type	None – assuming applied when no standing crop is present, or grassland receives a top-dressing.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Ingestion of contaminated crops
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ operative) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ operative) exposure. They would, however, need to be

(22)	Application of potassium fertilisers to arable soils and grassland
	assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Assuming that this recovery option is carried out where soil exchangeable K is below optimum for the crop, there will be potential increase in crop yield and quality. Changes in bioavailability and mobility of nutrients and pollutants may lead to deficiencies or toxicities in plants and animals. May restrict subsequent use of the land (e.g. organic farming)
Compensation issues	There may be requests for compensation from the farmer for applying fertiliser when not part of normal practice and for loss of income. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information on correct application of procedure including chemical hazards. Need for dialogue regarding selection of areas for treatment. Dialogue with gardeners, local communities and farmers required concerning timing and selection of land to be remediated. Advice may be required to dairy farmers to avoid unbalancing potassium-magnesium metabolism in livestock (from application of too much potassium).
Additional information	
Practical experience	Routinely applied in agriculture to optimise crop yields. This standard agricultural practice is acceptable to farmers, provided the incremental exposure to tractor drivers from the deposited contamination are trivial. It should be carried out on land that is normally fertilised to minimise loss of biodiversity. Reassurance, via monitoring programmes, that crops/grass subsequently grown on treated land have radionuclide concentrations less than intervention limits.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Potassium would normally be applied in conjunction with nitrogen (not ammonium) and phosphorus-based fertilisers. Mg fertilisation and liming may be required to maintain optimal ionic equilibrium in soil and plant. Little experience on unimproved pastures.
Document History	

(23)	Natural attenuation (with monitoring)
Objective	To allow contamination to return to acceptable or background level with no active intervention.
Other benefits	No active implementation required.
Recovery option description	Natural weathering via rain may lead to in increased leaching of certain chemicals from soil and therefore lower uptake by crops or exposure to animals. Also includes natural breakdown of chemical by exposure to sunlight, temperature and wind. Need to consider weather conditions, may be of less of benefit in hot/dry periods. When the contamination involves a chemical that has short persistency, then simply allowing sufficient time for the contamination to degrade due to natural sources of heat and radiation (e.g. sunlight), rain and wind can decontaminate agricultural land. Wind dispersal is also likely to be significant for volatile chemicals with short persistency.
Key information requirements	What is the chemical contaminant? Levels of contamination and half-life of contaminants of concern in soil
Linked recovery options	This is a **remediation option** and could be considered with (14) Selection of alternative land use (this could be temporary or permanent)
Target	N/A
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals with a short persistency. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include vapour pressure, persistence, water solubility.
Scale of application	**Any**
Exposure pathway prevention	Soil to plant Plant to animal Soil to animal
Time of application	N/A
Considerations	
Public health considerations	Contamination may remain a hazard until it has reduced to a safe level. Risk of contamination leaching into groundwater and contaminating water courses
Legal implications and obligations	Need to consider potential contamination of waterways. For more information on legislation please see Appendix A
Social implications	May be unacceptable to public to “do nothing”
Environmental considerations	The procedure imposes environmental risk i.e. could bring contamination closer to groundwater with leaching which may lead to transfer of chemicals to other areas and affect other populations. Biodiversity could be affected, particularly for soil dwelling organisms.
Ethical considerations	Potential redistribution of exposure from individuals ingesting food products to new populations
Effectiveness	
Recovery option effectiveness	This recovery option does not remove the chemical contamination from the affected area, contamination may degrade but this may take a prolonged period of time.
Technical factors influencing effectiveness of recovery option	Physicochemical properties of chemical Soil type Weather conditions (season) Vicinity of waterways

(23)	Natural attenuation (with monitoring)
Feasibility and intervention costs	
Specific equipment	Monitoring equipment. This option can't be used without checks of its effectiveness and the land may not be suitable again for food production until contamination is shown to have reduced to a 'safe' level. Monitoring of any 'at risk' water courses would also be necessary.
Utilities and infrastructure	None.
Consumables	Any consumables required for sampling, monitoring and analysis work. May require fencing / signs to prevent access to land.
Skills, personnel and operator time	Skilled personnel to sample, analyse and interpret monitoring data.
Safety precautions	None
Other limitations/factors influencing costs	Size of area. Nature of contamination
Waste	
Amount and type	This recovery option does not generate any waste.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A.
Exposure	
Averted exposure	None
Potential increased worker exposure	N/A.
Other considerations	
Agricultural impact	May result in agricultural land being unusable for a prolonged period of time.
Compensation issues	There may be requests for compensation for loss of earnings from farmers or food producers if they are unable to use the land. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Require dialogue between farmers, ecologists and public because of potential for groundwater or surface water contamination.
Additional information	
Practical experience	

(23)	Natural attenuation (with monitoring)
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(24)	Biological degradation/decomposition

Objective	To reduce mass and volume of contaminated biomass requiring disposal or to destroy the actual contaminants.
	Techniques for biological decomposition include;
	• Biological treatment
	  ○ Aerobic
	  ○ Anaerobic
	• Composting
	• Reed beds (for contaminated liquids)

Other benefits	This recovery option could be used for any biodegradable food or feed material. Reduction in the biological oxygen demand (BOD) and chemical oxygen demand (COD) The final end product may be usable as a fertiliser or soil conditioner. Biogas generated can also be used as an energy source.
Recovery option description	**Biological treatment (digestion)** This treatment option naturally degrades chemicals using biological processes that involve the conversion of chemicals into water and harmless gases by microbes. The right conditions (e.g., temperature, nutrients, amount of oxygen) must be present or created in order for bioremediation to be successful). Material may be processed through aerobic (activated sludge or fixed-film systems) and anaerobic digestion facilities present in sewage treatment works (STW) and dairy effluent plants (DEP). • **Aerobic systems** The provision of oxygen and bacteria accelerates processes that would naturally occur in oxygenated rivers. • **Anaerobic systems** Material is retained in an enclosed reactor at temperatures of 35-55°C for a period of 10-30 days. These biological treatments accelerate a series of natural processes and significantly reduce the mass of solids for disposal and the BOD of the effluent. Sludge and cake produced can be used as fertiliser and biogas for heating and electricity generation. **Composting** Composting may be considered where it is impractical to plough contaminated crops back into the soil and/ or when contaminated grass needs to be disposed of. Composting is the controlled biological decomposition of organic material in the presence of air to form a humus-like material. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, or placing the compost in piles out in the open air and mixing it or turning it periodically. Composting achieves a mass reduction of 50% and a volume reduction of 50-90%. It may be carried out at commercial facilities or *in situ* on the farm. Ideally, contaminated crops are mixed with woody material to provide bulk and aeration in the feedstock. The feedstock is degraded aerobically by a succession of micro-organisms, to produce stable humus.
Key information requirements	Microbial toxicity of contaminants; BOD and quantity of material to be treated.
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market, likely to be implemented prior to (37) Incineration and (38) Landfill
Target	Contaminated crops, grass and milk.
Targeted chemicals and important physicochemical properties	Seek expert advice and guidance. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include vapour pressure, physical form. It is unlikely that this option would be suitable for chemicals that could survive the process (i.e. heavy metals or dioxins)
Scale of application	**Any.** Capacity could be limited at commercial composting facilities within an affected area. Centralised sites have a larger capacity, but would involve the transportation of contaminated biomass into uncontaminated areas.

(24) Biological degradation/decomposition

Exposure pathway prevention	N/A. This is a waste disposal (fate of affected food products) recovery option.
Time of application	Early to late (hours to years). However, for contaminated crops it is best carried out in the early (hours to days) phase to reduce the amount of biomass to be composted.

Considerations

Public health considerations	None.
Legal implications and obligations	Need to consider animal by-products regulations For the degradation of milk at sewage treatment works of milk at a Sewage treatment works (STWs) or a Dairy Effluent Plant will be subject to waste water treatment regulations. Any waste treatment carried out would have to be within the terms of the operator's Environmental Permit. For more information on legislation please see Appendix A
Social implications	Contamination of soil may restrict subsequent uses (e.g. organic farming) where sludge and compost are spread on clean land. Stigma associated with areas and perceived contamination of food products (crops, dairy, meat) where the compost has been applied.
Environmental considerations	Careful consideration would be needed of possible environmental impacts in the case of *in situ* treatment. Nitrogen oxides, sulphur oxides and particulates are released to atmosphere as a result of combustion of biogas. These emissions can be offset against the reduced need for energy generation elsewhere. Large volumes of carbon dioxide and water vapour are released with composting. Trace gases such as ammonia and hydrogen sulphide may be produced if excess nitrogen or sulphides are present in the feedstock. These gases would cause odour problems at the composting site. Effluent after aerobic treatment is discharged to watercourses with minimal environmental impact. Large quantities of leachate are produced with composting, typically 30 litres of leachate per tonne of waste. If carried out on open ground the leachate might result in some contamination of land and groundwater. There may also be a release of bioaerosols. Inappropriate application of compost to land may cause pollution of watercourses. Sludge, cake and compost are used as soil conditioner and liquid fertiliser. They contain nutrients of the initial waste, so land spreading may be limited. Incineration of sludge can release acids, heavy metals and other noxious gases. Fly ash is generated as a result of incomplete combustion, but is normally prevented from release by use of filters or other gas cleaning systems. Ash it typically disposed of to landfill. Landfill of sludge and ash can result in contamination of ground and surface waters. This should be avoided using a properly maintained landfill site.
Ethical considerations	Need to consider populations living close to biological treatment facilities, consent of workers and environmental risk. *In situ* disposal option. Self-help for farmer if carried out on individual farms. Informed consent issues in relation to consumers of food produced in areas where compost applied. If carried out at composting facility, there may be a requirement for chemical protection training, consent of workers.

Effectiveness

Recovery option effectiveness	This is a waste disposal option.
Technical factors influencing effectiveness of recovery option	Climatic conditions affect speed and efficiency with which material is broken down. Availability of green (woody) waste for dilution. Quantity of precipitation. Willingness of farmers or commercial composters to carry out composting of contaminated biomass. Acceptability to farmers and the public of returning compost to land. **Aerobic** • BOD removal in excess of 95% • Pathogens are negligible in milk sludge's; • Sludge odours are strong so quick disposal is required. **Anaerobic** • BOD removal is usually between 80 - and 95% at DEPs; • Deactivation of plant and animal pathogens; • Greatly reduces waste odours

(24) Biological degradation/decomposition

Feasibility and intervention costs

Specific equipment	Biological treatment facility. Commercial composting facilities. On farms, composting can be carried out directly on agricultural land. Vehicles for transport. Temporary compost heaps such as those that a farmer might set up on open ground would benefit from temporary covering e.g. Dutch barn. Equipment for spreading compost, sludge and cake.
Utilities and infrastructure	Agricultural land, landfill and incinerators for sludge and cake disposal (i.e. sewage treatment works). Adequate storage space (i.e. hard standing) for materials to be treated.
Consumables	Green (woody) waste to dilute feedstock. This should be readily available at centralised and community facilities. Fuel for transporting compost to commercial site. Fuel for operating equipment on site.
Skills, personnel and operator time	The necessary skills should be available at commercial facilities. Many farmers will be able to carry out composting, but some may need instruction. The farmer will have experience of spreading wastes to land. Additional work incurred by operators at biological treatment facilities and operators involved with disposal of wastes. Time to establish a composting system on farm. Time to inspect and turn compost. Time to transport crops or grass to commercial facility.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). For example respiratory protection and protective clothing is recommended whenever materials are handled or moved. Aerosolisation of micro-organisms (bio-aerosols) and small fragments of vegetation can be problematic if inhaled or come in contact with eyes.
Other limitations/factors influencing costs	Volumes of crops and grass and liquid effluent to be treated. Whether composting carried out *in situ* or at commercial facilities. Capacity of biological treatment facilities for materials with high BOD.

Waste

Amount and type	**Aerobic** Sludge is produced and the amounts depend on the micro-organisms present, BOD of milk, treatment method used, etc. Excess sludge represents 1-5% of the volume of waste treated. **Anaerobic** Depends on the anaerobic digestion facility used. Typically the volume of material is reduced by 40 to 60%, but it can be as high as 80%. The sludge can be treated further to produce a solid cake and liquid. Anaerobic digestion produces biogas which is typically made up of 65% methane and 35% carbon dioxide. The conversion of solids to biogas varies by reactor type. Conversion can range from 30 to 80%. **Composting** Any compost that might not be considered suitable as a soil conditioner. As a rule of thumb, 1 m^3 of leachate may be generated for every 20 m^2 of composting area, depending on the nature of the wastes being composted (Environment Agency, 2001). This weight of material would produce in the region of 30 litres of leachate per tonne of material. Aerial emissions. Any unused compost may have to be disposed of to (38) Landfill or (37) Incineration. There are separate Recovery Options for these disposal options giving the relevant exposure pathways that should be considered. Any leachate generated during composting would be sent to a Sewage Treatment Works (STW): the relevant exposure pathways for this disposal route are given in the (38) Landfill option.
Possible transport, treatment, disposal and storage routes	**Aerobic** Biogas is normally used for process heating and electricity generation. Sludge and sludge cakes can be used in agriculture as fertilisers. The can also be stored on the farm until required. Sludge and cake

(24)	Biological degradation/decomposition
	can also be sent to landfill or incineration for disposal. Any liquid generated during cake production is usually returned to the beginning of the treatment process. **Anaerobic** Sludge can be used in agriculture as fertilisers. If the sludge is produced at a sewage treatment works it needs to be anaerobically treated in accordance with the 'Safe Sludge Matrix' before it can be spread on agricultural land. Sludge and cake can also be sent to landfill or incineration for disposal. The effluent produced during aerobic digestion is normally discharged to a watercourse. **Composting** Landfill or incineration of unusable compost. Leachate should be returned to the compost or if necessary disposed of to a sewage treatment works.
Factors influencing waste issues (i.e. cost)	Biological treatment method used. Disposal option chosen for sludge. Level of chemical contamination in the waste products and the impact of effluent discharged to watercourses. The application of the compost to arable land is dependent on the time of year and state of land (i.e. do not apply when frozen, waterlogged, or to land on a steep slope). Dependant on whether carried out at composting facility or on farms, if carried out on open ground on farms leachate will not be collected. Treatment and disposal of sludge and effluent. Landfill charges and landfill tax. Leachate treatment.
Exposure	
Averted exposure	N/A. This is a waste disposal (fate of affected food products) recovery option.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ STW operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ STW operative's) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Application of sludge, cake or compost provides additional nutrients for crop uptake and could lead to reduced requirements for fertiliser. The cake also provides organic matter that improves soil quality. In the long term it could improve soil structure, increase water retention and aeration and allow easier cultivation.
Compensation issues	There may be requests for compensation from; Biological treatment facilities for handling contaminated milk and decontamination of equipment. Transport companies for decontamination of vehicles. Incineration and landfill operators for decontamination of equipment. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information to farmers on rationale of this waste treatment option. Provision of information to operators on correct application of the procedure on farm so as to avoid pollution.
Additional information	

(24) Biological degradation/decomposition

Practical experience	Biological treatment is a current practice at all sewage treatment works and dairy effluent plants. Composting is current practice. Disposal of raw milk to STWs has been carried out on a small scale. STW are ubiquitous whereas DEPs are only found in milk producing areas. DEPs treat large volumes of dilute milk processing wastes.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	The Dairy Industry and Environment agency consider that it is preferable to use STWs rather than DEPs for treatment and disposal of contaminated milk. STWs are not connected with the supply of milk for human consumption and this separation of waste management and food production is thought to be important to public perception and the retail trade. Use of STWs is acceptable to the water industry provided the amounts of milk are kept to a minimum and personnel; assets and the environment are protected. The NFU raises concerns about the subsequent disposal of contaminated sludge to previously uncontaminated agricultural land, which may cause the land to be blighted.
Document History	

(25)	Bioremediation
Objective	Reduce level of contamination in soil and uptake by crops and animals.
Other benefits	Is likely to generate little or no waste.
Recovery option description	Bioremediation is defined as the process whereby organic wastes are biologically degraded under controlled conditions to an acceptable level, or to levels below concentration limits established by regulatory authorities. By definition, bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere. Simply aerating the soil can reduce the amount of certain chemical in a soil, as it biodegrades. This would enable, oxygen and microbes to digest chemical more readily. In some cases, bioremediation may take a prolonged period of time so could be seen as a constraint. However if carried out successfully it reduces the need for disposal of large amounts of waste (e.g. when compared to top soil removal) via incineration or landfill.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**.
Target	Agricultural land.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to chemicals which undergo biodegradation, and may be more applicable to chemicals with low mobility in soil. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include; persistence, water solubility, adsorption to soil.
Scale of application	**Any**
Exposure pathway prevention	Soil to Plants Plants to animals Soil to animals
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	Potential for minor health complaints as a result of waste gases if populations are in the vicinity. May be exacerbated by hot weather that can increase waste gas release and wind direction in relation to nearby populations.
Legal implications and obligations	Potential implications if farms participate in environmental stewardship or organic farming schemes. Legal restrictions may also apply in Nitrate Vulnerable Zones (NVZ's) Consents may be required before implementing on a Site of Special Scientific Interest or an Area of Special Scientific Interest. Other considerations before implementing this option include National Nature Reserves and archaeological areas. For more information on legislation please see Appendix A
Social implications	Aesthetic consequences of amenity or landscape changes. May take a prolonged period of time (months to years).

(25)	Bioremediation
Environmental considerations	Weather (e.g. cold temperature or rain) can slow bioremediation process. Waste gases may be produced by bioremediation. There may also be a release of bioaerosols. Risk of odour Composition of possible runoff from the treated field(s) should also be considered
Ethical considerations	Self-help for farmer if carried out on individual farms
Effectiveness	
Recovery option effectiveness	Up to 100% effective, all contamination may degrade but may take prolonged period of time.
Technical factors influencing effectiveness of recovery option	Physiochemical properties of chemical contaminant Time of year (effects weather) Time between incident and implementation (for chemicals mobile in soil). Weather (cold temperature or rain may slow process) Willingness of farmer to carry out bioremediation if this is not usual practice.
Feasibility and intervention costs	
Specific equipment	Dependent on scale of incident. Could be carried out using spades on a small scale. Bobcat mini bulldozer or bulldozer, windrow turners and screens may also be required. Bioremediation may be implemented directly on agricultural land.
Utilities and infrastructure	None.
Consumables	None.
Skills, personnel and operator time	Requires skilled personnel (e.g. consultant) to perform appropriate risk assessment
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved. Aerosolisation of micro-organisms (bioaerosols) and small fragments of vegetation can be problematic if inhaled or in contact with eyes.
Other limitations/factors influencing costs	None.
Waste	
Amount and type	Should produce limited waste (limited to gases)requiring disposal as a natural process
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	N/A – This is a waste disposal option.

(25) Bioremediation

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ STW operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ STW operative's) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	While process is undertaken land unlikely to be used for livestock / crops
Compensation issues	Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Need for dialogue regarding selection of areas for bioremediation. Need for dialogue between land owners or farmers. Farmers or operators require information on how to carry out the waste recovery option, including its objective

Additional information

Practical experience	This recovery option was implemented for the remediation of Seveso (dioxins), Italy, 1976.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32
Comments	
Document History	

(26)	Administration of chelation to animals
Objective	To reduce concentrations of chemicals in milk and meat to below permitted levels.
Other benefits	Reduction in quantities of animal produce that will need to be disposed of.
Recovery option description	Administration of chelators can be lifesaving to animals by chelating excess metals present in blood. Chelation therapy is intended to reduce body burden (e.g. lead) and would need to be repeated may times, which is unlikely to be economic and in most cases there is a risk of toxicity from the chelator. This recovery option is only likely to be applied on a relatively small scale (e.g. for rare breed animals or to maintain breeding lines). Seek expert advice and guidance as the Veterinary Medicines Directorate (VMD) have imposed a permanent ban on produce entering the food chain following the use of chelators which are not approved medicines. If this recovery option was being considered, increased chemical concentrations within slurry (as a result of this procedure) would also need to be taken into consideration.
Key information requirements	What is the chemical contaminant? What are the blood levels in affected livestock?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with (29) Clean feeding/ selective grazing regime.
Target	Livestock/ rare breeds of animals.
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to heavy metals. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties: Partition coefficient, biological half-life, potential for chelation/ absorption
Scale of application	**Small**
Exposure pathway prevention	Animal to food products. Ingestion of contaminated animal products.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented from the early to medium phase of a chemical incident. Chelating agents may be difficult to obtain and distribute to affected animals.
Considerations	
Public health considerations	None.
Legal implications and obligations	Seek expert advice and guidance as there may be restrictions or bans on livestock entering the food chain following the use of chelators which are not approved medicines. Animal welfare issues need to be considered. For more information on legislation please see Appendix A
Social implications	Acceptability to farmers or herders, food industry and consumers of using a chelating agent to remove contamination from the gut of livestock. May impact on public confidence e.g. loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are ‘safe’.
Environmental considerations	Increased chemical contaminant in slurry.

(26) Administration of chelation to animals

Ethical considerations	The balance of risks should be addressed, for example risks to public health of tetrathiomolybdate supplementation are likely to be negligible as it is a natural product of rumen metabolism. However, the risks to animal health of using chelators to reduce lead burden are higher than awaiting natural clearance and may not be effective for reducing lead contamination of animal produce.
Effectiveness	
Recovery option effectiveness	Moderately effective. Depends on the method used, unlikely to remove all contamination from livestock.
Technical factors influencing effectiveness of recovery option	Chelators are much less successful for depleting stored metals (e.g. lead). For example, EDTA administration to cattle immediately reduces blood lead concentrations and alleviates signs of poisoning, however blood lead levels return to pre-treatment levels after 10-14 days due to release of lead deposits sequestered in bone. Seek expert advice and guidance as these limitations are likely to apply to all metals that are sequestered / stored in significant quantities in bone or soft tissues. Period of adaptation to pelleted feed may be required. Farmers' compliance to the recovery option. Need to consider side effects of administering chelating agent to animals, some may be toxic at high levels.
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	None
Consumables	Concentrates with chelating agent
Skills, personnel and operator time	Depends on method of administration
Safety precautions	None.
Other limitations/factors influencing costs	Depends on the number of affected livestock that may require chelation. Can maintain the production of meat and milk without disrupting the normal farming practices .
Waste	
Amount and type	None directly but would need to take into consideration increased levels of contamination in slurry as a result of this procedure and appropriate disposal.
Possible transport, treatment, disposal and storage routes	N/A.
Factors influencing waste issues (i.e. cost)	N/A.
Exposure	
Averted exposure	Ingestion of contaminated meat / milk
Potential increased worker exposure	N/A.
Other considerations	
Agricultural impact	Less impact as conventional farming practices can be maintained without severe disruption. Change in production status for organic farms.

(26) Administration of chelation to animals

Compensation issues	There may be requests from the farmer for loss of earnings from livestock. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information to the farmer and consumers on the rationale of the recovery option and evidence of its effectiveness would be important.

Additional information

Practical experience	There is a clear benefit to use of Prussian blue supplementation following caesium contamination. But the use of Prussian blue for Caesium chelation requires continuous supplementation with Prussian blue for as long as caesium exposure persists, which could be years. Long term effects of Prussian blue on health and production (e.g. other elements such as potassium) are uncertain. It may be necessary to alter dietary levels of other elements e.g. increase potassium (potassium supplementation should also decrease caesium uptake).
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Veterinary Medicines Product Update. http://veterinaryrecord.bmj.com/content/167/15/549.full.pdf
Comments	
Document History	

(27)	Application of supplements to concentrate ration
Objective	To reduce concentrations of chemicals in milk and meat to below permitted levels.
Other benefits	Reduction in quantity of milk that will need to be disposed of. Normal animal management or grazing regimes can be used.
Recovery option description	Application of supplements to concentrate ration could enhance the excretion of certain chemicals or potentially reduce absorption. **Calcium supplementation;** could potentially enhance excretion of certain chemicals (not effective if chemical contaminant is arsenic). **Copper supplementation;** could potentially reduce lead absorption (not effective if chemical contaminant is arsenic). **Cysteine, Methionine or Vitamin E supplementation;** may alleviate arsenic toxicity **Selenium supplementation;** selenium deficiency exacerbates arsenic toxicity, so supplementation of selenium may be advantageous in arsenic poisoning. However, expert guidance must be sought as the margin between adequacy and toxicity for selenium is small so there is a relatively high risk of Se toxicity if Se supplementation is increased. An accurate method of Se supplementation would be needed e.g. soluble glass boluses This option is not likely to be cheaper option than chelation (26) Administration of chelation to animals. Would need to take into consideration increased contamination of slurry as a result of this procedure.
Key information requirements	What is the chemical contaminant? What are the blood levels in affected livestock?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with (29) Clean feeding/ selective grazing regime.
Target	Livestock/ rare breeds of animals.
Targeted chemicals and important physicochemical properties	Seek expert advice and guidance. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties include partition coefficient, biological half life
Scale of application	**Small/ Medium**
Exposure pathway prevention	Animal to food products. Ingestion of contaminated animal products.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented from the early to medium phase of a chemical incident..
Considerations	
Public health considerations	None
Legal implications and obligations	Seek expert advice and guidance. Animal welfare issues need to be considered. For more information on legislation please see Appendix A
Social implications	Acceptability to farmers or herders, food industry and consumers of using supplements to facilitate the excretion of contamination from livestock. May impact on public confidence e.g. loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are ‘safe’.
Environmental considerations	Increased chemical contaminant in slurry.

(27)	Application of supplements to concentrate ration
Ethical considerations	However, the risks to animal health of using supplements to facilitate excretion of contaminants should be considered.
Effectiveness	
Recovery option effectiveness	Moderately effective. Unlikely to remove all contamination from livestock.
Technical factors influencing effectiveness of recovery option	Farmers or public compliance to the recovery option. A high ratio of calcium to phosphorus reduces phosphorus uptake which could induce phosphorus deficiency. High level calcium supplementation is expected to reduce feed intake due to decreased palatability of feeds, which reduces production and in certain circumstances (high producing cows in early lactation) could precipitate metabolic disease (ketosis).
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	Supplements are likely to be fed with concentrate during milking
Consumables	Supplements
Skills, personnel and operator time	Farmers would already possess the necessary skills because of experience with using other additives/ supplements.
Safety precautions	None.
Other limitations/factors influencing costs	High levels of calcium intake can influence the absorption of other essential nutrients; the dietary Ca/P ratio should not exceed 7:1 for prolonged periods. Cannot be fed on a daily basis to free-grazing animals.
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A.
Exposure	
Averted exposure	Ingestion of contaminated milk/ meat.
Potential increased worker exposure	N/A.
Other considerations	
Agricultural impact	Conventional farming practices can be maintained without severe disruption. Change in production status for organic farms.
Compensation issues	There may be requests from the farmer for loss of earnings from livestock. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

(27) Application of supplements to concentrate ration

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information to the farmer and consumers on the rationale of the recovery option and evidence of its effectiveness would be important.

Additional information

Practical experience	There is limited practical experience for chemicals.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	In many countries, farmers will have values of Ca in the feeds they use (both commercial and home grown). In the long-term these could be used to optimise the use of Ca as a recovery option on a farm by farm basis. In the shorter term Ca intakes could be enhanced by farmers adding Ca-supplement to feed directly; however in the longer term it may be more efficient or effective to incorporate enhanced Ca into pelleted feeds during manufacture. Farmers consider calcium supplementation of food to be acceptable, as this will help to ensure that milk can still enter the food-chain. If the alternative to this option is mass slaughter of livestock, the public would probably favour the administration of additives to the diet. The administration of more ‘natural’ components (in this case calcium) to feed would be more acceptable to consumers
Document History	

(28)	Administration of clay minerals to feed
Objective	To reduce concentrations of chemicals in milk and meat to below permitted levels.
Other benefits	Reduce the amount of animal product waste that requires disposal.
Recovery option description	Clay materials may adsorb to certain chemicals and increase elimination from the body. Would depend on availability and cost of clay materials. Seek expert advice and guidance as there are approved products commercially available. The veterinary medicines directorate should be consulted to confirm the use of these products for unlicensed applications. If this recovery option was being considered, increased chemical concentrations within slurry (as a result of this procedure) would also need to be taken into consideration.
Key information requirements	What is the chemical contaminant? What are the blood levels in affected livestock?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with (29) Clean feeding/ selective grazing regime.
Target	Livestock/ rare breeds of animals.
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to aflatoxins or those which absorb to clay minerals. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties: partition coefficient, biological half-life, potential for chelation/ absorption
Scale of application	**Small**
Exposure pathway prevention	Animal to food products. Ingestion of contaminated animal products.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent.**
Considerations	
Public health considerations	None.
Legal implications and obligations	Animal welfare issues need to be considered. For more information on legislation please see Appendix A
Social implications	Public or farmers resistance to recovery option. Acceptability of method with respect to animal welfare issues. May impact on public confidence e.g. loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are ‘safe’. May impact on the ‘natural’ perception of some products.
Environmental considerations	Effect of extracting large quantities of clay minerals on the landscape if quarry is not already in operation. In early-medium phase clay minerals would be sourced from existing quarries for speed. Possible trace element deficiency in pasture if ‘large’ quantities of e.g. zeolite are spread to land with slurry or manure.
Ethical considerations	Animal health and well-being should be considered.
Effectiveness	
Recovery option effectiveness	Moderately effective, unlikely to remove all contamination from livestock.

(28)	Administration of clay minerals to feed
Technical factors influencing effectiveness of recovery option	Properties of chemical involved Effective administration of the clay minerals. May result in reduced uptake of minerals by contaminated animal causing health and welfare issues Loss of appetite and weight has been observed if too much clay is given (especially with excess calcium or magnesium supplementation of diets). Period of adaptation to pelleted feed may be required. Initial activity concentration and the biological half-life of the chemical in the animal. Clay minerals from different sources have different binding capacities. Compliance to the recovery option. Seek expert advice and guidance, as there may be possible adverse effects on feed intake, production and mineral imbalance should be anticipated. If farmers and nutritionists are warned to monitor for / expect such adverse effects then the beneficial effects of supplementation would probably outweigh the possible adverse effects.
Feasibility and intervention costs	
Specific equipment	None.
Utilities and infrastructure	Transportation of clay minerals from extraction site, and subsequent storage facilities. Ideally a factory to incorporate clay minerals into pelleted feed rations during manufacture.
Consumables	Clay minerals. Transportation costs.
Skills, personnel and operator time	Farmers or herders would possess the necessary skills to add clay minerals to feed provided instructions were given. If clay minerals were not provided to the farmer or herder already incorporated in feed, the farmer or herder would need to mix the clay minerals with the feed. Additional time would be required to oversee that each animal ingested an appropriate amount.
Safety precautions	None.
Other limitations/factors influencing costs	Cannot be fed on a daily basis to free grazing animals. May be used for free ranging animals in combination with confining them to enclosures (maybe especially applicable to reindeer). Determine the dose is critical. Moderate levels may be beneficial but high doses could induce adverse effects. Total diet ash may determine effect of a particular dose on feed intake. Therefore, higher levels of clay binders may be tolerated on higher digestibility diets. Animals ingesting large quantities of soil (dry dusty weather, wet weather and due to pica) would have lower tolerance than animals on good pasture (not overgrazed) with no mineral imbalances. Some problems reported in Sweden in the industrial incorporation of bentonite into feed pellets (at 2.5% by weight). However, bentonite has been previously incorporated into feeds as an anti-scouring agent.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	N/A.
Factors influencing waste issues (i.e. cost)	N/A.
Exposure	
Averted exposure	Ingestion of contaminated food / milk
Potential increased worker exposure	N/A.
Other considerations	

(28)	Administration of clay minerals to feed
Agricultural impact	May be necessary to provide additional water. Limited impact as conventional farming practices can be maintained without severe losses.
Compensation issues	There may be requests from the farmer due to additional work (labour) costs). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Provision of information to the farmer and consumers on the rationale of the recovery option and evidence of its effectiveness would be important.
Additional information	
Practical experience	Hs been used to reduce aflatoxin toxicity in livestock
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	It may be most effective to incorporate clay minerals into pelleted feeds at manufacture. This avoids loss of binder in feeding troughs. As with the use of all feed additives the faeces from treated animals will be more contaminated than for untreated animals. Farmers consider supplementation of feed with clay minerals to be acceptable, as this will help to ensure that milk / meat can still enter the food chain. If the alternative to this option is mass culling of livestock, the public would probably favour the administration of additives to the diet. The administration of more ‘natural’ components (in this case clay minerals) to feed would be more acceptable to consumers.
Document History	

(29) Clean feeding/selective grazing regime

Objective	To reduce concentrations of chemicals in eggs, honey, milk and meat to safe levels.
Other benefits	Reduces amount of animal food products (i.e. eggs, honey, milk and meat) requiring disposal.
Recovery option description	**Commercial livestock** Provide animals with less or uncontaminated feedstuffs or clean pasture. If contamination has occurred from animal bedding / housing they may also be replaced as appropriate. Target animals may be those grazing contaminated pastures or already housed animals which would otherwise be receiving contaminated diets. Clean feeding can be used to prevent animals from becoming contaminated in the first place or to minimise the time needed for metabolism and excretion to reduce the contamination to an acceptable level. Commercial livestock may be fenced in enclosures or housed to prevent grazing of contaminated pasture. The animals are then given nutritionally balanced diets comprising uncontaminated and/or less contaminated feed so that the final animal product has chemical concentrations below relevant standards. For meat producing animals, clean feeding is only required for a suitable period prior to slaughter (depending upon initial concentrations and biological half-lives). Animals are housed and clean fed for the time it takes for the contaminant to come down to compliant levels; there is a requirement for monitoring to demonstrate compliance. **Non-commercial livestock** (i.e. home apiaries (bee hives), chicken coops (hens) and other non-commercial livestock). Non-commercial livestock may be fenced in or housed to prevent grazing on contaminated pasture. The animals are then given nutritionally balanced diets comprising uncontaminated or less contaminated feed. Bee hives may be moved to uncontaminated areas.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal options). Clean feeding may also be used for delaying decision on livestock slaughter; (7) Control of entry into the food chain. Waste disposal options that also need to be considered include; (24) Biological degradation/ decomposition; (32) Culling of livestock; (38) Landfill and (39) Land spreading of milk and/ or slurry.
Target	All livestock that are destined for the food chain.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals with a relatively short biological half-life. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include partition coefficient, biological half-life.
Scale of application	**Any.** However, large scale application may be dependent on supply of suitable clean feed at a reasonable price.
Exposure pathway prevention	Ingestion of contaminated feedstuff.
Time of application	This recovery option has to be implemented **as soon as risk becomes apparent**. The time between notification and contamination is **important** and this may limit the feasibility of this option.

Considerations

Public health considerations	None.

(29)	Clean feeding/selective grazing regime
Legal implications and obligations	Standards of animal husbandry and welfare and regulations governing feed storage would need to be observed as some certification schemes may be contravened. Free range and organic schemes may also be restricted following an accident, if animals have to be housed. Animal welfare issues also need to be considered Local regulations on the use and siting of buildings must also be consulted which may include restrictions in archaeological areas. There may be potential implications if farms participate in environmental stewardship or organic farming schemes. For more information on legislation please see Appendix A
Social implications	Disruption to people's image or perception of 'countryside' e.g. if there are no animals in the fields, with potential impacts on tourism etc. Willingness of farmer to participate. Willingness of farmers at receiving farms to accept contaminated stock. Stigma associated to affected areas. May impact on public confidence e.g. loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe'. Increased confidence that the problem of contamination is being effectively managed. Disruption to farming and other related activities (e.g. tourism). Credibility of recovery option suggestions may be at risk if a measure does not comply with existing resources on farms.
Environmental considerations	Housing or moving herds of livestock to alternative sites will produce large volumes of slurry or manure. This must be stored and disposed of taking into account possible contamination and to land at suitable times (under suitable weather conditions). Inappropriate disposal of additional slurry or manure could lead to pollution of water courses. Possible changes in landscape due to citing of new buildings. There may be restrictions on where temporary fences can be erected e.g. in National Parks and Environmentally Sensitive Areas. Change in biodiversity of fenced area. Contamination of agricultural land with slurry with increased concentrations.
Ethical considerations	Animal welfare issues if animals are housed in the summer when temperature and ventilation could be a problem (e.g. humidity, high levels of ammonia in buildings). Animal welfare issues may also arise when enclosures are used (e.g. parasite burden, general animal hygiene). This is a **self-help** option for the farmer, however there could be a knock-on effect for public use of amenities if areas are fenced off.
Effectiveness	
Recovery option effectiveness	The effectiveness of this option will depend on time of implementation and physicochemical properties of the chemical contaminant.
Technical factors influencing effectiveness of recovery option	Properties of chemical(s) involved Farmers or herders' willingness and ability to adapt to the new regime. Capacity for feed measurements and live monitoring. Availability and level of contamination of alternative feeds. Compliance with the recovery option **Animals**: The rate at which alternative diet is introduced and duration of feeding regime. If grazing stopped and the new (less contaminated) diet comprise root crops and cereals a period of adaptation of 2 weeks is desirable. This is less important if the uncontaminated diet contains silage and hay. Willingness and ability of livestock to adapt to new regime. The requirement for clean feeding and the availability of conserved feed will be dependent on the time of year that an accident occurs. For example, in winter there would be little impact for housed livestock being fed stored feeds. Finishing lambs grazing forage crops however would have to be housed and given conserved clean feed. Late spring would be the worst time for a contamination event, since cattle and lambs would be grazing outside and no new hay or silage would have been harvested. If the

	accident was later in summer animals could be fed hay or silage that had been cut before the accident. For some of the alternative diets, reduction in grazing is only worth considering for restrictions lasting more than a few weeks because of time required to introduce alternative diets. **Bees**: the distance that the bees need to be moved should be considered and the availability of nectar around the new site.

Feasibility and intervention costs

Specific equipment	Monitoring equipment to assess contamination status of the land. Machinery to aid construction of fences or temporary housing and to restrict access of animals to contaminated land. Fencing in or housing livestock to administer alternative diets should be possible on most livestock farms (particularly dairy and systems where animals are normally housed). Existing fences or farm buildings could be used to house livestock prior to sale, although some would require modification to penning and feeding arrangements or ventilation. New, purpose built sheds could also be considered if period of clean feeding warranted this. Storage facilities for clean feed. Storage facilities for slurry or manure. Feeding and drinking troughs, and possibly shelters for these where being used outdoors. Possibly animal transporters and vehicles to deliver feed. Forage harvester to cut grass for pasture recovery (see below).
Utilities and infrastructure	Water. Power supply. Ventilation.
Consumables	Alternative feeds. Organic feed may be required to maintain organic status of some farms. Straw for bedding.
Skills, personnel and operator time	Farmers would possess the necessary skills as housing animals is an existing practice. **Farmer/herder**: • obtaining uncontaminated feed (and harvesting grass pre-contamination); • looking after animals not normally housed or fenced; • implementation of the alternative feeding regime; • collection, storage and disposal of slurry/manure; • time required for construction of additional enclosures, housing etc.
Safety precautions	General precautions for animal handling.
Other limitations/factors influencing costs	Must ensure that alternative diets are nutritionally balanced and introduced at a rate such that gut flora can adapt. Availability of housing, fences, feeds, machinery and manpower. The period of clean feeding required will be influenced by the initial chemical concentration within livestock, biological half-life and any chemical contamination within replacement feed.

Waste

Amount and type	Slurry or manure produced while livestock are fenced in or housed. Non-compliant milk or eggs
Possible transport, treatment, disposal and storage routes	Slurry or manure should be stored and may require subsequent disposal by (25) Bioremediation; (37) Incineration or (38) Landfill.
Factors influencing waste issues (i.e. cost)	Length of time during which animals are producing non-compliant food. Storage, transport and disposal of contaminated food and slurry

Exposure

Averted exposure	Ingestion of contaminated feedstuff.

(29) Clean feeding/selective grazing regime

Potential increased worker exposure	Will depend on the physicochemical properties of the chemical (i.e. stability and volatility). Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ herder) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ herder) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	Reduced grazing on fields. If clean feeding occurs in areas with high stocking rate surface vegetation will be destroyed. Greater volumes of manure or slurry.
Compensation issues	There may be requests for compensation; **Farmer/herder**: • using up stores of alternative feed; • additional work; • for additional labour required in moving animals to less contaminated pasture • for accepting stock from other farms • loss of income from not adhering to conservation schemes. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Explaining recovery option to farmers or herders. Ensuring communication re harvesting of grass in early (hours to days) phase, prior to contamination

Additional information

Practical experience	Only slight modification to normal farming practice.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Can be expensive depending on time of year
Document History	

(30) Suppression of lactation

Objective	To reduce the volume of milk requiring disposal
Other benefits	Protection of farm staff from environmental contamination e.g. as for radiation emergencies. This recovery option may apply with heavy contamination with acutely toxic chemicals such as some pesticides and cumulative chemicals such as dioxins (i.e. Seveso, Italy 1976).
Recovery option description	If dairy livestock have been contaminated, methods for suppressing lactation can be used to reduce volumes of waste milk requiring disposal. Synthetic oestrogens are effective at inhibiting milk production, although many forms are currently banned by the EU for food producing animals. Progestogens or prostaglandins could also be considered. The more natural method of drying off involves the abrupt cessation of milking, accompanied by provision of poor quality feed, removal of concentrates from the diet and restricted access to water. For high yielding cows the drying off method would be to reduce the frequency of milking over a 2 week period. This option may be implemented before culling occurs to limit the amount of waste milk produced prior to slaughter.
Key information requirements	What is the chemical contaminant? For persistent organic pollutants [POPs] such as dioxins, milk is a major route of excretion. Lactation suppression would extend necessary withdrawal interval in dairy cows exposed to excess dioxins.
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option will have to be considered in conjunction with waste disposal options, including; (39) Land spreading of milk and/or slurry; (34) Disposal of contaminated milk to sea; (24) Biological degradation/ decomposition; (36) Rendering and (37) Incineration.
Target	Dairy animals.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals which pass into milk. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties that should be considered includes biological half-life. For persistent organic pollutants [POPs] such as dioxins, milk is a major route of excretion. Lactation suppression would extend necessary withdrawal interval in dairy cows exposed to excess dioxins.
Scale of application	**Any**
Exposure pathway prevention	From livestock (dairy cows) to milk. Ingestion of contaminated milk
Time of application	This recovery option is most beneficial is implemented **as soon as risk becomes apparent**.

Considerations

Public health considerations	None.
Legal implications and obligations	Hormonal treatments using synthetic oestrogens are not permitted for food producing animals in the EU but may be used if a decision has been made to slaughter animals Animal welfare issues also need to be considered. For more information on legislation please see Appendix A
Social implications	Farmers' resistance to recovery option. Opposition by the public to using hormone treatments due to the perception that those hormones may damage the environment. May impact on public confidence e.g. loss of confidence that farm produce and derivative products (e.g. cheese) from affected areas are 'safe'. Disruption of milk production at dairy farms and to the supply of milk to food industry and market shortages.

(30)	Suppression of lactation
Environmental considerations	Pollution issues related to hormone treatments e.g. if waste milk is allowed to contaminate waterways. Synthetic oestrogens are known to persist in waterways causing endocrine disruption to fish.
Ethical considerations	Animal welfare issues. The process of drying-off in a situation other than for preparation for calving, lambing or kidding and the next lactation cycle has associated animal welfare concerns. For high milk producing animals the drying-off method should be applied gradually over a longer time period as they are more likely to experience discomfort and pain than lower yielding animals. Distribution of costs or benefits between rural and urban population.
Effectiveness	
Recovery option effectiveness	Both hormone treatments and drying-off naturally can be considered as 100% effective if lactation is ceased. The time taken to achieve this depends on the method adopted but can take up to 2 weeks. The shorter the period that drying-off is achieved over, the greater the potential for animal welfare problems to evolve. Suppression of lactation can also be regarded as being highly effective if the rate of milk production is greatly reduced but not ceased.
Technical factors influencing effectiveness of recovery option	The method used to suppress lactation. If hormonal, the type of treatment selected. The daily milk yield or stage of lactation of the dairy animal. Acceptability of suppressing lactation and methods used to achieve it.
Feasibility and intervention costs	
Specific equipment	None
Utilities and infrastructure	None
Consumables	Synthetic oestrogens, progestogens or prostaglandins. Long acting antibiotic for udders (in case of mastitis) if more natural methods of drying off used.
Skills, personnel and operator time	Farmers would possess necessary skills for drying off ‘naturally’ in preparation for calving, lambing or kidding. Some instruction may be required for administering hormonal treatments Less time would be spent milking, but an increased amount of time might be spent controlling animal welfare issues
Safety precautions	None.
Other limitations/factors influencing costs	This recovery option assumes synthetic oestrogens, progestogens or prostaglandins are available.
Waste	
Amount and type	Large volumes of chemically contaminated milk (for chemicals that pass into milk) may be produced until milk production ceases. Levels are likely to be above implementation levels and will require an adequate disposal route. If synthetic oestrogens have been used, all milk will require disposal irrespective of chemical concentration
Possible transport, treatment, disposal and storage routes	Disposal options to consider (but will depend on chemical contaminant): land spreading (39) Land spreading of milk and/or slurry), biological treatment (24) Biological degradation/ decomposition), processing into a milk product suitable for storage prior to disposal (10) Processing and storage of food products and disposal to sea (34) Disposal of contaminated milk to sea.
Factors influencing waste issues (i.e. cost)	High biochemical oxygen demand (BOD) level associated with milk. Dependent on disposal route for milk chosen.
Exposure	

(30)	Suppression of lactation
Averted exposure	Ingestion of contaminated milk
Potential increased worker exposure	None.

Other considerations

Agricultural impact	Possible risk of abortion associated with some methods of drying off. Loss of milk production.
Compensation issues	There may be requests for compensation from the farmer for loss of milk production. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dialogue with farmers or herders is necessary to identify means of ameliorating negative consequences of recovery option on other farming and related activities. Debate and dialogue is required on ethical premises of this recovery option. Effective communication would be especially important if used as an early phase precautionary measure. Communications are required to be updated as the incident develops.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Further research is required to establish the most appropriate methods of drying off dairy animals at different stages of lactation. As drying off is normally in preparation for calving and the next lactation cycle, an artificial dry period would mean that problems would be encountered in initiating the next lactation cycle. If dairy animals are also used in meat production then the suppression of lactation could be of benefit, although the use of oestrogens to achieve this would not be possible under current legislation. Drying off without the use of synthetic hormones would be unacceptable to farmers with high yielding cows because of animal welfare concerns. Similarly there may be public reaction on animal welfare grounds. Generally felt that capacity for immediate slaughter would be sufficient to negate the need for drying off.
Document History	

(31)	Restrictions on animal breeding
Objective	Reduce number of animals affected by contamination and animal products unfit for consumption
Other benefits	Does not generate waste directly.
Recovery option description	If animals are allowed to breed following exposure to a reproductive toxin (i.e. teratogen) this may result in an increased number of malformed offspring. Within this option animals would be segregated according to sex to prevent breeding and to prevent milk production. Would require suitable land (i.e. fields) and potentially additional fencing (to separate animals). Reduces potential of malformations in offspring and transfer of contamination to offspring. Could be implemented relatively easily as it is regularly implemented on farms as normal procedure, similar to changing animal breeding season
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **remediation option** and should be linked to **protection** and **fate of affected produce** (waste disposal) **options**. This recovery option should also be considered in conjunction with (14) Selection of alternative land use
Target	Animal livestock
Targeted chemicals and important physicochemical properties	This recovery option is applicable to chemicals with the potential to have teratogenic effects (e.g. methylmercury, dioxins). Also chemicals which pass into milk (e.g. dioxins). However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties that should be considered include; biological half-life and partition coefficient.
Scale of application	**Any**
Exposure pathway prevention	Livestock – offspring. Ingestion of contaminated animal products including; dairy (i.e. milk), eggs and meat.
Time of application	This recovery option is most beneficial is implemented **as soon as risk becomes apparent**.
Considerations	
Public health considerations	None.
Legal implications and obligations	There is no legislation to enforce this option it would need to take part on a voluntary basis. Potential for animal welfare issues in rearing animals. For more information on legislation please see Appendix A
Social implications	None.
Environmental considerations	Need to consider that slurry from contaminated animals may increase contamination on agricultural land they move to.
Ethical considerations	Need effective dialogue with farmers
Effectiveness	
Recovery option effectiveness	Likely to be up to 100% effective for reducing contaminated offspring. Will significantly reduce the likelihood of congenital anomalies in offspring of animal livestock exposed to mutagenic and teratogenic chemicals. Can reduce the amount of waste milk requiring disposal.

(31) Restrictions on animal breeding

Technical factors influencing effectiveness of recovery option	How soon it is implemented following an incident?

Feasibility and intervention costs

Specific equipment	Fencing materials Transport for fencing materials
Utilities and infrastructure	None.
Consumables	Fencing.
Skills, personnel and operator time	Specialist skills are not required to implement this option.
Safety precautions	None.
Other limitations/factors influencing costs	Number of animals contaminated Availability of new fields/ animal housing

Waste

Amount and type	No waste is generated with this recovery option
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A

Exposure

Averted exposure	Ingestion of contaminated animal products including; dairy (i.e. milk), eggs and meat.
Potential increased worker exposure	Unlikely to result in exposure to operatives unless there is contamination on agricultural land also

Other considerations

Agricultural impact	None expected.
Compensation issues	Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dialogue with farmers or herders is necessary to identify means of ameliorating negative consequences of recovery option on other farming and related activities.

Additional information

Practical experience	

(31)	Restrictions on animal breeding
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Could be implemented relatively easily as it is regularly implemented on farms as normal procedure, effectively changing animal breeding season.
Document History	

(32)	Culling of livestock
Objective	To remove the source of contaminated milk/meat (i.e. animals) that are not expected to re-achieve compliance from the food chain.
Other benefits	Allows restocking (assuming contamination source and/or pathway have been removed) Maintains consumer confidence in food products. Potentially reduces suffering from an animal welfare perspective.
Recovery option description	Culling could be considered for those animals whose milk / meat is so contaminated that it would be considered unfit for human consumption for a significant proportion of their productive life, even when placed on clean feeding regimes. It could also be considered on animal welfare grounds in areas where stock keepers were evacuated leaving animals un-milked and possibly unfed or suffering due to the toxicity of the chemical of concern. It is likely that, following a large scale incident, free bullets or chemical euthanasia would be the primary method of culling considered initially (on abattoir/ farm). Other options would include culling an animal on the farm or at a knacker's yard using a bullet and gun. Condemnation completely removes contaminated food from the market but can leave large quantities of animal waste needing disposal.
Key information requirements	The main driver is whether or not the animals will be able to produce safe and/or compliant food within a reasonable time, taking account of the normal productive lifetime of the animal as well as the associated socio-economic factors i.e. is it cheaper to replace the animals quickly or spend money maintaining them while they are unproductive. The balance of risks is also important to consider when considering implementing this recovery option. Are the risks to public health real or marginal? For example has a safety margin been eroded but risk of physical harm probably remained very low? What are the downside risks / costs of culling compared with the perceived benefits?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be considered as an alternative to (7) Control of entry into the food chain, and linked to **protection** and **remediation options**. This recovery option will have to be considered in conjunction with waste disposal recovery options, including; (33) Burial of carcasses; (36) Rendering; (37) Incineration; and (38) Landfill.
Target	Dairy, egg or meat producing animals.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. The physicochemical form of the chemical, biological half-life, products of metabolism, partition coefficient and tissue distribution are important physicochemical properties that should be considered, as the physicochemical form of many toxic chemicals affects absorption (uptake), metabolism and excretion; • Metal sulphides are poorly absorbed compared with metal oxides. Persistent organic pollutants [POPs] (e.g. dioxins, PCBs) are retained in liver but also in body lipids, therefore all tissues contain residues. POPs are excreted slowly (half-lives generally several months) so it is essential to know the starting level of contamination .
Scale of application	**Any.** Scale will depend on severity of the incident.
Exposure pathway prevention	Ingestion of contaminated animal food products, including dairy (cream, butter, cheese and milk), eggs and meat.
Time of application	**No restrictions on time.** There are no restrictions on time with implementing this recovery option (hours to years), although it should be considered as soon as a risk is recognised.
Considerations	
Public health considerations	None.

(32) Culling of livestock

Legal implications and obligations	Animal welfare issues need to be considered, especially if the animal is suffering due to toxicity of the chemical of concern. It is unlikely a slaughterhouse would be used due to the risk of cross-contamination. Animal by-products regulations would need to be considered for disposal routes. Legislative issues, for example in the UK burning or burial of carcasses on the farm is prohibited by the Animal By Product Order 1999 except if it is a place where access is difficult or in certain limited circumstances.
Social implications	Resistance to culling due to the impact on the farming community and cost. Resistance to the selection process for areas where recovery option is to be applied. Resistance of public to large scale culling of animals. Resistance of public to culling of rare breeds (e.g. individual animals) May impact on public confidence e.g. loss of confidence that farm produce and derivative products from affected areas is ‘safe’ (may i.e. result in loss of employment in local ‘cottage’ industries or growth of a black market). Increased confidence that the problem of contamination is being effectively managed. Possible stigma associated with the area affected. Disruption of farming and associated communities, disruption to people’s image or perception of ‘countryside’ e.g. if there are no animals in the fields, with potential impacts on tourism. Market shortages of dairy (i.e. milk), eggs and meat products. Negative psychological impact especially on farming community.
Environmental considerations	Potential for contamination of surface waters due to run off from carcasses Cull sites outside of controlled premises are likely to require an environmental impact assessment. Indirect effects depend on the disposal route selected for carcasses.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). For complete and detailed guidance, see the Human Rights Act. Animal welfare must not be compromised by extra time spent at, or waiting to be sent to slaughterhouses prior to slaughter or in travelling long distances to remote slaughterhouses. Political, production related and animal welfare motives should be transparent to all stakeholders before decisions on implementing this recovery option are made.

Effectiveness

Recovery option effectiveness	Highly effective (i.e. 100%) as this option removes contaminated animals and animal products from the food chain.
Technical factors influencing effectiveness of recovery option	Appropriate selection of priority areas. Availability of licensed operatives to visit farms in immediate aftermath of accident. Availability of transport to move animals. In large scale incidents, movement of animals may be infeasible and risk spread of contamination Waste products (e.g. meat) require careful control to prevent recycling back into the food chain

Feasibility and intervention costs

Specific equipment	Abattoir, knackers yard or culling equipment on farm (e.g. firearms). Vehicles for transport of livestock to abattoir or knackers yard if necessary.
Utilities and infrastructure	Disposal routes for carcasses e.g. incinerators, rendering plants, burning and burial sites.
Consumables	Fuel for transport to abattoir or knackers yard if necessary. Cartridges for firearms etc Bullets
Skills, personnel and operator time	Culling must be carried out by licensed operatives with necessary skills. Time to cull livestock. Time to transport livestock if necessary.

(32) Culling of livestock

Safety precautions	None above normal for handling and culling of livestock. If being used on animal welfare grounds in conjunction with evacuation of population, health advice or monitoring and protective clothing will be required. Respiratory protection may be required for intensive poultry farms due to high ammonia levels.
Other limitations/factors influencing costs	Capacity of disposal routes. Whether culling is carried out at abattoir, knackers yard or on farm.
Waste	
Amount and type	Condemned livestock carcasses. Disinfectants used to prevent disease if carcases cannot be moved quickly; animal body fluids & faeces will need to be managed on the culling cull site.
Possible transport, treatment, disposal and storage routes	Disposal by: (33) Burial of carcasses, (36) Rendering; (37) Incineration and (38) Landfill
Factors influencing waste issues (i.e. cost)	Acceptability of and compliance with waste disposal practice. Transportation of carcasses to rendering or incineration plant or burial or burning site. Costs of the chosen disposal route; incineration, rendering, burning and burial.
Exposure	
Averted exposure	Ingestion of contaminated animal food products, including dairy products (i.e. milk), eggs and meat.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ plant operative) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ plant operative) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	If the entire herd or flock is culled, under-grazing of pasture will occur but this can be remedied by cutting forage for hay etc except on a land unsuitable for agricultural vehicles.
Compensation issues	There may be requests for compensation; **Farmer/herder:** • Immediate culling • For milk unable to be sold, for loss of livestock and for maintaining pastures if all livestock is removed. **Abattoir or knackers yard**: • For decontamination of culling premises, if necessary. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and

(32) Culling of livestock

international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States.
Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Implementation of this recovery option is likely to meet resistance from some farmers, so good stakeholder dialogue will be essential. Dialogue with farmers or herders is necessary to ensure understanding of the reasons and conduct of slaughter, and to identify means of ameliorating negative consequences of recovery option on other farming and related activities.
Effective communication would be especially important if used as an early phase precautionary measure.

Additional information

Practical experience

Slaughtering of cattle has been carried out in the UK and other European countries following the condemnation of beef because of BSE. On a larger scale there has been slaughter and burning or burial of complete farm stocks (ruminants and pigs) as a consequence of the foot and mouth epidemic in the UK. Herds and flocks were also slaughtered and disposed of in many other Member States including France, Belgium, Germany and the Netherlands.

Key references

Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report. Health Protection Agency. 2010 (17); pg6
Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce. Capitolo 3: Le Richerche della Fondazione . Fondazione Lombardia per L' Ambiente.1998;32
Rose M. Studies made to assess risk concerning a 'dioxin' contamination incident near Bolsover, Derbyshire, UK. Food Addit Contam. 2001; 18 (12): 1094-8.

Comments

Cattle excrete dioxins in milk therefore persistent organic pollutants [POPs] residues in beef fattening animals may be even longer than for dairy cows (POPs concentrations in beef cattle are moderated / diluted by increasing body mass). POPs contamination incidents are likely to result in uneconomic withdrawal periods even if livestock could theoretically excrete the POPs (however this would take several years). Slaughter is likely to be the most economic option for the farmer.
Pigs and poultry have relatively short economic life spans, are cheaper to replace and are therefore more likely to be disposed of by culling.
The farming industry will choose to cull when it is uneconomic to continue to feed animals due to a long withdrawal period. In such cases the only actions necessary by government are to impose the required withdrawal interval, ensure there are adequate facilities for cull and disposal and ensure that welfare and other regulations are complied with.

Document History

(33)	Burial of carcasses
Objective	To dispose of animal carcasses following culling/ slaughter.
Other benefits	No treatment of carcasses needed prior to burial, therefore, no risk of additional contamination of for example would occur in rendering plants, incinerators etc.
Recovery option description	After culling and slaughter, animal carcasses may be disposed of in purpose built burial pits, on-farm or at mass burial sites.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market; (7) Control of entry into food chain and (32) Culling of livestock.
Target	Meat and milk producing livestock.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic and have a low motility in soil. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option would only be applicable to chemicals with low mobility in soil. Important physicochemical properties that should be considered include; adsorption to soil, persistence and water solubility
Scale of application	**Any**
Exposure pathway prevention	Not applicable, this is a waste disposal option.
Time of application	**No restrictions on time.**
Considerations	
Public health considerations	There are likely to be public health concerns of the population in the affected area. Potential risk of psychosocial impact in affected population.
Legal implications and obligations	Under normal circumstances the burial of animal by-products is prohibited by the Animal By-Products Regulations although there are derogations from this prohibition permitting burial in remote areas, defined as Lundy and Isles of Scilly in England and a number of areas in Scotland, and in the event of a disease outbreak. The Transmissible Spongiform Encephalopathies (TSE) regulations also prevent the burial of animals suspected of being infected with Specified Risk Material (SRM) which needs to be disposed of in accordance with Animal By-Products Regulations. Waste controls also need to be considered Groundwater regulations aim to prevent List I or List II substances from entering groundwater. A Groundwater Authorisation (GWA) would need to be given by the EA prior to disposal. Due to the potential for large volumes of leachate from a burial site, regulations applying to the contamination of controlled waters would also apply – i.e. tidal and coastal waters (up to 3 miles from land), rivers, lakes, ponds and ground waters For on-farm burial (where not prohibited by the ABPR) carcasses should never be buried near to watercourses, boreholes or springs. Transport of dangerous good regulations would also apply if the carcasses were to be transferred to a burial site. For more information on legislation please see Appendix A

(33) Burial of carcasses

Social implications	Acceptability of changes to landscapes and of other environmental effects, to relevant populations. Local opposition to the selection of burial sites e.g. where contaminated carcasses are disposed of in previously uncontaminated areas. Aesthetic consequences of landscape or amenity changes. Changed relationship to the countryside and potential loss of amenity or social value resulting from changes in people's perception of land as 'natural' to being 'unnatural' or in some way damaged. Disruption to farming and other related activities e.g. tourism. Policing the carcass burial and averting growth of a black market. Contamination of the soil may restrict subsequent uses (e.g. organic farming). Potential for dispute regarding selection of burial pit sites. Stigma associated with areas surrounding designated burial pits.
Environmental considerations	Availability and capacity of suitable burial sites. Animal carcasses must be disposed of without endangering human health or harming the environment. Minimal risk of contamination of surface and groundwater from leachate from correctly designed and managed purpose built burial pits. However animal leachate may contain very high concentrations of ammonium (2000 mg l^{-1}), biological strength (COD) (100,000 mg l^{-1}) and potassium (3000 mg l^{-1}) as well as sheep dip chemicals, barbiturates and disinfectants. Animal leachate can contain pathogens such as Escherichia coli 0157, Campylobacter, Salmonella, Leptospira and protozoa Cryptosporidium and Giardia and BSE prions from cattle born before 01/08/96. In the early stages of decomposition carcasses will release carbon dioxide and other gases such as methane, carbon monoxide and hydrogen sulphide.
Ethical considerations	Negative side effects on populations living close to burial sites. Possible environmental and aesthetic consequences. Loss of amenity or change in public perception of land used for burial. Liability for potential negative effects from disposal site (e.g., leakage).
Effectiveness	
Recovery option effectiveness	Recovery option does not remove the contamination, but removes contaminated livestock from the food-chain.
Technical factors influencing effectiveness of recovery option	Engineering of burial pit, suitability and availability of land for burial pit (i.e. away from water sources and not on land with high water table). On-farm burial site relies on the dispersal and dilution of animal leachate (fluids from carcasses) in the ground to protect water, so number of disposal sites is limited. Normally 8 tonnes of carcasses can be buried. This is equivalent to 16 adult cattle, 40 pigs or 100 sheep. More may be allowed in a crisis. Mass burial site: sewage treatment works (STW) must have the capacity to treat the volumes of animal leachate produced. Time to construct mass burial sites. Transportation of carcasses to burial site. Acceptability of this disposal option to farmers and the public. There is potential for a black market in culled meat. Willingness of private landowners and local populations to accept carcasses for burial. Maintenance of correct burial pit procedures (e.g. clay lining) including burial of non-carcass material (e.g. sheep dip, paint diesel manure). There is a potential risk from carcasses awaiting disposal to contaminate private and public water supplies. The extent of risk will depend on the state of decomposition of the carcasses and type of ground. Disposal of potentially hazardous non-carcass wastes to on-farm burial sites.
Feasibility and intervention costs	
Specific equipment	Civil engineering equipment required to dig pit e.g. excavators for digging pits. JCB's, bulldozers or tractors with bucket loaders for moving carcasses. Lamps to allow night working. For mass burial site: clay liner 1m thick, geoclay liner and geocomposite liner to prevent seepage. Vents to collect and burn off gasses produced by decomposition. Sumps or wells and pumps to collect and remove any animal leachate produced. Ideally on-site treatment facilities to pre-treat leachate and reduce biological strength (COD) before removal to sewage treatment works (either inland or coastal). Fencing to contain the site and prevent dumping of non-carcass material. Transportation of carcasses to burial site and animal leachate to sewage treatment works.
Utilities and infrastructure	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site gas control measures.
Consumables	Fuel for transportation of carcasses to burial pit and animal leachate to sewage treatment works.

(33)	Burial of carcasses
Skills, personnel and operator time	Engineers and construction workers to build burial pit. Time to construct burial pit and transport carcasses and animal leachate. Time required monitoring groundwater after burial. Operators at sewage treatment works.
Safety precautions	Risk assessment to be carried out before purpose built burial pit constructed. Protective clothing and equipment for engineers, construction workers and sewage plant operators.
Other limitations/factors influencing costs	Mass burial sites can only be kept open when being filled rapidly and soil capped. When there is only a small daily supply there is potential for carcasses to be left exposed to carnivorous animals with the possible transmission of pathogens. All-purpose built burial pits should ensure that carcasses remain permanently buried in such a way that carnivorous animals cannot gain access to them. Factors influencing costs include; numbers of animals requiring burial, size of pit required and volume of animal leachate to be treated.
Waste	
Amount and type	Animal leachate e.g. body fluids from carcasses are released (about 0.1 m^3 per adult sheep and 1.0 m^3 per adult cow) within the first year, and gas.
Possible transport, treatment, disposal and storage routes	Animal leachate has to be removed by tanker for treatment and disposal at sewage treatment works and on site treatment of gas.
Factors influencing waste issues (i.e. cost)	Volume of leachate to be treated and the chemical concentration of the leachate. The leachate generated during burial will be disposed of at a Sewage Treatment Works (STW): the relevant exposure pathways for this disposal route are given in the (36) Rendering and (37) Incineration and (38) Landfill recovery option.
Exposure	
Averted exposure	Recovery option does not remove the contamination, but removes contaminated livestock from the food-chain.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ STW operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ STW operative's) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	Potential risk of land becoming blighted.
Compensation issues	There may be requests for compensation from transport and machinery hire companies for cleaning and decontamination of vehicles, but this is more likely to be covered by a contractual agreement to return in a clean condition. To sewage treatment works for handling contaminated animal leachate and for decontamination of equipment. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and

(33)	Burial of carcasses
	international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some farmers, so good stakeholder dialogue will be essential. Dialogue with farmers or herders is necessary to ensure understanding of the reasons and conduct of slaughter, and to identify means of ameliorating negative consequences of recovery option on other farming and related activities. Dissemination of information about carcass burial to the general public.
Additional information	
Practical experience	Mass burial in UK to deal with Foot and Mouth infected animal carcasses: multiple pits, each capable of holding 10,000 to 60,000 carcasses were constructed.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Burial of carcasses may be appropriate if the quantity of material or distance and access to premises in which disposal is otherwise permitted, does not justify transporting it. Acceptable to the Environment Agency on a small scale and then with suitable management. Unlikely to be acceptable for cattle due to potential contamination from BSE.
Document History	

(34) Disposal of contaminated milk to sea

Objective	To dispose of contaminated milk.
Other benefits	None.
Recovery option description	Contaminated milk may in principle, be discharged to sea via outfalls of coolant water or liquid effluent at nuclear installations or via long sea outfalls at coastal sewage treatment works.
Key information requirements	What is the chemical contaminant?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**.
Target	Contaminated milk.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option **is only applicable to chemicals that have the potential to pass into milk**. Important physicochemical properties that should be considered include; biological half-life and persistence.
Scale of application	**Any**
Exposure pathway prevention	N/A this is a fate of affected produce (waste disposal) option.
Time of application	**No restrictions on time.** However, contaminated milk will require storage until it can be disposed of.

Considerations

Public health considerations	None.
Legal implications and obligations	Coastal sewage treatment works used to discharge milk to sea via long sea outfalls will be subject to the Urban Waste Water Treatment Regulations Sewage treatment works with capacities over 50 tonnes per day are also subject to environmental permitting controls. Discharges from Sewage Treatment Works regulations applying to the contamination of controlled coastal waters (up to 3 miles from land). Exemptions from these regulations can occur where such discharges are made 'in an emergency in order to avoid danger to life or health'. Disposal of untreated milk to sea is prohibited by the Animal By-Products Regulations. For more information on legislation please see Appendix A
Social implications	Discharge of chemical wastes to sea is currently highly contentious and unlikely to be publicly acceptable. However, in emergency conditions, or conditions of high levels of widespread contamination, it may be more acceptable. Potential for dispute regarding selection of this waste disposal option. Stigma associated with areas or fish produce where milk has been disposed of to sea. Disruptions to people's image or perception of the 'seaside' e.g. milk flowing onto the beach from outflow pipes, with potential impacts on tourism etc.
Environmental considerations	Limits on total biological oxygen demand (BOD) discharged by long sea outfalls. These vary according to the degree of mixing of water body receiving contaminated milk. Effects of discharge on the dissolved oxygen content of the seawater should be small, but must have been demonstrated in advance on a site specific basis. In the worst case, dissolved oxygen content should return to ambient levels within about 17 days if 40 million litres are discharged over a 6 week period.
Ethical considerations	Additional exposure to tanker drivers, marine life and consumers of marine produce. Aesthetic or ecological effects from sea disposal.

(34)	Disposal of contaminated milk to sea
Effectiveness	
Recovery option effectiveness	N/A.
Technical factors influencing effectiveness of recovery option	Ability to transport waste milk to discharge points and offload it easily. Limits on total BOD discharged by long sea outfalls that vary according to the degree of mixing of the receiving water body. Acceptability of the intervention of the waste recovery option to operators, haulage companies and the public. Compliance or resistance to the waste recovery option.
Feasibility and intervention costs	
Specific equipment	Large capacity vehicles with specialised equipment and couplings for transport. A 13,000 litre tanker would hold milk from around 10 average size dairy farms. An average size dairy farm has a herd of 80 cows, each producing 16 l d^{-1}. Pumps will be required to offload milk from tankers into holding pits. One (13,000 l) tanker per 30 average size farms, with milk collected from 10 farms each journey for 3 journeys per day. Pumps. Approximately £2000 to buy, or use plant hire companies.
Utilities and infrastructure	Coolant water and liquid effluent outfalls at nuclear installations or long sea outfalls at sewage treatment works.
Consumables	Fuel for transporting milk to outfalls.
Skills, personnel and operator time	The vehicle drivers and operators at the power stations and sewage works should have the necessary skills. Little additional training would be needed. Modellers' time will be required to demonstrate the effects of discharge of milk on BOD on a site specific basis. Tanker drivers 10 hour shifts. Operators at power stations and sewage works as necessary.
Safety precautions	Not necessary at the levels of contamination for which this method would be considered. However, the discharge of milk to sea is a non-standard practice that will require station managers to carry out a full risk assessment. Potential hazards need to be identified and controlled. A constant stream of tankers arriving at a nuclear or sewage treatment plant may require traffic recovery and parking.
Other limitations/factors influencing costs	Contingency plans for dealing with protestors at the gates need to be made. Distance from farms to sea outfalls.
Waste	
Amount and type	None. This is a fate of affected produce (waste disposal) option.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	N/A.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ drivers/ operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ drivers/ operatives) exposure. They would, however,

(34)	Disposal of contaminated milk to sea
	need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).
Other considerations	
Agricultural impact	None.
Compensation issues	There may be requests for compensation from power stations and sewage works for use of facilities, also from milk transporters for decontamination of tankers and equipment and plant hire companies for decontamination of equipment. . Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Rapid communication may pre-empt conflicting actions in other Member States. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementation of this recovery option is likely to meet resistance from some farmers, so good stakeholder dialogue will be essential. Need for widespread dialogue to ascertain the acceptability of discharge to sea both nationally and internationally. Public consultation can be a lengthy process that might not be achievable on the timescales required for disposing of large volumes of milk. Requirement to monitor water quality in surrounding water body. Dialogue with the operators and regulators need to be established well in advance. This will involve considerable time and effort. Potential need to facilitate widespread debate regarding the ethics and practice of disposal at sea.
Additional information	
Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Acceptable in principle to the Environment Agency and water industry. Public reaction may be opposed to disposal of milk at sea, even if proven to be acceptable scientifically. Disposal of milk to sea will require pre-planning.
Document History	

(35)	Burning in-situ
Objective	To reduce volume of contaminated food products prior to disposal and to produce a stable end product
Other benefits	None
Recovery option description	Open air burning involves the burning of carcasses or plant material in open fields, on combustible heaps called pyres and with other burning techniques that are unassisted by incineration equipment. Open air burning is generally prohibited in the UK. Therefore can only be used in exceptional circumstances involving large scale chemical contamination where there are major waste disposal issues. Carcasses or plant materials are burned in open air on the site where they were originally kept or grown. Can be used on all waste types provided material contains at least 30% solids. Drying prior to burning is preferable but may require extra fuel. To promote clean combustion, it is advisable to dig a shallow pit with shallow trenches to provide a sufficient supply of air.
Key information requirements	What is the chemical contaminant and potential degradation products?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market; (7) Control of entry into food chain and (32) Culling of livestock.
Target	Livestock / contaminated crops.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable to all chemicals that are could contaminant the food chain. Important physicochemical properties that should be considered include; biological half-life, persistence and degradation products.
Scale of application	**Medium/ large**
Exposure pathway prevention	Plant to animal Plant to human Animal to human (i.e. ingestion of contaminated food products).
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	There are public health constraints associated with this recovery option, including; • Psychosocial aspects • Poor air quality may impact on susceptible groups (children, elderly, people with chronic respiratory disease such as asthma or COPD).
Legal implications and obligations	Seek expert advice and guidance, as restrictions or prohibitions may apply (i.e. burning of straw on farms is restricted and burning of carcasses is usually prohibited). For more information on legislation please see Appendix A
Social implications	Impact on local communities. Suggested minimum distance of 2 miles to community.

(35)	Burning in-situ
Environmental considerations	Availability and capacity of suitable land. Animal carcasses and crops must be burned and the ash disposed of without endangering human health or harming the environment. Negative Impacts through gaseous emissions. Burning may increase the aerolisation or volatilisation of the contamination hazard. Groundwater contamination may occur potentially from hydrocarbons used as fuel for initial burning. Burning in windy areas poses a threat as a fire hazard. Burning could create a bigger or longer-term problem
Ethical considerations	The ethical considerations should be taken into account, particularly following the public outcry of burning-in-situ of animal carcasses following the foot and mouth epidemic in 2000.
Effectiveness	
Recovery option effectiveness	Open air burning does not have a consistent temperature range. However if metallic fuel (or alternatively diesel) temperatures of 1200 – 1400 degrees centigrade can be reached. The higher the temperature the more effective the procedure. There will not always be certainty of 100% destruction of the contaminants concerned.
Technical factors influencing effectiveness of recovery option	Relatively quick solution but the slowest of all incineration processes. The type of carcass being burned will influence time. The greater the percentage of animal fat the more efficient the process. The chemical contaminant involved and degradation products will influence the effectiveness of this recovery option.
Feasibility and intervention costs	
Specific equipment	None.
Utilities and infrastructure	Transport and fuel for vehicles
Consumables	Fuel, e.g. diesel
Skills, personnel and operator time	Depends on the chemical incident and the scale and size of affected area. Limited skills required to implement this option.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved.
Other limitations/factors influencing costs	Chemical contaminant and degradation products.
Waste	
Amount and type	Pyre ash
Possible transport, treatment, disposal and storage routes	Ash from burning process is usually disposed of to landfill
Factors influencing waste issues (i.e. cost)	Chemical contamination Composition of waste (e.g. crops / carcasses). .
Exposure	
Averted exposure	Ingestion of contaminated food products.

(35) Burning in-situ

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmer/ STW operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmer/ STW operative's) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	May damage and contaminate agricultural land with fuel used for burning
Compensation issues	There may be requests for compensation from farmers for damage to agricultural land. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Dissemination of information about burning of contaminated produce to farmers and the public. Essential to have good communication with local inhabitants.

Additional information

Practical experience	Non chemical: Foot and Mouth disease (UK). Outbreaks of anthrax in Canada (1993) and South East Missouri (2001).
Key references	
Comments	This option should be considered in conjunction with (36) Rendering and (37) Incineration
Document History	

(36)	Rendering
Objective	To reduce volume of contaminated carcasses or other material prior to disposal.
Other benefits	Waste disposal costs reduced, especially if contamination is concentrated in one by-product stream.
Recovery option description	Animal carcasses may be sent to licensed rendering plants and reduced to tallow, meat and bone meal (MBM), condensate (the condensed steam produced from boiling off the water from the rendering process) and blood. These products require subsequent disposal to landfill, incineration or wastewater treatment plant. Rendering can also be used to dewater milk.
Key information requirements	What is the chemical contaminant and subsequent degradation products?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market; (6) Product recall; (7) Control of entry into food chain; and (32) Culling of livestock. (37) Incineration may be performed post rendering.
Target	Meat and milk producing livestock or associated food products.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable **to all persistent chemicals that are can bio-accumulate**. Important physicochemical properties that should be considered include; biological half-life and partition coefficient.
Scale of application	**Medium/ large**
Exposure pathway prevention	N/A - this is a fate of affected produce (waste disposal) option.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	There may be some public health concerns and psychosocial impacts due to air quality, perceived air pollution and odour.
Legal implications and obligations	Rendering plants are subject to environmental permitting controls in England and Wales. Rendering plants must be approved under the Animal By-Products Regulations and conform to the TSE regulations Rendering by-products (MBM, tallow and greaves) have to be disposed of to landfill or incineration under ABPR regulations Rendering plants which treat waste liquids on site are also subject to the Urban Waste Water Treatment Regulations. For more information on legislation please see Appendix A
Social implications	Public or stakeholder acceptability. Most rendering plants have local protest groups due to odours. Low acceptance of chemically contaminated material to these groups.
Environmental considerations	Rendering should result in minimal environmental impact provided all control measures and best practice is fully implemented.
Ethical considerations	Additional exposure to operators and populations living close to rendering plants. Consent of plant operators.

(36) Rendering

Effectiveness	
Recovery option effectiveness	The effectiveness of this option will vary, dependant on the type of food products and chemical contamination. It may be that further processes are required to complete remediation (i.e. (37) Incineration may be performed post rendering).
Technical factors influencing effectiveness of recovery option	The availability and capacity of rendering plants to cope with large numbers of livestock carcasses at any one time. The reduction of the carcasses to tallow, meat and bone meal (MBM) is dependent on temperature, time, and pressure combinations at each facility. Acceptability of disposal or treatment procedures.
Feasibility and intervention costs	
Specific equipment	Transportation of carcasses from farm to rendering plant and waste products to landfill or incineration and waste water treatment plant.
Utilities and infrastructure	This recovery option assumes that all infrastructure needed is readily available. Rendering plants suitable for disposal of mammalian carcasses. Disposal route for waste products e.g. landfill, incineration, wastewater treatment.
Consumables	Fuel for transportation of carcasses and waste products.
Skills, personnel and operator time	Rendering operators should have the necessary skills. Rendering plant operators for additional work. Additional time to transport carcasses.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. rendering operators) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved.
Other limitations/factors influencing costs	Capacity of rendering plants. Number of carcasses to be treated and disposal routes of rendered products. Risk of contaminating rendering plant and vehicles used to transport carcasses.
Waste	
Amount and type	The main products of rendering are: • MBM (Meat and Bone Meal) – dust like end product containing 60-65% protein; • tallow – solid hard fat; • greaves – same material as MBM but the final grinding stage has been omitted; • condensate – generated from the rendering process; • blood – blood meal. When a whole carcass is rendered the volume is reduced by 12%. Generally this is made up of 60% MBM and 40% tallow. Upon incineration this is reduced further. Between 100 and 150 kg ash is produced per tonne of carcass. Depending on the nature of the chemical incident, rendering waste may be classed as 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Rendering products are disposed of by (37) Incineration or to (38) Landfill. There are separate Recovery Options for these disposal options giving the relevant exposure pathways that should be considered. The condensate generated during rendering may be sent to a Sewage Treatment Works (STW): the relevant exposure pathways for this disposal route are given in the (38) Landfill Recovery Option.
Factors influencing waste issues (i.e. cost)	Transportation of waste products to disposal site or plant. Costs of incineration or landfill and treating condensate. Compensation to landfill, incinerator and waste water treatment owners for decontamination of the plant and vehicles if necessary.
Exposure	
Averted exposure	N/A.

(36) Rendering

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. rendering operatives) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. rendering operatives) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	None.
Compensation issues	There may be requests for compensation from rendering plant owners for decontamination of the plant and vehicles. However, it is unlikely rendering would be used if the contamination risk was unacceptable. Therefore, it would be a contractual matter. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Operators may require information on rendering contaminated carcasses. Information and training for operators.

Additional information

Practical experience	Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report-Health Protection Agency. 2010 (17); pg6
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	Rendering is the preferred method of whole carcass disposal as it has the least disposal hazards associated with it, but is only an intermediate stage. Rendering is an acceptable method to reduce the final volume of waste that will subsequently be disposed of either by (37) Incineration or (38) Landfill.
Document History	

(37)	Incineration
Objective	To destroy contaminated material in a controlled manner.
Other benefits	This is normally a straightforward, routine and rapid process. In most cases, all of the technical, legal and socioeconomic considerations will already have been addressed, however in view of the potential cost, other disposal options may turn out to be preferable.
Recovery option description	Incineration is the controlled burning of waste at high temperatures, typically around 900°C. Organic components present in waste are released as exhaust gases, and mineral matter is left as a residual ash. The volume of the ash is about an order of magnitude less than the original waste; the corresponding reduction in terms of mass is about a factor of 3. The ash is typically disposed of to landfill. Milk would require dewatering prior to incineration.
Key information requirements	What is the chemical contaminant? What is the capacity of incinerators under consideration? How far are incinerators? Would mobile incinerators be suitable?
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market; (6) Product recall; (7) Control of entry into food chain; (32) Culling of livestock. (38) Landfill is likely to be performed on waste from incineration process.
Target	Contaminated cereals, vegetables, fruit, fish, rendered meat, eggs, milk powder, honey, mushrooms, berries, grass.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic and could contaminate the food chain. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable to **all chemicals that are could contaminate the food chain**. Important physicochemical properties that should be considered include; persistence and degradation products.
Scale of application	**Any in principle.** There may be limitations due to cost or capacity.
Exposure pathway prevention	N/A - this is a fate of affected produce (waste disposal) option.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	Incineration is a normal waste disposal practice, therefore there should be no increased risk to public health.
Legal implications and obligations	Environmental permitting controls need to be considered for incineration and co-incineration plants. The incinerator should already be regulated to ensure that it is Waste Incineration Directive-compliant. Exceptions to these controls include plants that only burn animal carcasses that are subject to the Animal By-products Regulations (e.g. animal carcass incinerators) For more information on legislation please see Appendix A
Social implications	The introduction of large quantities of additional waste for incineration may attract adverse local publicity. There may be objections to the bringing in of a mobile incinerator.

(37)	Incineration
Environmental considerations	Availability and capacity of suitable incinerators. Animal carcasses and crops must be incinerated and the ash disposed of without endangering human health or harming the environment. Atmospheric emissions from incineration include: • gases: CO, CO_2, NO_x, SO_2, etc; • mineral dust: fly ash (PM10); • heavy metals: Pb, Cu, Hg, Cd, etc; • organic molecules: dioxins, furans, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). All of these are damaging to human and animal health and the environment. However the amounts discharged have been significantly reduced (and continue to be) due to advances in incinerator and flue gas treatment technologies. Chemicals released during incineration may be taken up into the food chain by animals grazing on grass nearby. Possible risk of pollution to soil, surface waters and ground waters from ash associated contaminants. However, all of these issues will be managed if the incineration activity is properly run.
Ethical considerations	None.
Effectiveness	
Recovery option effectiveness	100% for a correctly-run process
Technical factors influencing effectiveness of recovery option	None.
Feasibility and intervention costs	
Specific equipment	Commercial high-temperature incinerators, on-farm incinerators and mobile air-curtain incinerators capable of disposing of crops and/or mammalian carcasses. Vehicles for transporting materials, crops or carcasses to incineration site and ash to landfill site.
Utilities and infrastructure	Disposal route for ash if it is not handled as part of a routine commercial operation. There are a number of beneficial reuse options for incinerator bottom ash, although fly ash must normally be disposed of to landfill as hazardous waste.
Consumables	Fuel for transporting crops or carcasses to incineration site and to run incinerator. Mobile air-curtain incinerators only work effectively when fed with dry seasoned timber.
Skills, personnel and operator time	Trained personnel will be available at incineration facilities. Time to transport food products. Incineration plant operatives for processing additional material.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. rendering operators) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved.
Other limitations/factors influencing costs	Availability of the correct type of incinerator.
Waste	
Amount and type	Ash. The volume of ash produced is usually 10% of the original material and the mass is reduced to 25-30% of the original material.
Possible transport, treatment, disposal and storage routes	Ash from commercial incinerators must be disposed of to landfill. Ash from air-curtain and on-farm incinerators can be buried on site providing there is no possibility of ground and surface water contamination. Otherwise it must be collected, stored and sent to landfill.

(37) Incineration

Factors influencing waste issues (i.e. cost)	Chemical concentration of waste product. Quantity of ash produced and space available for landfill. If land filling is not possible then the ash should be safely stored. Transportation of ash to disposal site. Cost of landfill – charges or tax if appropriate.

Exposure

Averted exposure	N/A
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. incinerator operatives/ drivers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. incinerator operatives/ drivers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	Ash has high concentrations of micro and macronutrients that may be used to fertilise soil.
Compensation issues	There should be none. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Operators require information on the incineration of contaminated material. Likely requirement to monitor air or water quality in area neighbouring the incinerator and publish results.

Additional information

Practical experience	
Key references	Bennett S, Bolton P. Operation MSC Napoli. Chemical Hazards and Poisons report- Incident response. 2009 ;14:15 Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Mortimer D. The Irish Dioxin Incident-2008. Chemical Hazards and Poisons Report-Health Protection Agency. 2010 (17); pg6
Comments	This is an acceptable option for small quantities of waste as incinerators are already licensed to accept food wastes. There could be local opposition near to an incineration plant due to public perception that contamination will be released to the atmosphere. A valuable option when landfill space is scarce.
Document History	

(38)	Landfill
Objective	To dispose of contaminated food products before or after volume reduction techniques.
Other benefits	None.
Recovery option description	Organic material can be disposed of to fully engineered landfill sites. These have clay or membrane liners and collection systems designed to contain leachates and landfill gas and are regulated. In normal operation cannot be used to dispose of category 1 animal waste
Key information requirements	Location and availability of landfill sites (e.g. hazardous waste landfills)
Linked recovery options	This is a **fate of affected produce** (waste disposal) **option** and should be linked to **protection** and **remediation options**.
Target	Any contaminated material associated with an incident.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option **is applicable to all chemicals that could contaminate the food chain**. Important physicochemical properties that should be considered include; persistence and degradation products
Scale of application	**Any**
Exposure pathway prevention	N/A - this is a fate of affected produce (waste disposal) option.
Time of application	**No restrictions on time.** This recovery option is not time limited and can be implemented at any stage during a chemical incident.
Considerations	
Public health considerations	None.
Legal implications and obligations	Landfills cannot be used for the direct disposal of category 1 animal waste. In the UK landfill sites currently fall under 2 regimes: • all new landfills and landfills receiving over 10 tonnes a day or with a total capacity exceeding 25,000 tonnes (excluding inert waste) are regulated under the Pollution Prevention and Control regime (PPC). The Landfill Regulations classify landfills as hazardous, non-hazardous or inert, setting strict criteria under which wastes may be deposited at each site: • a ban on the disposal of all liquids to landfill, both hazardous and non-hazardous (excluding sludge); • a ban on infectious hospital, clinical and veterinary wastes, and on wastes that might be corrosive, oxidising, flammable or explosive within a landfill; • a requirement for waste to be treated prior to landfilling (other than for some inert wastes and where pre-treatment would not reduce hazard to human health or the environment. The Animal By-Products Regulations ban any animal by-products from directly being disposed of to landfill. However, products produced after processing may be sent to landfill. Due to the potential for leachate from a landfill site, regulations applying to the contamination of controlled waters would also apply – i.e tidal and coastal waters (up to 3 miles from land), rivers, lakes, ponds and ground waters. This authorisation is not required for sites coming under control of the PPC/EPR regime. In any event, a landfill site may only accept waste permitted under the terms of its licence or permit. For more information on legislation please see Appendix A
Social implications	Local opposition to use of particular landfill sites e.g. where contaminated crops are disposed of in previously uncontaminated areas. Potential for dispute regarding waste disposal sites and selection of areas for disposal. Stigma associated with areas surrounding designated landfill sites.

(38)	Landfill
Environmental considerations	The leachate may have a high BOD or contain significant quantities of ammonia-nitrogen. In a fully engineered site, this will be collected and disposed of via an appropriate route, so environmental impact should be minimised. Both methane and carbon dioxide are greenhouse gases that contribute to global climate change. A high proportion of food wastes in a landfill would provide conditions for maximum gas production. Unless landfill gas is used for electricity generation, land filling of organic wastes will not result in energy or nutrient recovery.
Ethical considerations	Additional exposure to site operators and populations living close to disposal sites. Consent of landfill workers. Environmental risk.
Effectiveness	
Recovery option effectiveness	N/A.
Technical factors influencing effectiveness of recovery option	Large quantities of putrescible wastes can cause instability and uneven settlement in a landfill. These effects mean that it is necessary to restrict the proportion of foodstuffs entering a landfill. The maximum proportion of putrescible wastes which could practicably be disposed of to landfill is estimated to be 50% by weight of the inventory. The contaminated organic waste should only be disposed of to a fully engineered sanitary landfill licensed to accept putrescible waste. Willingness of privately owned landfill sites and local populations to accept the wastes. Maintenance of correct landfill procedures.
Feasibility and intervention costs	
Specific equipment	Vehicles for transport of food products, compost, soil and ash to landfill.
Utilities and infrastructure	Landfill site. Appropriate transport network.
Consumables	Fuel for transport of food products, compost, soil and ash to landfill.
Skills, personnel and operator time	At landfill sites the necessary skills will be available. Additional work by landfill operator as required. Additional journeys made by lorry driver.
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. landfill operators) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Consider protective clothing. Respiratory protection is recommended whenever materials are handled or moved.
Other limitations/factors influencing costs	Putrescible waste must be thoroughly mixed with inert wastes to provide a suitable medium to allow continuation of normal landfill operations e.g. waste spreading and compaction. Future recovery of landfills may further restrict quantities of putrescible wastes admitted.
Waste	
Amount and type	Leachate, landfill gas (methane and carbon dioxide). Depending on the nature of the chemical incident, rendering waste may be classed as 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Leachate treatment may involve on-site pre-treatment including aeration, biodegradation or reed bed filtration. The treated leachate can be discharged to a sewer or directly tankered away for further treatment at a sewage treatment works (STW). It can also be discharged to waterways provided the relevant discharge authorisations are held. Landfill gas is usually managed either by a pumping system with passive venting or flaring or by a pumping system with a condensation system to remove moisture and permit use of gas for heating or electricity generation
Factors influencing waste issues (i.e. cost)	Quantity and timing of leachate production dependent on rate of ingress of water to landfill and rate of waste decomposition. Factors influencing gas production include organic composition of waste, pH, waste density, moisture content, nutrient distribution and temperature.

(38) Landfill

Exposure

Averted exposure	N/A
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. landfill operatives/ drivers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. landfill operatives/ drivers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	
Compensation issues	There may be requests for compensation from; Landfill facility for handling contaminated material and decontamination of equipment. Transport companies for decontamination of vehicles. Sewage treatment works (STW's) for handling contaminated leachate and for decontamination of equipment. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Likely requirement to monitor area around landfill site and publish results.

Additional information

Practical experience	Landfill is a current practice. Bennett S, Bolton P. Operation MSC Napoli. Chemical Hazards and Poisons report- Incident response. 2009 ;14:15
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	An acceptable option because landfill sites are already licensed to accept food wastes. Public acceptance of large quantities of contaminated produce may be low.
Document History	

(39) Land spreading of milk and/or slurry

Objective	To dispose of contaminated milk and/or slurry.
Other benefits	Additional source of nutrients to soil.
Recovery option description	Some agricultural land is potentially suitable for the spreading of milk, either in conjunction with slurry or diluted with water. The spreading of slurry is a normal agricultural practice. In the event of an accident, contaminated milk and slurry would be land spread *in situ*.
Key information requirements	What is the chemical contaminant and what is its concentration in the milk or slurry?
Linked recovery options	This is a **fate of affected product** (waste disposal) **option** and should be linked to **protection** and **remediation options**. This recovery option should also be considered in conjunction with; (5) Restriction of entry into food chain/ withdrawal from market and (6) Product recall
Target	Contaminated milk and/or contaminated slurry.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that **pose a risk to public health, especially** if persistent or toxic. However, the physicochemical properties and physical form (**solid, liquid or gas**) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option **is more applicable to chemicals with short persistency**. Important physicochemical properties that should be considered include; adsorption to soil, biological half-life, persistence and water solubility.
Scale of application	**Any.** Large scale application on most farms that stock dairy herds. Application may be more restricted on farms stocking alpine sheep and goats.
Exposure pathway prevention	N/A - this is a fate of affected produce (waste disposal) option.
Time of application	**There are some restrictions on time.** Land spreading milk is highly seasonal, because of the danger of pollution when fields are waterlogged or frozen. Under such circumstances it is possible to store the milk in slurry tanks, if space is available: spreading may then be carried out at a later date. Spreading of slurry is also controlled on a seasonal basis.

Considerations

Public health considerations	Public reaction may be opposed to disposal of milk on land even if proven to be acceptable scientifically
Legal implications and obligations	The Waste Management Licensing regime and waste management regulations also need to be considered as agricultural waste is classified as "controlled waste". The amounts of milk spread will be limited by its nitrogen content if the land is in the boundaries of a Nitrate Vulnerable Zone (NVZ). The Landfill Regulations define landfill as land onto or into which waste is deposited to dispose of it and prohibits the disposal of any liquids. Therefore the spreading of milk for disposal (but not for recovery) will be prohibited. Due to the potential for volumes of milk / slurry being spread to land, regulations applying to the contamination of controlled waters would also apply – i.e. tidal and coastal waters (up to 3 miles from land), rivers, lakes, ponds and ground waters Spreading of milk (and colostrum) on the farm of origin is excluded from the Animal By-Products Regulations. For more information on legislation please see Appendix A
Social implications	Variable depending on usual practice. Willingness of farmer to carry out land spreading if this is not usual practice. Possible perception of causing additional contamination of the soil if milk or slurry is

(39)	Land spreading of milk and/or slurry
	spread on farmland. Acceptability to food industry or consumers of residual levels of contamination in food produced on land where spreading is practised. Stigma associated with food products where the waste recovery option has been applied. Land spreading of contaminated milk may restrict subsequent use of the land (e.g. organic farming).
Environmental considerations	The spreading activity must not lead to unacceptable contamination of the soil, which is an important factor in deciding on acceptability of this option. Milk should not be spread on land with a high risk of runoff or near to any watercourses, and should be diluted with the same volume of water or slurry. The amount of diluted milk spread at any one time should not exceed 50 m^3 ha^{-1} y^{-1} and at least 3 weeks should be left between each application to reduce surface sealing. On bare land the soil should be lightly cultivated after spreading to quickly mix the waste. Inappropriate disposal of milk or slurry to land could lead to pollution of water courses.
Ethical considerations	*In situ* disposal option. Self-help for farmer. Highly dependent on the area and status of land used for spreading. Run-off may cause transfer of chemicals to other, non-contaminated areas.
Effectiveness	
Recovery option effectiveness	N/A.
Technical factors influencing effectiveness of recovery option	Land available for land spreading. Soil type. Storage space in slurry tank. Environmental conditions on farm. Chemical content of the milk or slurry. Predicted impact in terms of soil contamination. Degree to which land spreading diverges from common practice will affect willingness of farmers to implement this option. Status of the land.
Feasibility and intervention costs	
Specific equipment	Slurry transport and distribution systems (usually available on farms). Slurry storage tanks (usually available on farm).
Utilities and infrastructure	None.
Consumables	Fuel (ca. 7 l ha^{-1}).
Skills, personnel and operator time	Farmers would possess the necessary skills as land spreading is an existing practice. 22 min ha^{-1} when spreading milk at a rate of 20,000 l ha^{-1}
Safety precautions	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Capacity of slurry storage tanks. Due to potential risk of contaminating water courses, the quantity of nitrogen being applied to land should be monitored. Volume of milk or slurry to be spread.
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	If some or all of the milk cannot be land-spread alternative disposal routes will have to be established.
Factors influencing waste issues (i.e. cost)	None.
Exposure	
Averted exposure	N/A

(39) Land spreading of milk and/or slurry

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. farmers) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker (i.e. farmers) exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident processing or treatment of food products as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant).

Other considerations

Agricultural impact	Additional nutrients provided for crop uptake which could lead to reduced requirements for fertiliser.
Compensation issues	There may be requests for compensation from the farmer if storage and distribution equipment permanently contaminated. Otherwise to farmer for decontaminating equipment. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Need for dialogue regarding selection of areas for treatment. Need for dialogue between land owners or farmers, environmentalists and public.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	An acceptable option if emphasis is placed on appropriate planning to avoid water pollution. Public reaction may be opposed to disposal of milk on land even if proven to be acceptable scientifically.
Document History	

6 Inhabited areas

What is an 'inhabited area'?

Inhabited area places where people spend their time. They can be divided into several sub-areas such as residential, industrial and recreational. These sub-areas contain a variety of surfaces such as buildings, roads, woodlands and parks.

The sub-areas considered within the scope of the Handbook are described in Table 6.1 to 6.3. Guidance on the importance of outdoor land surfaces is summarised in Table 6.4.

When developing a recovery strategy for managing contaminated inhabited areas, decision-makers need a framework for choosing between the many possible recovery options. Throughout this process, they will also require a significant amount of information to support decisions to implement timely and effective recovery measures. This handbook provides a decision framework and a compilation of information to help users evaluate the available recovery options following a chemical incident.

For small-scale, single chemical releases the recovery strategy may comprise of one or 2 recovery options that could be applied over the first few days or weeks following the incident. For a wide-scale, multi chemical release involving persistent chemicals the recovery strategy is likely to be more complex, comprising a series of recovery options that could be implemented over different phases of the incident response and affecting a large range of inhabited areas. Some aspects can be considered in advance of an incident as part of contingency planning. A series of checklists are provided in Section 3 to highlight the type of information that can be gathered under non-crisis conditions to help manage the pre-release and early phases of an incident. Expert input and guidance will also be needed to supplement this information, particularly to provide decision-makers with expert advice on the suitability of recovery options for the chemical of concern, and the practicability of their implementation.

Contamination of areas of habitation presents several different problems. The properties of the chemical contaminant are of prime importance, but other factors must also be considered. These include:

- The presence of critical assets or infrastructure (e.g. hospitals).
- The length of time spent in the area.
- The activities of people within the area.
- The susceptibilities of different population groups within the area e.g. elderly, infants or the immune-compromised.
- The range of different surface types to clean up.
- The presence of high value or irreplaceable items e.g. heritage sites, precious objects, personal items or important documentation.
- The acceptability of remediation to the affected population.
- Interactions with animals e.g. wildlife and companion animals who may spread contamination.

The recovery options relevant to inhabited areas are concerned with reducing or eliminating the exposure resulting from chemical materials deposited on surfaces or present in the air.

Inhabited areas within the Handbook

The range of sub-areas, surfaces and surface types considered within the scope of the Handbook are summarised in Table 6.1, Table 6.2 and Table 6.3 respectively[1].

Table 6.1: Types of sub-areas in Inhabited areas

Area	Description
Residential	Areas used for residential purposes (e.g. houses, small settlements, housing estates, block of flats).
Non-residential	Areas accessed by the public for services and employment (e.g. commercial districts, hospitals, schools, shopping centres, supermarkets, town and city centres).
Industrial	Non-residential areas where production and/or commercial activities are undertaken (e.g. industrial estates, factories).
Recreational	Outdoor areas accessed by the public for recreation.
Sub areas may comprise:	
Buildings	Buildings used for residential, public, commercial and industrial purposes. Also includes buildings having an important role in the provision of infrastructure in an area, such as railway stations, airports and water treatment plants. Also includes buildings used for essential services such as hospitals, fire/ambulance stations.
Outdoor areas	Areas with private access from residential dwellings (e.g. playing areas, driveways, patios, gardens) and areas with public access (e.g. pavements, car parks, gardens, playing fields, playgrounds).
Transport networks (above ground)	Areas essential for public/private transport. Would include airports, railway lines, roads and seaports.
Transport networks (underground)	Areas specific to underground transport networks (e.g. tunnels, tracks, stations).
Parks and open spaces	All gardens, parks, children's play areas and sports fields with public access. Size of these areas is typically greater than 300 m^2.
City farms, allotments	City farms and allotments may be found in inhabited areas. However, these are considered in the food section of the handbook
Woods and forests	Managed and unmanaged deciduous and coniferous woods and forests used for recreation purposes by the public.
Countryside	Managed and unmanaged areas used for recreational purposes by the public (e.g. footpaths, national parks, moorland).
Underground spaces	Would include areas that could potentially be used by members of the public. Also includes car parks, service ducts and subways.
Swimming pools	The buildings and infrastructure surrounding indoor or outdoor swimming pools are part of inhabited areas. The treatment of water found in swimming pools is considered in the water section of the handbook

Guidance on the importance of outdoor land surfaces is summarised in Table 6.4. The link between sub areas and surface types are outlined in Figure 6.1.

Table 6.2 Surfaces in Inhabited areas

Surface	Description of surface
Buildings – external surfaces	External surfaces (e.g. walls, roofs, windows, treated timber and doors of all buildings).
Buildings – indoor surfaces and objects	Indoor building surfaces (e.g. walls, floors, ceilings, soft furnishings and furniture). In addition, objects (e.g. precious) for which disposal is unacceptable and for which normal decontamination methods may cause unacceptable damage (e.g. museum pieces, artwork, original documents and personal items such as mobile phones/credit cards etc.
Roads and paved areas	All roads, pavements, large paved or asphalt areas (e.g. playgrounds, yards and car parks)
Street furnishings	Includes all traffic lights, signs, bollards.
Vehicles	All vehicles used for public or private transport (e.g. cars, lorries, trains, buses, trams and aircraft)
Soil and vegetation to include grass, plants, shrubs and trees	Includes lawns, flowerbeds and vegetable plots, trees, shrubs and bushes within the gardens of residential dwellings, landscaping around commercial and public buildings, allotments, parks, playing fields and other managed green areas.

Table 6.3 Surface material types in Inhabited areas (see also Table 6.6)

Robust	Robust surfaces that can normally withstand potentially damaging decontamination techniques (e.g. marble, steel, vinyl tile). Potentially damaging recovery options would include the use of reactive liquids and pressure hosing.
Sensitive	Sensitive surfaces that are less likely to withstand or for which it is unacceptable to use potentially damaging decontamination techniques. Examples include the wall of a heritage building, electrical equipment or upholstery fabric. It is likely that less damaging recovery option would be used on these surfaces such as storage, covering, gentle cleaning of precious objects or vacuum cleaning.
Absorbent	Surfaces that are permeable or porous that have the potential to absorb chemical contamination (e.g. concrete, marble, fabrics). These surfaces are usually more difficult to decontaminate than non-absorbent surfaces
Non-absorbent	Surfaces that are neither permeable or porous so do not have the potential to absorb chemical contamination (e.g. steel, glass). These surfaces are usually easier to decontaminate as chemical contamination lies 'free' on the surface
Inaccessible	Inaccessible surfaces include the interior of electrical equipment (e.g. computers) or the space between a screw and a bolt. Inaccessible surfaces are usually more difficult to decontaminate

* surface materials may have one or more of these properties or traits, which can influence the remediation strategy.

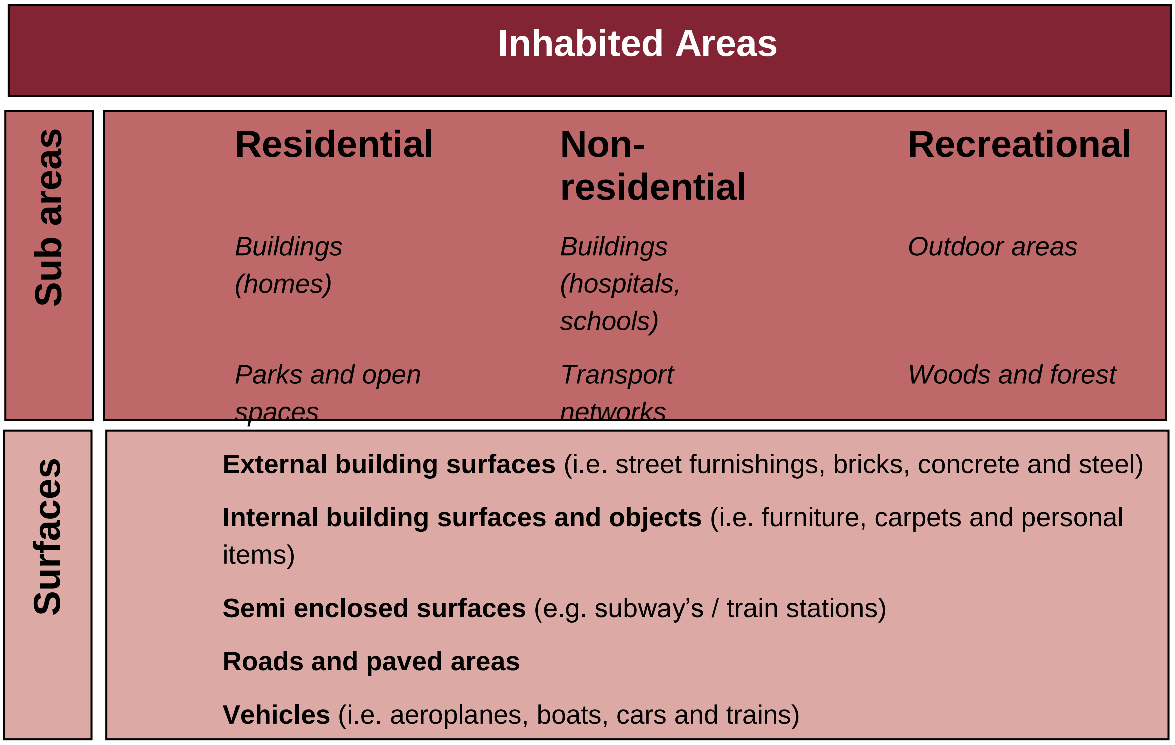


Figure 6.1 Links between inhabited areas and surface types

Table 6.4 Guidance on importance of outdoor land surfaces

Do you have measurements of chemical concentrations in the environment?	No – likely to be reliant, at least initially, on models to indicate which surfaces may be contributing to exposures. Yes – Information can be used to help identify which surfaces are likely to be contributing to exposures.
How much of your outdoor area is covered by soil or grass compared to roads or paved areas?	The proportion of the area covered by the land surface multiplied by the contamination on the surface gives an indication of the relative importance of the surface in contributing to the total outdoor exposure.
Do people spend a significant amount of time outdoors in the area?	The total outdoor exposure is a function of the time people spend outdoors. If people do not spend significant time outdoors in this area, it may not be necessary to undertake substantial clean-up of outdoor surfaces. However, these surfaces also contribute to indoor exposure and therefore, although exposures are substantially lower indoors; they may be reduced by cleaning outdoor land surfaces.
Can the outdoor area (or part of it) be cordoned off to restrict access?	Outdoor exposure can be reduced by cordoning off the area. This may reduce the need to clean-up outdoor surfaces, particularly if the deposited chemical has a short persistency.

6.1 Health protection criteria for Inhabited areas

Any health protection criteria aimed at reducing the risks of adverse health effects, i.e. skin irritation, liver damage, and cancer or birth outcomes, must consider all the wider consequences of the proposed protective measure. Hence, for example, costs and disruption to implement the measure must be balanced against the expected benefits, which will include public reassurance. This balance must take account of the specific circumstances of the event which are likely to vary between different types of incidents and contamination[1]. At present there are no international or national regulations outlining clean-up criteria that could be used directly following an incident involving chemical release in the UK.

In its published advice for radiation, PHE recognises that some clean-up techniques are considerably more resource-intensive and disruptive than others[2]. This principle, in part, could also be applied to chemical releases. In its advice, PHE recognises that it is difficult to specify numerical clean-up criteria in advance of an incident and that other aspects of planning for a response are important and should be given due consideration (see Section 3). PHE therefore advises that, following an incident, assessments should be undertaken of all the likely consequences of a range of clean-up strategies. These consequences should include cost, timescales, public acceptability and the availability of the necessary resources, as well as the expected reduction in risks of health effects. Clearly, collection in advance of information relevant to these assessments, such as the likely efficacy and resource requirements of different clean-up options, and prior identification and preparation of appropriate equipment and contractors, would facilitate the timely completion of such assessments in the event of an incident. Potential strategies that involve high levels of cost and disruption should only be undertaken if the expected reduction in risk of adverse health effects is also high, thereby maintaining a balance between the expected harms and benefits of the strategy.

6.2 Estimating exposure in Inhabited areas

The exposure to an individual from a given amount of chemical contamination following an incident can vary widely, depending on the chemicals involved, the spread of the contamination between different surfaces and the time spent by the individual at locations with different levels of contamination. The total exposure of an individual living in a contaminated environment is the sum of the exposures arising from the differing levels of contamination on different surfaces at a variety of locations. The total exposure received by an individual is therefore determined by the time spent in each location and the exposure rate at that location, which is likely to decrease with time as the level of the chemical decreases.

In general, members of the public should be equally protected in all areas where they spend time or, in other words, the exposures in areas where they work and spend their spare time should be no higher than those where they live. PHE advice should be applicable to any location in the contaminated area. This means that the exposure at which the various categories of options should be considered should be calculated assuming that people spend all their time at that location, taking account of the time spent indoors at the location if appropriate[1].

6.3 Constructing a recovery strategy for inhabited areas

Selecting an appropriate recovery strategy is a multistage process and an overview of the decision framework is given in the flowchart in Figure 6.2. It should be noted that the decision framework is not a substitute for expert specialist advice, but provides a framework for requesting, recording and evaluating the advice (Steps 1 to 3). The selection of the most appropriate subset of recovery options is a 6-step process, involving the elimination of inappropriate options through the use of a series of selection figures, look up tables or checklists. The 6-step process is summarised in Figure 6.2. The selection diagrams (Figure 6.4) are relevant for surface types (i.e. external building surfaces) within contaminated inhabited areas.

Step 1 describes the initial identification of the chemical and the nature and extent of the incident. Step 2 of the framework leads the user to the decision tree in Figure 6.3. This decision tree guides the user through the initial decision-making process and the range of issues that need to be considered. Steps 3 to 5 then provide a methodology for eliminating options that are unsuitable or ineffective by evaluating their characteristics. From the remaining options, a recovery strategy can be determined (Step 6). A template table is provided (Table 6.9) that could be used to help record the decisions made during the recovery option elimination process.

Implementation of the recovery strategy then follows, and if monitoring confirms that acceptable levels have been reached then it is possible to return to normality. If monitoring indicates that acceptable levels have not been reached, then the user returns to the decision tree in Step 2.

The final step is to document the incident and evaluate the response, including the effectiveness of the Handbook. Further details of the steps are given in the following sections.

The inhabited areas decision framework does not include a strategy for performing a risk assessment or for designing or implementing a monitoring strategy following a chemical incident. This falls outside the scope of the UK Recovery Handbook for Chemical Incidents.

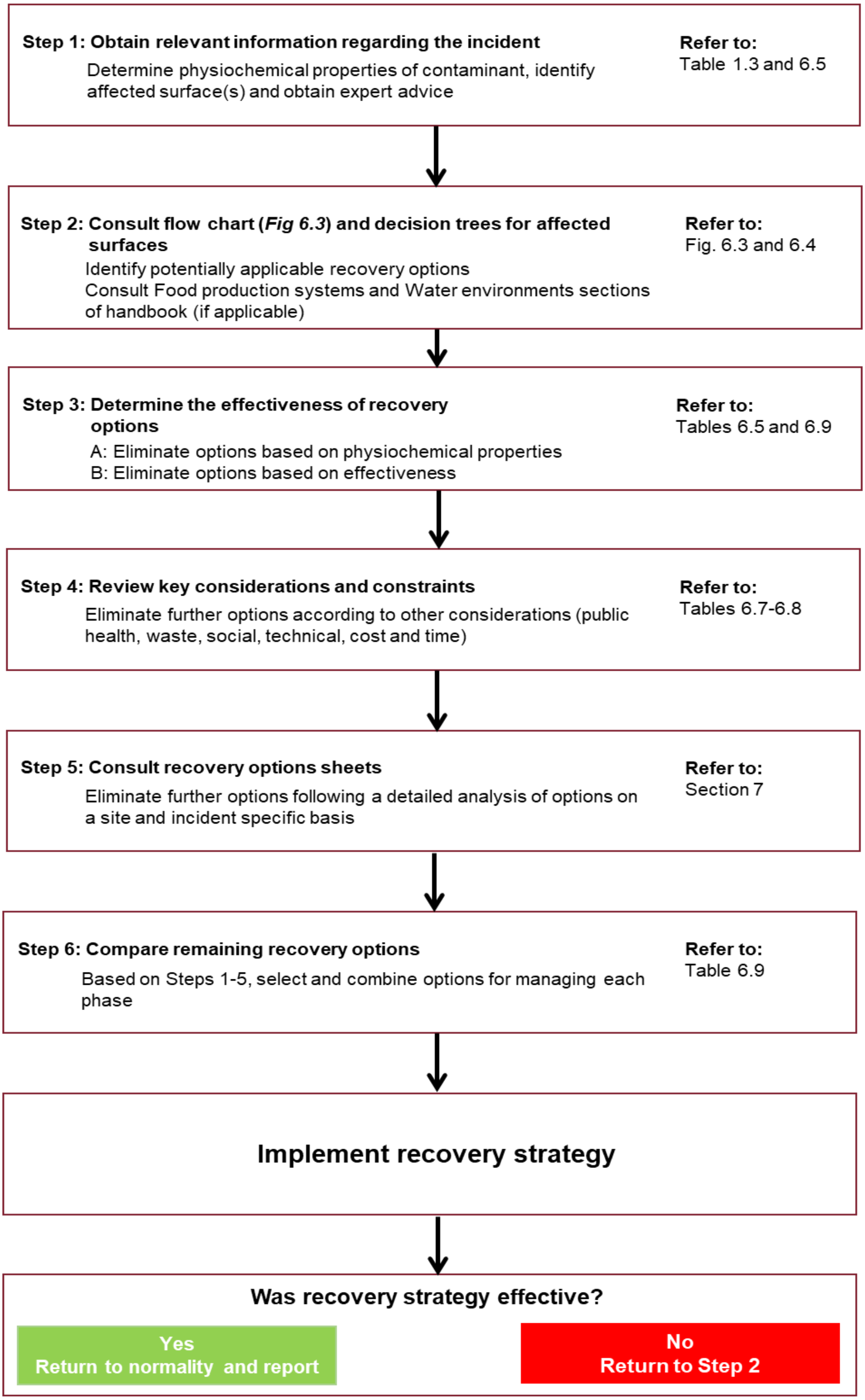


Figure 6.2 Key considerations for recovery

6.3.1 Step 1: Obtain relevant information regarding the incident

When a chemical incident occurs, the initial steps are to identify the chemical(s) involved and seek technical (chemical) expertise. Having identified the chemical, information should then be collected on its physicochemical properties e.g. toxicity, water solubility and persistency amongst others.

The handbook has identified a subset of physicochemical and toxicological properties that should be considered in Table 6.5 and Table 1.3 (Section 1). These properties will then be used to eliminate options in Step 3 of the decision-making process. Only when this information is available can an appropriate recovery strategy be developed.

Particular attention must be taken when an incident involves a mixture of chemicals as it is not only useful to look at the individual chemicals, but it is of utmost importance to assess the potential interactions between the chemicals themselves. This will have a direct influence on the recovery options selected. Implementation of an option should ideally not cause further damage or unnecessary complications.

Table 6.5: Important physicochemical properties

Physical characteristic	Description	Interpretation		Chemical	
				Description/ value	Interpretation
Physical form (solid/liquid gas)	**Gases** and vapours spread out in the environment until they are equally distributed throughout the space available to them. **Liquids** will flow with gravity when released and therefore require safe containment to stabilise the incident and prevent further risk to persons, property and the environment. **Solids** need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion				
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. For instance, where the vapours being given off by a liquid pose a hazard (e.g. Sulphur Mustard) fixative / strippable coating options may be considered. Higher volatility would result in a higher vapour pressure. Interpretation (Units = Pascals) < 1.3 x 10^{-4}: Unlikely to volatilise Between 1.3 x 10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	**High VP** Likely to: Be an inhalational risk Evaporate quickly	**Low VP** Unlikely to be: An inhalational risk		
Vapour Density (D vapour)	This refers to the relative weight of a gas or vapour compared to air (or sometimes it can be compared to hydrogen gas). Air is assigned an arbitrary value of 1 and if a gas has a vapour density of <1.29 it will generally rise in air. If the vapour density is >1.29 the gas will generally sink in air. All vapours tend to be heavier than air.	**D > 1.29** Will: Stay close to the ground	**D < 1.29** Will: Rise and mix in air more easily		
Density of liquid (D Liquid)	The density (specific gravity) of a liquid is determined by comparing the weight of an equal amount of water. (Water = 1.0). If the specific gravity is less than 1.0 then it will float, if greater than 1.0 it will sink. This is likely to be an important factor following release to water where the use of certain recovery options (e.g. use of adsorbent booms/mats) could be considered for chemicals that float on water.	**D > 1** Will: Sink in water	**D < 1** Will: Form a surface film on water		
Persistence	The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.	**Short persistence**: Hours to days **Moderate Persistence:** Weeks to months **Long Persistence:** Months to Years			

Table 6.5: Important physicochemical properties					
Physical characteristic	**Description**	**Interpretation**		**Chemical**	
				Description/ value	**Interpretation**
Absorption on porous surfaces	The ability of a substance to absorb to porous surfaces (e.g. concrete) is an important consideration as this may influence the effectiveness of decontamination options. In some cases (e.g. Sulphur mustard) options such as surface removal may be more appropriate	**Absorbs** Likely to be effectively removed via: Surface removal Disposal and dismantling	**Does not absorb** Likely to be: Easier to decontaminate		
Surface Tension	Chemicals with a low surface tension are more likely to seep into relatively inaccessible surfaces (e.g. between screws/ bolts) which has implications for the remediation of these surfaces. Those with a higher surface tension are more likely to accumulate on a surface without penetrating inaccessible areas. Examples, units: dynes /cm Ethanol: 22.3 (low) Water: 75.6 Mercury: 465 (high)	**High** Likely to: Accumulate on surface	**Low** Likely to: Contaminate inaccessible surfaces		
Water solubility	The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread by flowing water. Water based decontamination of surfaces may be more effective if a chemical is water soluble; removal options or active decontamination may be more appropriate for non-water-soluble chemicals Interpretation: Units ppm (mg/l) <10: Negligible solubility Between 10 and 1000: Increasing likelihood of solubilising >1000: Likely to solubilise	**High Solubility** Likely to be: Mobile Decontaminated by water-based solutions Unlikely to be: Volatilised Persistent	**Low solubility** Likely to be: Immobilised by adsorption Persistent Unlikely to be: Mobile		

Table 6.5: Important physicochemical properties

Physical characteristic	Description	Interpretation		Chemical	
				Description/ value	Interpretation
Soil sorption	Measures how readily a chemical is adsorbed to organic surfaces in the soil matrix. Some soils have very limited abilities to sorb chemicals e.g. sandy soils or ones with low clay or organic matter contents. Gives an indication of likely persistence in soil. Interpretation (Units = $\mathbf{K_{OC}}$) > 10,000: Likely to adsorb Between 1,000 and 10,000: Increasing likelihood of adsorbing < 1,000: Unlikely to adsorb	**High K_{OC}** Likely to be: Adsorbed Accumulated Unlikely to be Mobile	**Low K_{OC}** Likely to be: Mobile Unlikely to be Adsorbed		
Partition coefficient between water and octanol (**K_{OW}**)	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = $\mathbf{K_{OW}}$) > 1,000: Likely to bioaccumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bioaccumulating < 500: Unlikely to bioaccumulate (hydrophilic)- Low	**High K_{OW}** Likely to be Bioaccumulated: Sorbed in soil or sediments Unlikely to be: Mobile	**Low K_{OW}** Likely to be: Mobile Soluble Biodegraded Unlikely to be: Bio-accumulated		
Viscosity	The viscosity of a chemical determines how easily it flows within an environment. It may influence how easy it is to remove from an environment (e.g. it would be difficult to vacuum a highly viscous chemical). Viscous chemicals are also less likely to re - suspend in the environment. Examples: Units = mPa. Water: 0.894 (low) Corn syrup: 81 (high)	**High:** Likely to be: Difficult to decontaminate Unlikely to be: Vacuumed Resuspended Mobile	**Low:** Likely to be: Mobile Easier to decontaminate		
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.				
Toxicity	Sum of adverse effects or the degree of danger posed by a substance to living organisms. It is expressed generally as a dose response relationship involving the quantity of substance to which the organism is exposed and the route of exposure skin (absorption), mouth (ingestion), or respiratory tract (inhalation).				

6.3.2 Step 2: Consult decision tree/diagram for Inhabited areas

Consult flowchart (Figure 6.3) which provides an overview of the decision-making process and highlights the general/ protection options that may be applicable (i.e. should be considered).

Follow the decision tree in Figure 6.3 to identify which recovery options are applicable.

The decision tree then leads into Figure 6.4, which identifies recovery options that are specific for the type of contaminated surfaces (e.g. internal building surfaces/ external building surfaces). Recovery options include **protection** (actions taken to protect the population) and **remediation** (return the area back to normal), which include waste disposal options. This step may have to be repeated for each different surface type requiring remediation to identify relevant recovery options. This will help identify recovery options that could be applicable for each surface under consideration.

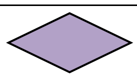
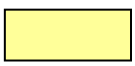
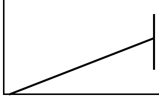
This step is essentially an ‘inclusive’ step, identifying potential recovery options. Elimination of options is carried out in Steps 3 to 5.

Decision diagrams (Figure 6.4) are presented for the following surfaces:

- External building surfaces (including street furnishing e.g. bricks, concrete and steel).
- Internal building surfaces and objects (including furniture, carpets and personal items).
- Semi-enclosed areas (e.g. surfaces in subways/ train stations).
- Roads and paved areas
- Vehicles (including aeroplanes, cars, trains and boats)
- Soil and vegetation (e.g. grass, shrubs, plants and trees).

The remediation of food production systems (e.g. crops or livestock) are covered in Food production systems (Section 4) of the handbook. The remediation of affected Water environments is covered in the Water environments (Section 8). Where there may be cross-over between sections of the Handbook (food production systems/ water environments) these are highlighted in Figures 6.3.

Figure 6.3 should be interpreted in the following way:

	Indicates a decision point
	Indicates a step in the decision framework where action is required
	Indicates implementation of recovery options need to be considered
	Indicates a termination point
	This indicates where a further explanation of the decision step or other supporting information is given.

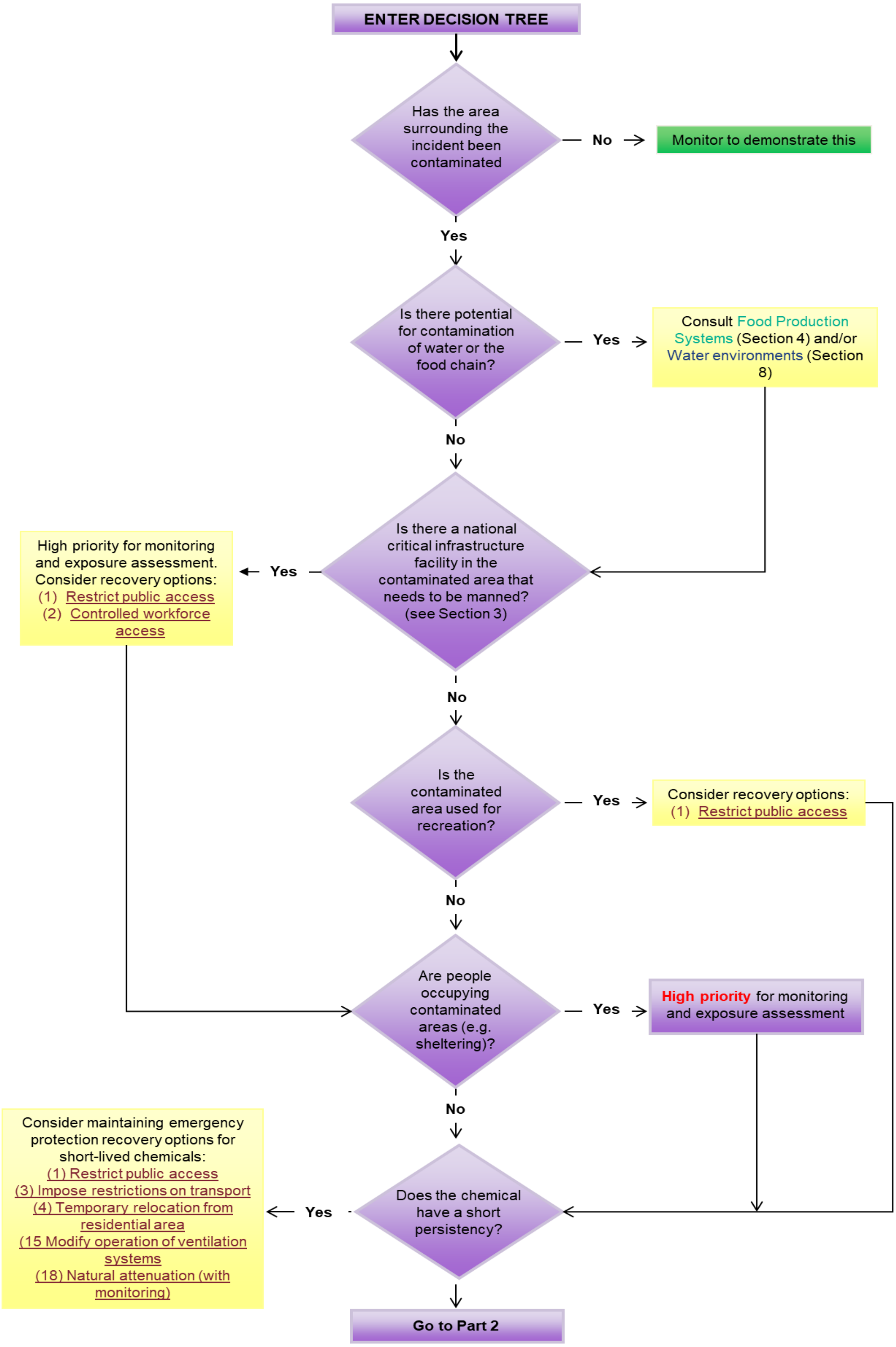


Figure 6.3: Decision Tree for Inhabited Areas

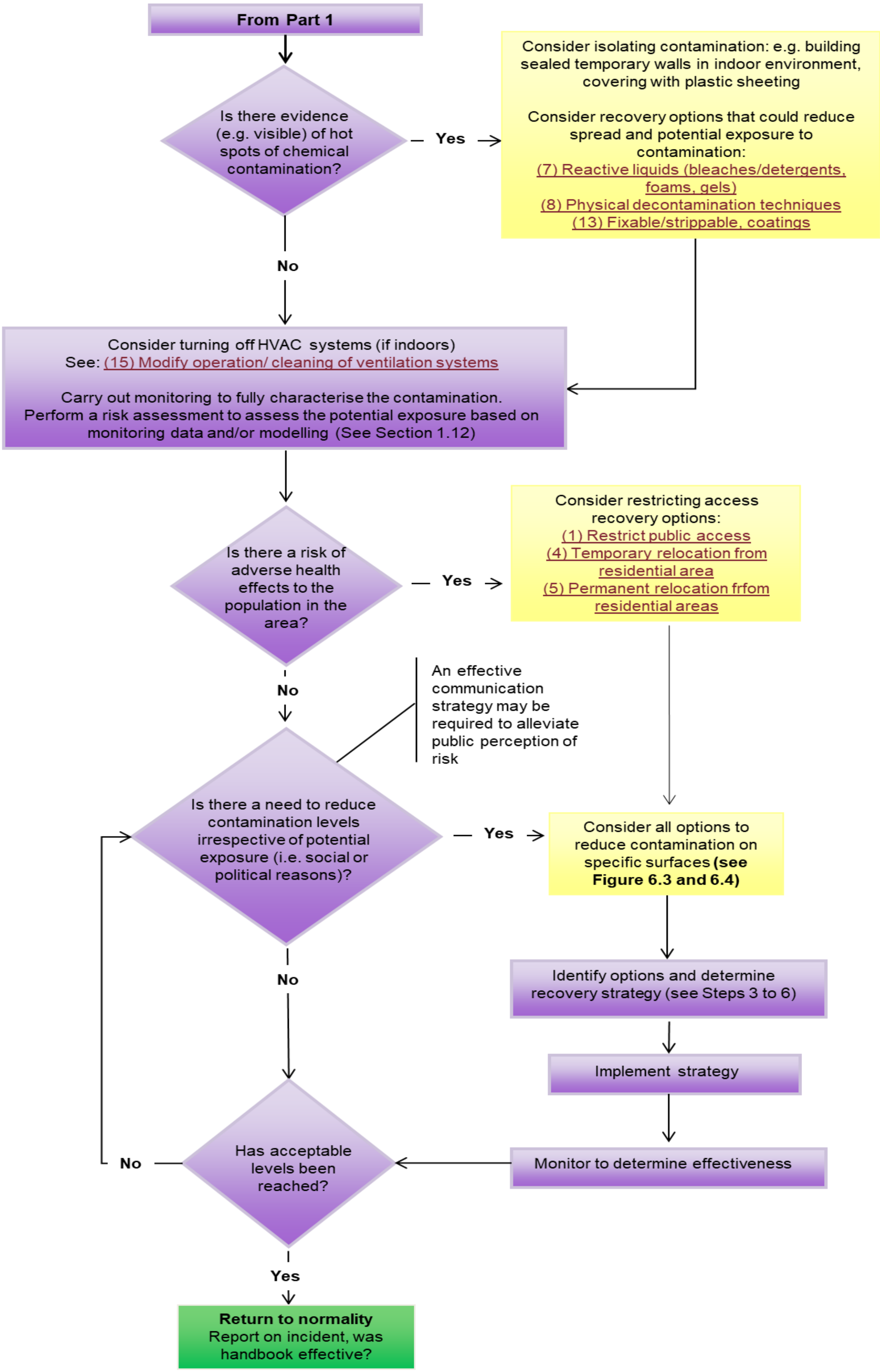


Figure 6.3: Decision Tree for Inhabited Areas

Figure 6.4: Surfaces in Inhabited areas

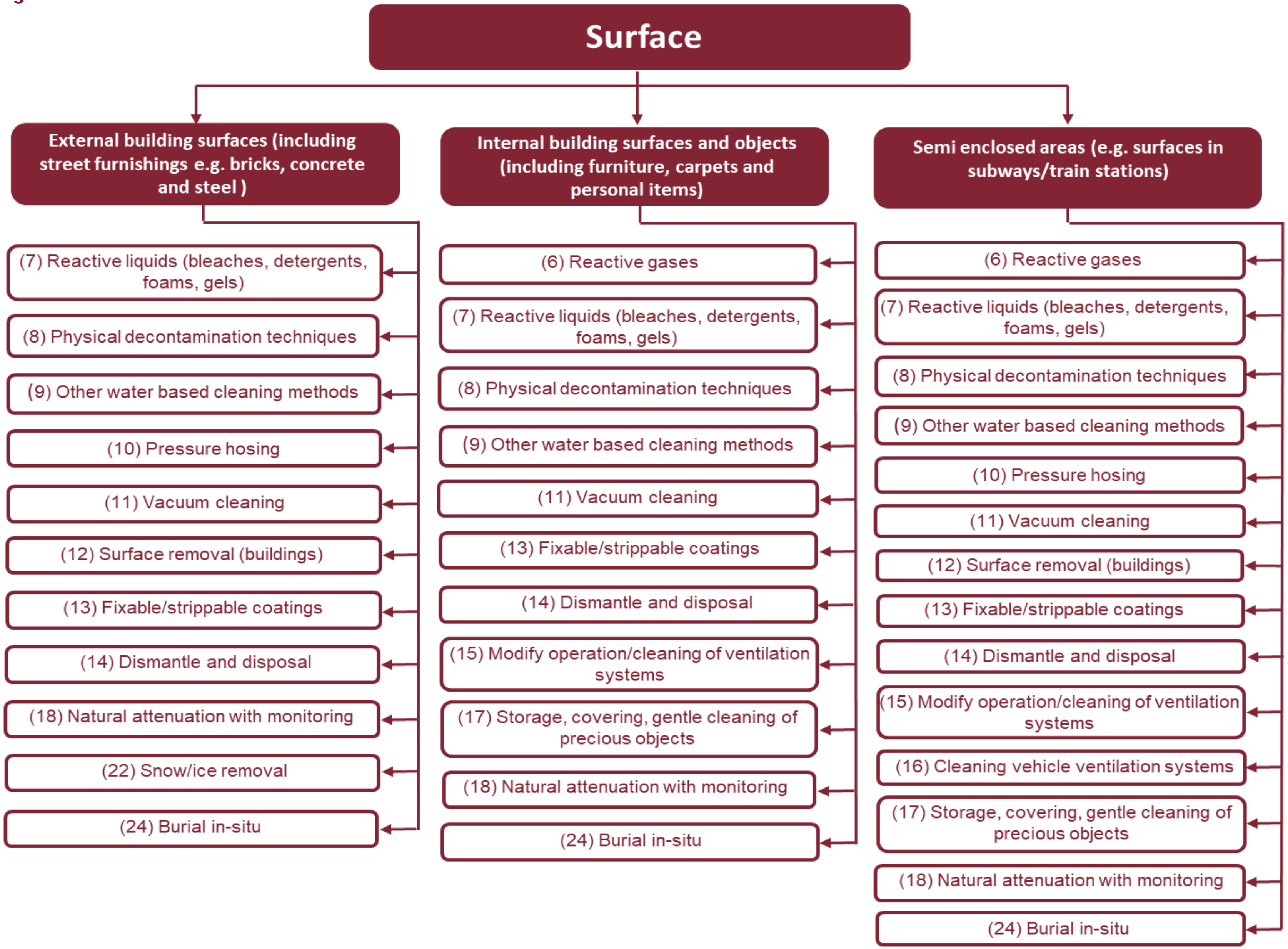
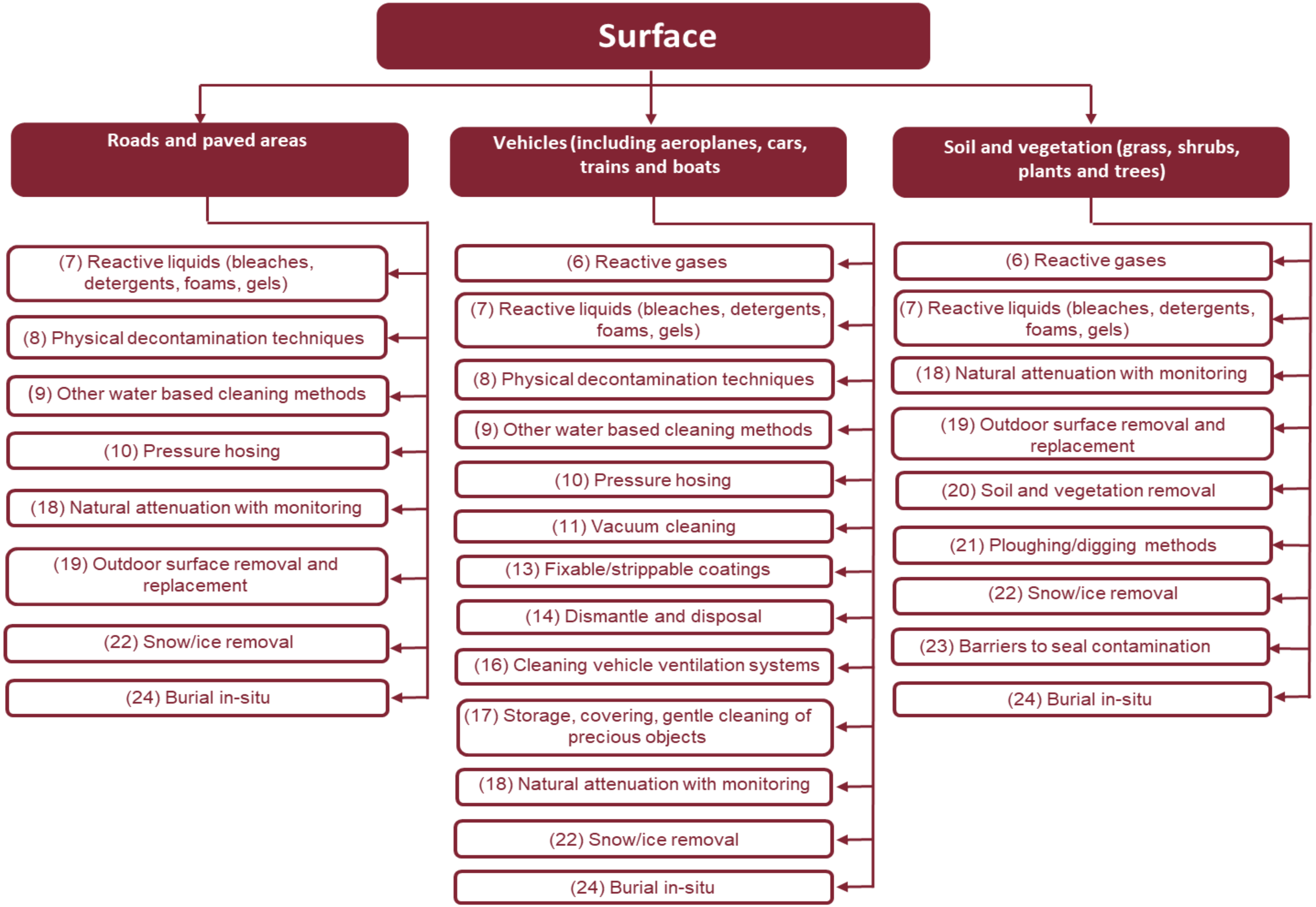


Figure 6.4: Surfaces in Inhabited areas



6.3.3 Step 3: review applicability of recovery options

A: Elimination of recovery options based on physicochemical properties only

Working through Figure 6.3 and Figure 6.4 has identified potential recovery options that may be applicable for the following categories of surfaces or areas:

- External building surfaces (including street furnishing e.g. bricks, concrete and steel).
- Internal building surfaces and objects (including furniture, carpets and personal items).
- Semi-enclosed areas (e.g. surfaces in subways/ train stations).
- Roads and paved areas
- Vehicles (including aeroplanes, cars, trains and boats)
- Soil and vegetation (e.g. grass, shrubs, plants and trees).

At this stage expert advice (e.g. PHE) should be sought to determine and interpret the physicochemical properties of the chemical(s), using data identified in Table 6.5 (Step 1) to assist in eliminating recovery options. For example, if information obtained in Table 6.5 indicates that a chemical is water insoluble the recovery option (9) Other water-based cleaning methods could be eliminated at this stage.

PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is openly available at:

https://www.gov.uk/government/collections/chemical-hazards-compendium

B: Elimination of options based on surface material and physicochemical properties

Determining which recovery options may be further eliminated can be achieved by considering the physicochemical properties of the chemical and the surface type in more detail. The different surface/area categories can be further broken down into different types of material, e.g. soil, plastics, concrete, wood and glass (see also Table 6.3) The different types of surface material may affect how different chemicals behave, and influence how chemical contaminants can be effectively decontaminated. The type of contamination and the type of surface can influence how effective a recovery option may be at removing chemical contamination and are summarised in Table 6.6. The type of contamination and surface material contaminated would need to be considered. This includes:

Type of contamination

- Free – indicates whether a recovery option be considered if contamination is free on a non-absorbent surface e.g. powder/liquid lying on steel.
- Absorbed – Indicates whether a recovery option be considered if contamination is absorbed into a surface e.g. into an absorbent material such as concrete.
- Inaccessible – Indicates whether a recover option can be considered if contamination has occurred within an inaccessible surface (e.g. between a screw and bolt).

Type of Surface Material

- Robust surface – Indicates whether a recovery option can be considered for robust surfaces (e.g. steel /marble).
- Sensitive surface- Indicates whether a recovery option can be considered for sensitive surfaces (e.g. historical brick building).

The colour-coding in Table 6.6 gives an indication of whether options would fall into “up to 100% effective”, “potentially effective” or “limited effectiveness” for the surface type and type of contamination under consideration. The classification used in the selection tables is intended to be a generic guide and is **not chemical specific**.

The colour coding in Table 6.6 is based on an evaluation of the evidence base, stakeholder experience, advice or ongoing decontamination research within the UK. Therefore, Table 6.6 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (see Table 6.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. PHE/ GDS).

A recovery option should only be eliminated if it is deemed to be ineffective for contamination type **OR** surface type. All other recovery options should be retained. However, if the option is ‘potentially effective’ (grey) it should be recognised that there may be potential technical difficulties in implementing the option, or it may be that the option would only partially remove any residual contamination. If it is not possible to readily eliminate a recovery option at this stage, then it should be retained for consideration in Step 4.

The implementation of “protective" recovery options (e.g. temporary relocation) are not influenced by the surface material, or type of contamination so cannot be eliminated at this stage.

Therefore, options are applicable if:

- There is direct evidence that it would be effective for the chemical (known applicability)
- The mechanism of action is such that it would be highly likely to be effective for the chemical (probable applicability)

An option is taken as not being applicable if one or more of the following criteria are met:

- There is direct evidence that the option would not be applicable to the chemical.
- The chemical’s properties are such that the option would not be expected to have any effect.
- The hazard posed by the chemical would not be reduced.
- The time taken to implement the recovery option would be longer than the chemical’s persistence in the environment.
- There is a risk that implementing the recovery option should make the hazard worse (i.e. volatilization).
- Implementation of this option would place operatives at an unacceptable risk.

An example (Figure 6.5) of how to interpret Table 6.6 is given below for an incident where chemical contamination is absorbed on a sensitive surface.

	Surface Type		Contamination type			
Recovery Option	**Robust surface**	**Sensitive Surface**	**Free**	**Absorbed**	**Inaccessible**	**Interpretation**
A						Eliminate option- likely to damage surface
B						Eliminate option- not effective for absorbed contamination
C						Retain option but may only partially remove contamination
D						Retain option may only partially remove contamination and potentially damage surface
E						Retain option but may potentially damage sensitive surfaces
F						Retain option

Figure 6.5. An example of how to interpret Table 6.6 – chemical contamination on a sensitive surface

Table 6.6 Overview of recovery option effectiveness ***Classification is based on evaluation of the evidence base and stakeholder input.**

Recovery Option	Efficacy for type of contamination and surface material				
	Surface Type		Contamination type		
	Robust	**Sensitive**	**Free**	**Absorbed**	**Inaccessible**
(6) Reactive gases and vapours					
(7) Reactive liquids (bleaches, detergents, foams, gels)					
(8) Physical decontamination techniques					
(9) Other water-based cleaning methods (scrubbing, shampoo)					
(10) Pressure hosing					
(11) Vacuum cleaning					
(12) Surface removal (buildings)					
(13) Fixative/ strippable coatings					
(14) Dismantle and disposal of contaminated material					
(15) Modify operation/ cleaning of ventilation systems					
(16) Cleaning vehicle ventilation systems					
(17) Storage, covering, gentle cleaning of precious objects					
(18) Natural attenuation (with monitoring)					
(19) Outdoor surface removal and replacement (road, soil)					
(23) Barriers to seal land contamination					
(24) Burial in-situ					

Effectiveness	**Up to 100% effective**	**Potentially effective**	**Limited effectiveness**

6.3.4 Step 4: Review key considerations and constraints

Recovery options invariably have other considerations or constraints associated with their implementation. A detailed description of these considerations is provided in the recovery option sheets (Section 7). To further assist in eliminating unsuitable options some of the key considerations for each option are described in Table 6.7 and summarised in Table 6.8 for public health, waste, social, technical, cost and time issues for each option. These tables can be used in conjunction with the recovery option sheets (Section 7) to reduce the subset of options that may require more in-depth review.

The colour coding in Table 6.7 and Table 6.8 is based on an evaluation of the evidence base, stakeholder experience and advice or ongoing decontamination research within the UK. The colour-coding gives an indication of whether options have “none or minor”, “moderate” or “important/ key” constraints or considerations associated with their implementation. The classification used in the selection tables is intended to be a generic guide and is **not chemical specific**. Therefore, Table 6.7 and Table 6.8 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (see Table 6.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. DEFRA CBRN/ PHE).

The numbers in the brackets in Table 6.8 refers to the recovery option number. If an important (key) constraint is identified, it **does not** indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis (Step 5).

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
Protective options		
(1) Restrict public access	**Time -** This option should be implemented as soon as a contaminated area is identified with cordons and signage to prevent access. These measures will need to be in place until the contamination has been completely removed from the area in question.	**Social -** Effective communication is required to inform the public about the restriction and the potential health risks posed by the contaminant with the aim of ensuring compliance. Possible disruption and access to an area may not be well received by members of the public with pressure to reopen the area.
Practical experience	**Incident**: Binghampton state office building fire (1981) [3] **Incident:** Sulphur Mustard Incident in Swansea (2009) [4]	
(2) Controlled workforce access	**Time -** This option should be implemented as soon as a contaminated area is identified with cordons and signage to prevent access. These measures will need to be in place until the contamination has been completely removed from the area in question.	**Social -** There may be issues with compliance, a guard may need to be appointed to prevent access.
Practical Experience	**Incident:** Binghampton state office building fire (1981) [3] **Incident:** PCB release at commerce building in Washington (1999) [5]	
(3) Impose restrictions on transport	**Social -** There may be issues with compliance. Disruptions to normal travel, disruptions to transport which may delay emergency vehicles and people requiring the urgent use of vehicles may not be perceived well by the public. Effective communication will therefore be required to deliver information on access to emergency services vehicles – ambulance etc and possible alternative transport methods.	**Technical -** For this measure to be implemented successfully road blocks need to be erected, combined with notices, signs and traffic cameras
Practical experience	**Incident:** Dioxins, Seveso Italy (1976) [6] **Incident:** Tokyo subway Sarin attack (1995) [7]	
(4) Temporary relocation from residential areas	**Social -** Evacuation can be a disturbing exercise to the community. In some cases, it can be difficult to ensure compliance, for example local business owners may resist leaving an area. Residents cannot be forced to leave homes. **Technical -** To minimise the social disruptions caused by relocation, certain measures should be taken to assist the process, for example leaflets consisting of important information for people being relocated need to be distributed (effective communication). Transport availability needs to be considered to aid the relocation process, especially if the affected area has an elderly population or people with disabilities (population profile). Additionally, an effective monitoring strategy needs to be implemented to determine the risk of adverse health effects to occupants upon return to the area.	**Cost -** This measure can prove to be expensive for local authorities responsible for relocating residents from an affected area. Cost is also influenced by the length of time residents will be temporarily relocated for, and the quality of the temporary housing offered (hotels vs. hostels) **Time -** Evacuation and relocation need to be implemented as soon as a potential health risk to residents are identified. This measure would need to remain in place as long as the contamination is being investigated/ remediated.
Practical experience	**Incident:** Mexborough Tyre Fire (2010) [8] **Incident:** Weston sand stone Quarries, used for disposal of chemicals between (1970's-1999) [9]	

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(5) Permanent relocation from residential areas	**Social -** Evacuation leading to permanent relocation is generally a very difficult and disturbing exercise to the community, Disruption can affect those being relocated, those within the receiving communities and those left behind. This measure should therefore not be undertaken unless clearly necessary i.e. significant contamination posing serious risk to health. The decision should be taken in conjunction with the local health authority.	**Public health:** There may be psychological impacts (e.g. stress) on members of the public who are required to relocate permanently from their homes. They may be unable to undertake their usual jobs, children may require new schools and lose their sense of community **Cost -** This measure can prove to be very expensive to local authorities responsible for relocating the residents from an affected area. Often, they would have to offer to buy the properties affected in an area at a price higher than the predicted market value. **Time -** Permanent relocation might be considered when the alternative temporary relocation is expected to last longer than one year. A lengthy temporary relocation may not be acceptable to a community.
Practical experience	**Incident:** Weston sand stone Quarries, used for disposal of chemicals between (1970's-1999) [9] **Incident:** Love canal, New York (1978) [10]	
Remediation options		
(6) Reactive gases and vapours	**Social -** There is a potential that the reactive chemicals used could damage the surface of buildings. Disruptions may also encourage residents to access their properties. **Cost -** Financial costs can potentially be high but depends on a number of factors such as; the gas/vapour used, the number of workers required, the size of the building and if scaffolding or repainting will be required.	**Technical -** Surfaces may need to be repeatedly treated to ensure the contaminant is effectively removed. Sampling and monitoring is required to confirm removal. **Time -** This recovery option needs to be implemented soon after a chemical incident as weathering processes may disperse the contaminant from the surface of the affected area into the environment.
Practical experience	**Incident:** San Francisco high rise building transformer fire (1983) [7] **Incident:** IREQ high voltage laboratory PCB fire (1984) [5]	
(7) Reactive liquids (bleaches, detergents, foams, gels)	None	**Waste –** Depends on which decontamination liquid used; waste products in various forms can be generated which may require disposal and/ or storage under a waste transfer licence. **Social -** Disruptions may encourage residents to access their properties during the remediation process. **Technical -** Surfaces may need to be repeatedly treated to ensure the contaminant has effectively been removed. Sampling and monitoring is required to confirm this. **Cost -** Variable, depending on the type and amount of reactive liquid used, size of the building and amount of waste generated that will require appropriate disposal. **Time -** This recovery option needs to be implemented soon after a chemical incident as weathering processes may disperse the contaminant from the surface of the affected area into the environment.
Practical experience	**Incident:** Emergency room contamination with organophosphate (2000) [7] **Incident:** Leakage of PCB containing transformers (1990) [11]	

Recovery Options	**Major (key) considerations** for selected recovery options	**Moderate considerations** for selected recovery options
(8) Physical decontamination techniques	**Waste -** Depending on which techniques are used; waste products in various forms will be generated. The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and Northern Ireland Environment Agency (NIEA) should be consulted on possible disposal routes (i.e. incineration and landfill).	**Technical -** The decontamination technique used depends on the nature of contaminated surface. For example, the type of surface, its evenness and the condition it is in. An effective monitoring programme needs to be implemented to determine when the contaminant has been removed. **Time -** Weathering will reduce contamination, rapid implementation of this option will improve the effectiveness.
Practical experience	**Incident:** Leakage of PCB containing transformers [11] **Incident:** Steel Mill (Sodium Fluoroacetate contamination) (1992) [12]	
(9) Other water based cleaning methods (scrubbing, shampoo, steam cleaning)	None	**Waste -** Produces water-based wash solutions that are likely to be contaminated which may require disposal and/ or storage under a waste transfer licence. **Time -** Maximum effectiveness is achieved when carried out soon after a chemical incident, this is when the maximum concentration of the contaminant is still on the surface as with time weathering will disperse the contaminant into the surrounding environment.
Practical experience	**Incident:** Asbestos incident Nottingham (2010) [13] **Incident:** Factory fire with asbestos containing fall out, Tranmere (1994) [14]	
(10) Pressure hosing	**Waste -** Pressure washers may produce large volumes of effluent and waste water. To prevent run off on to other sensitive surfaces such as soil and ground water, the effluent needs to be effectively collected and may require disposal and/ or storage under a waste transfer licence. **Cost-** Cost will vary depending on the size and scale of the affected area. **Time -** Maximum effectiveness is achieved when carried out soon after a chemical incident, this is when the maximum concentration of the contaminant is still on the surface, as with time weathering will disperse the contaminant into the surrounding environment.	**Technical -** The effectiveness of this option depends on the nature of the surface in question, for example the type, evenness and condition of the surface, including the amount of moss on the roof. The height of the buildings also needs to be considered e.g. high-rise blocks may limit the effectiveness.
Practical experience	**Incident:** Hydrofluoric acid spill at Chemical Plant, Twin City, Georgia (1999) [5]. **Incident:** Four Alarm Fire (NJ, USA) (1981)[15]	
(11) Vacuum cleaning	None	**Waste -** Potential for large amounts of dust contaminated filters which may have high contamination levels being generated. This waste may require disposal and/or storage under a waste transfer licence. **Technical -** The nature and condition of the surface in question can determine the effectiveness of this measure, for example vacuuming is not very effective on wet soot. **Time -** Maximum effectiveness is achieved soon after an incident when the maximum contamination is on surfaces. However, over longer periods, contamination may be brought into buildings e.g. on the soles of shoes, and so repeated application regularly may be beneficial until any surrounding soil or grass areas are cleaned.
Practical experience	**Incident:** 9/11, New York (2001) [17] Incident**:** Mercury Release in Elementary School (1999) [14]	

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(12) Surface removal (buildings)		**Waste -** This option is likely to produce significant quantities of contaminated surface material. The solid phase may be disposed of at a hazardous waste landfill, but this can be influenced by the chemicals involved. **Technical -** Effectiveness depends on the surface in question e.g. ease of removal, thickness of the surfaces and the scale. It also depends on the nature of the chemical involved e.g. persistence and how easily it could become dispersed. **Public health** – Certain destructive techniques such as sandblasting may produce chemically contaminated dust that could result in a public health risk if not contained appropriately.
Practical experience	**Incident:** Binghampton state office building transformer incident (1981) [3] **Incident:** PCB release at commerce building, Washington DC (1999) [5]	
(13) Fixative/ strippable coatings	**Waste -** Strippable coatings when removed are likely to be highly contaminated and will therefore require disposal and/or storage under a waste transfer licence. **Cost:** Likely to be high. Peel-able strippable coatings are highly labour intensive and likely to require significant resources which will vary depending on factors such as the level of contamination, type of coating used and size of the contaminated building. **Time -** The maximum benefit is achieved if this option is carried out soon after an incident when the maximum contamination is still on the surface, before it can be dispersed into the environment.	**Social -** Residents of the contaminated area may be sceptical of the contamination remaining in-situ, fears are likely to arise concerning potential future exposure. **Technical -** The effectiveness of this option depends on the nature of the chemical involved (i.e. its absorbent properties and if it is likely to migrate through the coating) Effectiveness also depends on the type, evenness and condition of the surface the coating is applied on. The size of the area in question can also influence effectiveness, fixative coatings can be applied over a large area, but strippable coating is more suitable for smaller areas.
Practical experience	**Incident:** 9/11, New York (2011) [17] **Incident:** Dioxins, Seveso (1976) [6]	
(14) Dismantle and disposal of contaminated material	**Social -** Entering homes to remove contaminated objects can be disruptive to residents. Compliance issues can arise if personal items such as clothes or home appliances are being removed and are not covered by compensation packages. Dust emissions from building demolition could be a nuisance to the public. **Waste -** This option is likely to generate large amounts of contaminated material which will require disposal and/or storage under a waste transfer licence. **Cost-** Likely to be high. Dismantling is a highly labour-intensive process. Additionally, the large amount of waste generated will be costly to dispose of appropriately.	**Public health -** Building demolition results in dust and particulate matter emissions. This dust can be potentially toxic and pose a health risk to people in the surrounding area. Dust will therefore need to be monitored and controlled effectively. **Time:** The maximum benefit is achieved if this option is carried out soon after an incident when the maximum contamination is still on the contaminated material before it can be dispersed into the environment.
Practical experience	**Incident:** Dioxins, Seveso (1976) [6] **Incident:** Discovery of Phosphorous (SIP) grenades in a Wiltshire garden (2006) [17] **Incident:** Hurricane Katrina (2005) [18]	
(15) Modify operation/ cleaning of ventilation systems	None	**Technical -** It may be difficult for workers to access ventilation systems to clean them effectively **Time -** The maximum benefit is achieved if this option is carried out shortly after a contamination as it can have a significant effect on reducing the spread of contamination
Practical experience	**Incident:** PCB release at commerce building. Washington DC (1999) [5] **Incident:** San Francisco high rise building transformer fire (1983) [5].	

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(16) Cleaning vehicle ventilation systems	None	**Social -** Acceptability of car being dismantled for decontamination purposes. **Technical -** Difficulties in workers accessing ventilation systems to clean them effectively. **Time -** The maximum benefit is achieved if this option is carried out shortly after a contamination as it can have a significant effect on reducing the spread of contamination via car ventilation systems.
Practical experience		
(17) Storage, covering, gentle cleaning of precious objects	None	**Public health -** Cleaning of objects can liberate the contaminant (or a product of the contaminant once mixed with water) so advised to take place in a well-ventilated area to avoid health risk. **Social -** People maybe anxious about cleaning methods causing damage to their belongings.
Practical experience	**Incident:** An incident of cyanide poisoning (2008) [19] **Incident:** Baltimore Loft Apartment Building - formation of mercury pods (1994) [20]	
(18) Natural attenuation (with monitoring)	**Technical -** Monitoring equipment, skilled personnel to take samples. This method may take a prolonged period for the contaminant to be broken down in the environment. The length of time is partly dependant on the location of the area in question, for example allowing chemical attenuation within a building would take a significantly longer period of time than an outdoor area. Also, this option may be more feasible for rural areas rarely used, in comparison to an important commercial district which would need a more urgent remediation due to social pressures.	**Social -** This option may be perceived as doing "nothing" by the public which may have negative implications. **Cost -** May be high**,** considering, monitoring equipment, consumables, skilled personnel (including laboratory analysis) and time (natural attenuation can take months-years)
Practical experience	**Incident:** MSC Napoli (2007) [21] **Incident:** Secondary beach contamination from gasworks (1997) [22]	
(19) Outdoor surface removal and replacement (road, soil)	None	**Waste -** Large quantities of chemically contaminated tarmac/soil/concrete will be produced, which will require disposal and/or storage under a waste transfer licence. **Social -** There may be disruptions to access route due to damage to roads, soiled areas or pavements. This method may also cause aesthetic issues. **Time -** The maximum benefit is achieved if this option is carried out soon after an incident when the maximum contamination is still on the surface, before it can be dispersed into the environment.
Practical experience	**Incident:** Petrol fuel leak requiring remediation, Islington (2009) [23]	
(20) Soil and vegetation removal	**Social-** May cause damage to habitats and biodiversity. May also cause soil erosion.	**Waste -** Large quantities of contaminated soil and vegetation like to be produced which will require appropriate disposal. **Technical -** Effectiveness of this measure depends on the physicochemical properties of the contaminant (i.e. Water solubility, needs to bind to clay and soil) An effective monitoring strategy needs to also be implemented. **Cost -** Monitoring equipment required and therefore likely to be very expensive.
Practical experience	**Incident:** Long-term leakage of heating oil into soil (1996) [22] **Incident:** Castlegate, contaminated land, Caerphilly (1948 onwards) [25]	

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(21) Ploughing/ digging methods	**Technical -** Ploughing and digging may bring the contamination closer to groundwater, therefore the possibility that chemicals may leach into ground or surface water needs to be considered. Also, this method may result in soil erosion disturbing habitats and reduction in biodiversity.	**Social -** This method may be negatively perceived by the public as just digging and allowing the contaminant to remain in-situ, it may also cause adverse aesthetic effects. An effective communication strategy is therefore essential. **Time -**Maximum benefit is achieved if digging or ploughing is carried out soon after a contamination. This is to ensure that chemicals do not migrate deeper into the soil where they cannot be reached.
Practical experience	**Incident:** Olympic site contaminated land soil remediation (ongoing) [24]	
(22) Snow/ ice removal	**Time -** Maximum benefit is achieved if carried out soon after contamination. This method must be carried out before the first thaw following the contamination to prevent the contaminants from reaching the underlying ground surface. Also, to prevent human activity from compressing the snow which will make it more difficult to completely remove.	**Waste -** Depending on the thickness of the ice and the size of the area, this method could potentially generate large quantities of contaminated snow and resulting melt-water which will require appropriate disposal.
Practical experience		
(23) Barriers to seal contamination	**Technical -** To determine the extent and depth of the barriers to be installed, site specific assessments are required initially, which include geology hydrology, and local availability of possible materials for use in the vapour barriers. As an additional protection measure, houses built on top of vapour barriers need to have gas protection measures in place. An effective and long-term monitoring of the barriers is recommended as post work strategy.	**Cost -** Could prove to be expensive, due to machinery required, surveys conducted, labour costs, extra protection measures required and long-term monitoring. **Social -** Residents living in a contaminated area may be anxious about the possibility of vapours leaking into their homes. An effective communication strategy also needs to be implemented to address these health concerns.
Practical experience	**Incident:** Castlegate, contaminated land, Caerphilly (1948 onwards) [25]	
(24) Burial in-situ	**Social -** Potentially significant resistance from residents in the area against burial of contamination in situ as well as transporting the waste through/nearby the inhabited areas. Effective communication will be required to keep the public informed and address health concerns. **Technical -** This method requires specialised engineering expertise and materials which depend on the nature of the contaminant in question, e.g. water solubility in order to construct an effective membrane to contain the chemical. A suitable and robust monitoring programme will also need to be implemented to ensure the membrane remains intact.	**Cost -** Likely to be expensive due to transportation needs, specialised engineering expertise and the cost of the materials used to construct an effective membrane to line basins.
Practical experience	**Incident:** Dioxins, Seveso (1976) [6]	

Table 6.8 Overview of recovery option considerations *** Classification is based on evaluation of evidence base and stakeholder input**

Recovery Options Considerations	Public Health	Waste	Social	Technical	Cost	Time
Protection options						
(1) Restrict public access						
(2) Controlled workforce access						
(3) Impose restrictions on transport						
(4) Temporary relocation from residential areas						
(5) Permanent relocation from residential areas						
Remediation options						
(6) Reactive gases and vapours						
(7) Reactive liquids						
(8) Physical decontamination techniques						
(9) Other (water based) cleaning methods						
(10) Pressure hosing						
(11) Vacuum cleaning						
(12) Surface removal (buildings)						
(13) Fixative/ strippable coatings						
(14) Dismantle and disposal of contaminated material						
(15) Modify operation/ cleaning of ventilation systems						
(16) Cleaning vehicle ventilation systems						
(17) Storage, covering, gentle cleaning						
(18) Natural attenuation (with monitoring)						
(19) Outdoor surface removal and replacement						
(20) Soil and vegetation removal						
(21) Ploughing/ digging methods						
(22) Snow/ ice removal						
(23) Barriers to seal contamination						
(24) Burial in-situ						

Considerations	**None or minor**	**Moderate**	**Important (key)**
Time – when to implement recovery option	**No restrictions on time**	**Weeks to months/ years**	**Hours – days**

6.3.5 Step 5: Consult recovery option sheets

Refer to individual recovery option sheets (Section 7) for all remaining options that have been identified in the selection process and note other relevant constraints. This step involves a detailed analysis of all remaining options by careful consideration of the information on the relevant recovery options. This step can only be completed on an incident specific basis and in close consultation with local stakeholders to take into account local circumstances.

6.3.6 Step 6: Compare the remaining recovery options

Once options have been eliminated from the selection tables, if appropriate, the next step is to identify all the remaining options that could be considered for the type of surface within the affected Inhabited area. These options need to be evaluated on a site and chemical incident specific basis using detailed information provided in terms, for example, of exposure reductions, resources requirements, costs and amounts of waste generated, which may help to identify options that are not worth pursuing.

To aid with this selection strategy, a table could be designed to compare remaining recovery options. Table 6.9 gives an example of a template that could be used for such a purpose. Key questions that must also be considered include;

- What are the potential risks?
- What are the associated/linked recovery options?

Once a recovery strategy has been implemented then the remaining steps are to monitor to determine if the recovery strategy has been effective, and to report on the incident and the response, including the effectiveness of the handbook (see Figure 6.2). These steps are outside the scope of the handbook and are not discussed further.

Table 6.9: Further analysis of identified recovery options

Option number	Recovery option name	Step 1 Obtain information regarding the incident (refer to Table 6.5)	Step 2 Identify preliminary options for affected Inhabited Area (refer to Figure 6.3 and 6.4).	Step 3 Determine applicability of recovery options, eliminate options on: A: Physicochemical properties B: Surface material (refer to Figures 6.4 and Table 6.5)		Step 4 – Review key considerations and constraints (refer to Tables 6.6 and 6.7).	Step 5- Consult recovery option sheets (Section 7)	Option applicable?	Reason for elimination?
				Surface type	*Surface type*				

6.3.7 References

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7 Recovery options for inhabited areas

(1) Restrict public access
(2) Controlled workforce access
(3) Impose restrictions on transport
(4) Temporary relocation from residential areas
(5) Permanent relocation from residential areas
(6) Reactive gases and vapours
(7) Reactive liquids (bleaches, detergents, foams and gels)
(8) Physical decontamination techniques
(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning)
(10) Pressure hosing
(11) Vacuum cleaning
(12) Surface removal (buildings)
(13) Fixative and strippable coatings
(14) Dismantle and disposal of contaminated material
(15) Modify operation/cleaning of ventilation systems
(16) Cleaning vehicle ventilation systems
(17) Storage, covering, gentle cleaning of precious objects/personal items
(18) Natural attenuation (with monitoring)
(19) Outdoor surface removal and replacement
(20) Soil and vegetation removal
(21) Ploughing/digging methods
(22) Snow/ice removal
(23) Barriers to seal land contamination
(24) Burial in-situ

(1) Restrict public access

Objective	To reduce potential exposure of the public to chemical contamination from surfaces within contaminated areas.
Other benefits	Any necessary recovery options will be implemented more easily whilst the population is absent from the area. Will also prevent the spread of contamination.
Recovery option description	This option could be implemented in the short or long-term. **Temporary restriction (prohibition) of access to non-residential areas:** Recreational areas are initially likely to be a lower priority for clean-up and so restricting access may be necessary prior to any clean-up being implemented. **Temporary restriction (prohibition) of access to residential/ commercial areas:** Commercial districts of cities/towns and residential areas are likely to be a higher priority for clean-up and remediation, which will be facilitated by restricting access. Temporary restriction of access may be enforced while clean-up and remediation are being implemented. Partial restrictions cannot be controlled and it will not be possible to control exposure received by members of the public. Restriction of public access requires appropriate security measures (including signs, barriers and cordons). * Land is only likely to be fenced-off in the long term if it is privately owned. Public land would be controlled with notices and barriers on main access routes (if practicable).
Key information requirements	What is the land-use and demographics of the affected area? (i.e. city centre). Access to commercial, industrial, educational and health care facilities (i.e. national critical infrastructure sites) within the affected area will have to be considered.
Linked recovery options	This is a **protective option** and should be linked to **remediation options**.
Target	People living in and visiting contaminated areas.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that pose a risk to public health, especially if persistent or toxic. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. The PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, absorbance into porous surfaces and water solubility.
Scale of application	Any
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	There is maximum benefit if this option is carried out soon after contamination. However, there are no time limits associated with this option; it can be applied at any time and for any duration.

Considerations

Public health considerations	None
Legal implications and obligations	Seek specialist advice and guidance. This recovery option may require legislation to restrict access to land, depending on ownership.
Social implications	There may be issues with acceptability of this option (and enforcement). Partial restrictions cannot be controlled and it will not be possible to control exposure received by members of the public. This option may result in the loss of access to public amenities. There is a risk that there could be a change in public perception/ acceptance of the affected area (i.e. recreational areas/ city centre), which may affect public confidence. An effective public information strategy will be essential

Environmental considerations	Prohibition of access to countryside may benefit fauna and flora.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Exposure should be reduced significantly if implemented and enforced appropriately.
Technical factors influencing effectiveness of recovery option	Small areas of residential accommodation are often found in largely commercial and industrial areas Effective exclusion of people from an area may be difficult to demonstrate. Success of barriers and fences (if used).
Feasibility and intervention costs	
Specific equipment	Signs, barriers and fencing.
Utilities and infrastructure	None
Consumables	Signs and barriers
Skills, personnel and operator time	Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated area that requires restriction of public access (i.e. recreational area/ commercial districts).
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water company workers use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Costs may be influenced by: • Size of areas(s) where public access is to be restricted. • Possible need to regulate access to certain areas (i.e. access to national critical infrastructure facility). • Erecting and manufacturing signs and barriers
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Potential exposure of members of the public will be reduced by 100% if access is effectively restricted. There may be issues with public acceptability and compliance (partial restrictions cannot be controlled and is will not be possible to control the exposure received by members of the public). Population habits, for example, if people do not spend significant quantities of time in areas where access is restricted, this option will not reduce the overall exposure. Success of cordons (if used).
Potential increased worker exposure	None.
Other considerations	

Agricultural impact	This will depend on the nature of the affected area (i.e. farmland or urban). There may be animal welfare issues (i.e. provision of feed) that should be considered. Seek specialist advice and guidance.
Compensation issues	There may be requests for compensation for costs associated with loss of trade and earnings (i.e. manufacturing processes or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Brunt H, Russell D, Brooke N. Sulphur mustard, Wales Swansea 2009. Chemical Hazards and poisons report, Incident response, Health Protection Agency. 2009;17:4
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	
Document History	

(2) Controlled workforce access

Objective	To enable the workforce to remain in a contaminated area on a limited basis to keep essential services and infrastructure operating (i.e. national critical infrastructure facilities).
Other benefits	Any necessary recovery options may be implemented more easily whilst the (non-workforce) population is absent from the affected area.
Recovery option description	Work environments can be controlled (both the people who are allowed to enter a workplace and the time that workers spend there). Employers have a duty of care towards their employees; therefore it will not generally be acceptable for employees to work in a contaminated area where it has been deemed unacceptable for people to live. In this instance, access of the general population to the area is likely to be prohibited. For employees who are providing essential services; restricted access can be used with close control on their potential exposure. This recovery option would require an appropriate risk assessment depending on the chemical and the level of contamination. May be enforced while recovery options are being implemented.
Key information requirements	What are the occupational health restrictions or relevant exposure limits / levels?
Linked recovery options	This is a **protective option** and should be linked to **remediation options**. This option is likely to be combined with (1) Restrict public access.
Target	People working in contaminated areas.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that pose a risk to public health, especially if persistent or toxic. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, absorbance into porous surfaces and water solubility.
Scale of application	**Any**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	It is likely that this recovery option would be implemented soon after the initial incident, but may continue for some time. This '**protective'** option may be implemented while remediation options are being undertaken in the contaminated area.

Considerations

Public health considerations	Potential for exposure of public to chemical contamination to continue
Legal implications and obligations	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace.
Social implications	Compliance with restricted access times by workers. Workers may not be willing to enter or work in a contaminated environment. Loss of public amenities.
Environmental considerations	Buildings and outdoor areas may not be maintained

(2) Controlled workforce access

Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Workers may not want to enter or work in a contaminated environment.
Effectiveness	
Recovery option effectiveness	Variable, dependent on properties of chemical, level of contamination and time spent by workers in workplace
Technical factors influencing effectiveness of recovery option	None
Feasibility and intervention costs	
Specific equipment	Monitoring equipment for workforce entering the affected area.
Utilities and infrastructure	None
Consumables	System to control and monitor exposure to workforce.
Skills, personnel and operator time	None
Safety precautions	Seek specialist advice and guidance. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident where controlled workforce access is implemented as a recovery option.
Other limitations/factors influencing costs	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Monitoring health and safety when there is only a skeleton workforce in an establishment may be required. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers will have to comply with Health and Safety at Work Act to ensure that workers entering the contaminated area use appropriate PPE.
Waste	
Amount and type	Disposal of PPE and other work necessary items which now may be considered contaminated waste. Should be an issue of the asset owner but the LA may be approached for help.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Exposure to workers who are required to be work in contaminated area will be closely monitored; they will receive an additional exposure compared to other members of the public. Compliance with controlled workforce access.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with Health and Safety at Work Act to ensure that workers entering the contaminated area use appropriate PPE. Monitoring of workers entering the affected area may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals

(2) Controlled workforce access

	involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving controlled workforce access. Exposure pathways workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	N/A
Compensation issues	There may be requests for compensation for costs associated with loss of trade and earnings (i.e. manufacturing processes). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
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(3) Impose restrictions on transport

Objective	To prevent the re-suspension of chemical contamination by all vehicle types. To prevent the spread of chemical contamination on vehicle surfaces.
Other benefits	Any necessary recovery options related to cleaning or replacing of surfaces on roads may be implemented more easily whilst transport is restricted through the affected area.
Recovery option description	Prohibit members of the public from using their vehicles and /or impose restrictions on bus and train networks in a contaminated area. Closure of roads via the use of barriers/ signs. In extreme cases it could also include the prevention of flights to prevent spread of contamination nationally or internationally Lesser restrictions may include imposing stricter speed limits to minimise the dispersal of contaminated material deposited on the ground. Advice could also be provided to limit car use to essential tasks. Another consideration would be to allow public transport (e.g. buses) but prevent private vehicle use (i.e. cars). This option may not be required if the option (1) Restrict public access has already been implemented. However, in some cases access may be prohibited in heavily contaminated areas whilst transport may be restricted in less contaminated areas.
Key information requirements	What is the traffic type (air, rail or road) in the affected area? How long are the transport restrictions required and what groups will be affected i.e. commuters (rush-hour), school children or holidaymakers (if on a bank-holiday or weekend)? Will restrictions impact access to critical infrastructure sites? (e.g. hospital)
Linked recovery options	This is a **protective option** and should be linked to **remediation options**.
Target	All transport vehicles and networks – emergency vehicles may still be granted access.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that pose a risk to public health, especially if persistent or toxic. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, absorbance into porous surfaces and water solubility.
Scale of application	**Any**
Exposure pathway prevention	Will depend on the extent of contamination but will reduce exposure from inhalation of remobilised particulate material, including inhalation, dermal (skin) contact, eye contact and inadvertent ingestion.
Time of application	Maximum benefits are associated with this option if implemented soon after emergency phase to prevent further spread of contamination.

Considerations

Public health considerations	None
Legal implications and obligations	Seek specialist advice and guidance.
Social implications	Disruption in the affected communities may be extensive and members of public may refuse to adhere to advice There may be problems for people requiring urgent use of vehicles (e.g. medical emergency, food supplies), travel to/ from home/ work. Access criteria for emergency vehicles will need to be established.

(3) Impose restrictions on transport

Environmental considerations	Strong winds may negate the effectiveness of this option in reducing suspension of chemical contamination Restrictions on transport is could improve local air quality (due to reduction in car exhaust emissions).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	This option **will not reduce** contamination levels in the restricted area although it may prevent vehicles from re-suspending certain chemicals especially chemically contaminated dust like particulates.
Technical factors influencing effectiveness of recovery option	Level of contamination in area. Physiochemical properties of chemical(s) involved
Feasibility and intervention costs	
Specific equipment	Road blocks, notices, signs and traffic cameras. Monitoring equipment.
Utilities and infrastructure	Roads and transport networks
Consumables	Notices, signs amongst others
Skills, personnel and operator time	Operator time and personnel requirements will vary depending on the size and scale of the chemical incident where restrictions on transport are required.
Safety precautions	None
Other limitations/factors influencing costs	Duration. Restrictions may be progressively reduced as the clean-up and remediation is achieved.
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Exposure from re- suspended chemicals would be reduced for people living and working in the affected area. Averted exposure may be influenced by compliance with restrictions on transport; members of public may need to drive through contaminated area to obtain food / medical supplies.
Potential increased worker exposure	None.
Other considerations	
Agricultural impact	This will depend on the nature of the affected area (i.e. farmland or urban). There may be animal welfare issues (i.e. provision of feed) that should be considered. Seek specialist advice and guidance.

(3) Impose restrictions on transport

Compensation issues	There are likely to be requests for compensation for loss of earnings from measures which restrict the movement of transport, e.g. goods, produce. Shops in the affected area (i.e. underground stations or those surrounding effected tube stops may also require compensation). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Restrictions on transport were implemented during the remediation of the dioxin incident in Seveso, Italy.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015. Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce.. Fondazione Lombardia per L' Ambiente.1998:32.
Comments	
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(4) Temporary relocation from residential areas

Objective	To reduce exposure from chemical contamination within residential areas.
Other benefits	Any necessary recovery options will be implemented more easily whilst the population is absent from the area.
Recovery option description	This recovery option is essentially the removal of individuals from a contaminated area on a temporary basis. It is likely that people would be moved to an area that is sufficiently outside of the contaminated area so that exposure is minimal, but is near enough to allow commute them to their normal places of work. A temporary relocation of over a year is unlikely to be acceptable to residents, in which case (5) Permanent relocation from residential areas should be considered. This is a **protective option,** and should be considered alongside remediation options.
Key information requirements	Is alternative housing and associated resources (i.e. transport) available? What is the size and demographics of the affected population? What is the likely economic impact from implementing this option?
Linked recovery options	This is a **protective option** and should be linked to **remediation options**. Recovery options that may need to be considered with this option include; (1) Restrict public access; (2) Controlled workforce access and (3) Impose restrictions on transport.
Target	People living in contaminated areas, their possessions and animals
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that pose a risk to public health, especially if persistent or toxic. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, absorbance into porous surfaces and water solubility.
Scale of application	**Any**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	There is maximum benefit if people are moved out soon after incident or are evacuated during the emergency phase and do not return.
Considerations	
Public health considerations	There may be psychological effects from temporary relocating the affected population.
Legal implications and obligations	Seek specialist advice and guidance. There may be a requirement to provide security for empty buildings.
Social implications	There may be issues with compliance (people cannot be forced to leave their homes) and disruption in the affected communities (those moved and those in the receiving communities). This option could lead to fragmentation of communities. Other social considerations include; finding alternative accommodation, availability of infrastructure to support relocated populations, increased burden on schools, medical and recreational services in the receiving community, and preventing unauthorised access back into the affected area.
Environmental considerations	Increases in the size of the population in receiving community (where people are temporarily relocated to) may have impacts on the environment, e.g. amount of general waste generated, increased traffic.

(4) Temporary relocation from residential areas

Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	This option should be up-to 100% effective as residents will be temporarily removed from the affected area, and no longer be exposed to the contamination.
Technical factors influencing effectiveness of recovery option	The effectiveness of this option is limited by compliance (people staying out of the contaminated area) and may require security to ensure access is restricted.
Feasibility and intervention costs	
Specific equipment	Temporary housing, vehicles and transport to relocated affected populations.
Utilities and infrastructure	Alternative accommodation/ housing Infrastructure to support relocated populations: schools, medical and social services etc Security to prevent services for area that has been relocated
Consumables	Fuel and parts for vehicles and other transport
Skills, personnel and operator time	Personnel requirements will vary depending on the size and scale of the chemical incident. Assuming people are moved about 1 hour away, it is estimated that one driver can relocate 60 people every 4 hours.
Safety precautions	Seek specialist advice and guidance. There may be the need to decontaminate evacuees, animals and personal possessions before boarding transport out of the affected area. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	If moved away from the affected area, the population should not be further exposed to chemical contamination. Averted exposure may be influenced by compliance with relocation as people cannot be forced to leave their homes or give up contaminated possessions. There may also be issues with regard to people re-entering the contaminated area to obtain personal possessions or animals (i.e. pets). Level of exposure at new location.

(4) Temporary relocation from residential areas

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving temporary relocation from residential areas. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	This will depend on the nature of the affected area (i.e. farmland or urban). There may be animal welfare issues (i.e. provision of feed) that should be considered. Seek specialist advice and guidance.
Compensation issues	There are likely to be requests for compensation for loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, produce. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. There may be issues over public perception of risk (and that the incident is extreme). Additionally, considerations over attachment to partner animals (e.g. cats, dogs or other pets) should not be underestimated. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Experience also confirms the need to ensure that other measures are put into place to keep the community informed of developments when regular briefings have been terminated. Previous incidents and exercises suggest weekly or monthly newsletters; site boards or banners around sites can be effective ways of achieving this.

Additional information

Practical experience	
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
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(5) Permanent relocation from residential areas

Objective	To reduce exposure from chemical contamination within residential areas.
Other benefits	Any necessary recovery options will be implemented more easily whilst the population is absent from the area.
Recovery option description	The removal of people from a contaminated area on a permanent basis (a period lasting over 1 year). For example, it may have been determined that structures and open areas cannot be decontaminated to levels that are protective of human health for their intended use. Therefore, the decontamination alternative may not be practicable or require the imposition of unreasonable restrictions (e.g. children playing outdoors would have to be prohibited or severely limited). This option will depend on the size and scale of the affected area, in some instances, this option may be more cost effective than to remediate. There is a high social and economic impact associated with this option.
Key information requirements	Is alternative housing and associated resources (i.e. transport) available? What is the size and demographics of the affected population? What is the likely economic impact from implementing this option? What are the public's views on the acceptability of this option?
Linked recovery options	This is a **protective option** and should be linked to **remediation options**. This option is likely to be implemented following (4) Temporary relocation from residential areas as it will take time to find /build suitable housing to allow permanent resettlement to occur. Recovery options that may also need to be considered with this option include; (1) Restrict public access and (3) Impose restrictions on transport.
Target	People living in contaminated residential areas, their possessions and animals (i.e. pets).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are very persistent, toxic and difficult to decontaminate. However, the physicochemical properties and physical form (e.g. solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, absorbance to permeable surfaces and water solubility.
Scale of application	Any scale. However, this recovery option would be complex for densely populated areas.
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	Permanent relocation might be considered if the alternative option (4) Temporary relocation is expected to last longer than one year. A lengthy temporary relocation may not be acceptable to a community.

Considerations

Public health considerations	There may be psychological impacts (e.g. stress) on members of the public who are required to relocate permanently from their homes. This may unable to undertake their usual jobs children may require new schools and lose their sense of community Studies have shown proven psychological impacts on those-left behind in an effected area or close to the affected area that were not offered permanent housing elsewhere. This is believed to be the result of numerous factors including, stigma associated with the area, evacuated buildings (empty houses) and worries over possible health effects of the contaminant.
Legal implications and obligations	Seek specialist advice and guidance. The construction and building of new residential areas and waste facilities will need to comply with legislation and authorisation may need to be granted.
Social implications	In some communities, a permanent relocation may significantly impact on the fabric of a locality by affecting the services that the communities support, including small businesses, schools, churches,

(5) Permanent relocation from residential areas	
	and hospitals. Furthermore, permanent relocation can result in the dispersal of neighbourhoods, dissolving valuable social cohesion. There may be issues with compliance (people cannot be forced to leave their homes), and disruption in the affected communities (those moved and those in the receiving communities). Other social considerations include; finding alternative accommodation, availability of infrastructure to support relocated populations, increased burden on schools, medical and recreational services in the receiving communities and issues preventing unauthorised access back into the affected area. Additionally, considerations over attachment to partner animals (e.g. cats, dogs or other pets) should not be underestimated.
Environmental considerations	Building new residential areas will impact on the environment, for example the need to build a new infrastructure, changes of land use and generation of waste. If it is decided not to remediate the affected area then risks or concerns regarding potential transfer of contamination in the environment (e.g. leaching) should be evaluated and addressed.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	This recovery option should be up-to 100% effective as residents will be permanently relocated and removed from the affected area (and no longer exposed to the contamination).
Technical factors influencing effectiveness of recovery option	The effectiveness of this option is limited by compliance (people staying out of the contaminated area) and may require security to ensure access is restricted.
Feasibility and intervention costs	
Specific equipment	Alternative accommodation/ housing, transport vehicles for moving people and possessions
Utilities and infrastructure	Alternative accommodation/ housing (including land). Infrastructure to support relocated populations: schools, medical and social services, support for those seeking employment etc
Consumables	Fuel and parts for vehicles and other transport
Skills, personnel and operator time	Personnel requirements will vary depending on the size and scale of the chemical incident, but may include; Security personnel to support drivers and restrict access to area, removal personnel, drivers, (security personnel may be required to support drivers). Removal personnel. Supportive administration at new site. Builders, plumbers, electricians etc for building new homes.
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). There may be the need to decontaminate evacuees, possessions and animals (i.e. pets) before boarding transport
Other limitations/factors influencing costs	There is a need to decide what can and can't be taken from the location to accompany the moved population as this will impact on removal costs. Additional factors that may influence costs include; sampling and monitoring requirements, compensation claims etc.
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A

(5) Permanent relocation from residential areas

Factors influencing waste issues (i.e. cost)	N/A

Exposure

Averted exposure	If moved away from the affected area, the population should not be further exposed to chemical contamination. Averted exposure may be influenced by compliance with relocation as people cannot be forced to leave their homes or give up contaminated possessions. There may be issues with regard to people re-entering the contaminated area to obtain personal possessions or animals (i.e. pets). Level of exposure at new location
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving permanent relocation from residential areas. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	This will depend on the nature of the affected area (i.e. farmland or urban). There may be animal welfare issues (i.e. provision of feed) that should be considered. Seek specialist advice and guidance.
Compensation issues	There are likely to be requests for compensation for loss of homes, possessions and loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, produce. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Experience also confirms the need to ensure that other measures are put into place to keep the community informed of developments when regular briefings have been terminated. Previous incidents and exercises suggest weekly or monthly newsletters; site boards or banners around sites can be effective ways of achieving this.

Additional information

Practical experience	Fortunati, GU .The Seveso Lesson: Advances in reclamation and disposal techniques. In: Rappe C, Choudhary G. & Keith LH. (Eds). Chlorinated Dioxins and Dibenzofurans in Perspective. *Lewis.* 1986: 541-553
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
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(6) Reactive gases and vapours

Objective	To reduce potential exposure to chemical contamination by reducing concentrations on a variety of surfaces using reactive gases such as hydrogen peroxide and chlorine dioxide
Other benefits	This recovery option may decrease the need to carry out more destructive recovery options such as (14) Dismantling disposal of contaminated material.
Recovery option description	The use of reactive gases and vapours is a specialised recovery option that will require expert advice, and can only be undertaken by specialist contractors. Reactive gases and vapours are allowed to circulate around the building and permeate into porous surfaces or materials to react with contaminants. The chemical contaminant is usually converted into a low toxicity or less toxic chemical. Examples of reactive gases and vapours include; hydrogen peroxide, chlorine dioxide, ethylene oxide, methyl bromide, para- formaldehyde, peracetic acid or ozone. Certain reactive gases and vapours (e.g. ozone / vaporous hydrogen peroxide) may be suitable for decontaminating sensitive electrical equipment Waste may be produced (i.e. effluent or gases), which may also require decontamination. Multiple applications of reactive gases and vapours may be required to deactivate or degrade the chemical contaminant. Appropriate measures are required to ensure that when implemented inside a building, it is sealed effectively to prevent potentially toxic reactive gases and vapours used escaping into the surrounding environment.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel and contractors and specialist equipment. What surface or type of building has been contaminated? (i.e. multi-storey, terraced, semi-detached) Are appropriate air-exchange or ventilation systems in place?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This decontamination technique is usually carried out in a closed and controlled environment as the gases are generally toxic and potentially harmful to the environment. Residents would require relocation from residential areas, therefore this option would need to be carried out in conjunction with (4) Temporary relocation from residential areas.
Target	Indoor and enclosed spaces, sensitive electrical equipment.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all contaminants that pose a risk to public health especially if persistent, toxic and difficult to decontaminate. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include persistence, water solubility, ability to absorb to porous surfaces and chemical toxicity (acute and chronic health impacts).
Scale of application	**Any** (this option is only applicable for us in indoor environments or enclosed spaces).
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out soon after a chemical incident when maximum contamination is still on the surfaces and before natural weathering can disperse contamination throughout the environment.

Considerations

Public health considerations	Seek specialist advice and guidance. There may be the potential for the remediation agent (i.e. reactive gas or vapour) to remain in environment, which could pose a risk to public health.

(6) Reactive gases and vapours

Legal implications and obligations	Seek specialist advice and guidance. There may be liability issues with regard to possible damage to property. There may also be issues with ownership and access to property or affected site, or cultural heritage protection of listed and other historically important buildings. There may be restrictions on chemical use (i.e. reactive gas or vapour). Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste', which is subject to control under legislation. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Social implications	Potential for damage to sensitive surfaces, buildings or infrastructure (e.g. corrosion/ erosion). Access to residential properties to carry out remediation.
Environmental considerations	Depending on the reactive gas or vapour used and the type of chemical contaminant(s) involved, the toxicity of degradation products would need to be considered. Extreme cold weather and humidity can Influence the effectiveness of this option.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	The effectiveness of this technique depends on the reactive gas or vapour used, the chemical agent involved (contaminant) and the material/surface on which the chemical contaminant is found. If the chemical contaminant is converted or degraded effectively, there should be a significant reduction in potential exposure.
Technical factors influencing effectiveness of recovery option	The robustness and combustibility of surfaces when exposed to high velocity and hot gases should be considered. This option may be less effective on inaccessible surfaces i.e. under a screw.
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination and waste removal operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service. Monitoring equipment to determine efficacy of recovery option Appropriate containers for temporary storage of waste products
Utilities and infrastructure	Fuel and parts for transport vehicles, engines, water electricity.
Consumables	Chemicals (reactive gases and vapours) used in active decontamination.
Skills, personnel and operator time	Specialist personnel and suppliers are required to undertake this option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. floor tiles, bricks, upholstery).
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Factors influencing the costs of this option include; • Type of reactive gas/ vapour involved • Specialist personnel (as this is a specialist recovery technique) • Chemical contaminant involved • Weather • Building size • Access to contaminated area • Use of personal protective equipment (PPE) Note: costs will increase if scaffolding is required, and if repainting of walls is required.

(6) Reactive gases and vapours

Waste

Amount and type	There is likely to be chemical waste is likely to be in residual liquid from condensate or gaseous form, and may require abatement or treatment prior to being released into the environment or transferred for disposal. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste', which is subject to control under legislation. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. In addition, building materials and interiors may still require disposal after decontamination albeit at a lower level to landfill.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Options for packaging and conveying the waste, including treating the waste on site or at an off-site facility and the possibility of interim storage if final disposal is not yet available should be considered.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods

Exposure

Averted exposure	This technique will only reduce exposure to people while they are in particular environment (i.e. indoors). Averted exposure will be dependent on specific situations and the types of surfaces cleaned. Averted exposure may be influenced by the consistency in implementing this option effectively over a large area
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the implementation of reactive gases and vapours as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	N/A
Compensation issues	There may be requests for compensation for loss of homes, possessions and loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, produce. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

(6) Reactive gases and vapours

Practical experience	There is limited practical experience in the available literature on the use of reactive gases and vapours. GDS have some practical experience of implementing chlorine dioxide decontamination of a village hall following a suspected anthrax death. GDS have also exercised hydrogen peroxide and peracetic acid systems although these techniques are not yet “live” in the UK. Chlorine dioxide was used to remediate anthrax contaminated facilities following the Amerithrax incidents in the USA 2001.
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident. 2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3. 2011. Available; https://www.gov.uk/how-to-classify-different-types-of-waste M. M Simpson. Anthrax-Contaminated Facilities: Preparations and a Standard for Remediation. CRS Report for Congress (2005). Available [April 2012] at; https://www.everycrsreport.com/reports/RL33191.html
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(7) Reactive liquids (bleaches, detergents, foams and gels)

Objective	To reduce potential exposure to chemical contamination by reducing concentrations on a variety of surfaces
Other benefits	This recovery option may decrease the need to carry out more destructive recovery options e.g. (14) Dismantling and disposal of contaminated material.
Recovery option description	Reactive liquids (bleaches, detergents, foams and gels) are the most commonly used decontamination procedures. Dependent on the specific product involved via oxidation (e.g. bleaches), hydrolysis (water based decontaminants) or a combination of the 2. There are a number of chemical based reactive liquids that convert the contaminant into a low toxicity toxic or less toxic chemical product, however; multiple applications may be required to deactivate or degrade the chemical contaminant. These products can be a mixture of detergents, surfactants and bleaches (e.g. hydrogen peroxide /sodium hypochlorite), emulsions, micro-emulsions, neutralising agents, foams, caustic solutions and solvents. Could also be proprietary decontamination solutions employing blends/ combinations of the above i.e. solvents and surfactants. Waste may be produced (i.e. effluent), which may also require decontamination. Examples of reactive liquid include: **Decon Green** Decon Green has been used to effectively decontaminate a number of chemical warfare agents including VX, soman and sulphur mustard. The solution is hydrogen peroxide based, acts via hydrolysis an oxidation and produces low toxicity by-products when used with these agents. **CASCAD Foam** CASCAD foam has been used to effectively decontaminate a number of chemical warfare agents and organophosphate pesticides. It is applied in a foam that adheres to vertical surfaces, suppresses vapour release and can be used with fresh or sea water. It contains surfactant, a co-solvent a decontaminant and a buffer.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel, contractors and specialist equipment. What surface or type of building has been contaminated? (i.e. multi-storey, terraced, semi-detached) Are appropriate air-exchange or ventilation systems in place? Legality of using some of the reactive liquids listed above? How will the contaminated waste generated by this option (i.e. waste water, cleaning brushes/ equipment) be managed?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This decontamination technique is usually carried out in a closed and controlled environment as the liquids may potentially harmful to the environment. Residents would require relocation from residential areas, therefore this option would need to be carried out in conjunction with (4) Temporary relocation from residential areas. This option could also be combined with (10) Pressure hosing.
Target	Indoor and outdoor surfaces and objects
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all reactive chemicals that are persistent and difficult to decontaminate. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include persistence, water solubility, ability to absorb to porous surfaces and chemical toxicity (acute and chronic health impacts).
Scale of application	Any scale.
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination

(7) Reactive liquids (bleaches, detergents, foams and gels)

Time of application	Maximum benefit if carried out soon after a chemical incident when maximum contamination is still on the surfaces and before natural weathering can disperse contamination in an outdoor environment. With indoor environments, if the room or area could be sealed off time is not such an issue.

Considerations

Public health considerations	Potential for remediation agent to remain in environment and pose a public health risk
Legal implications and obligations	Seek specialist advice and guidance. There may be liability issues with regard to possible damage to property. There may also be issues with ownership and access to property or affected site, or cultural heritage protection of listed and other historically important buildings. There may be restrictions on chemical use (e.g. reactive liquids) for example under REACH. The disposal and transfer of contaminated wastes classified as 'hazardous' is subject to controls and legislation. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Social implications	Potential for damage to sensitive surfaces, buildings or infrastructure (e.g. corrosion/ erosion). Access to residential properties to carry out remediation.
Environmental considerations	Depending on the reactive liquid used and the type of chemical contaminant(s) involved, the toxicity of degradation products would need to be considered. Contaminated waste products from treatment (i.e. effluent) could run onto other surfaces (roads, soil, grass etc) if not controlled effectively, resulting in a transfer of contamination which may require subsequent clean-up thus generating more waste.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	The effectiveness of this technique depends on the reactive liquid used, the chemical agent involved (contaminant) and the material/surface on which the chemical contaminant is found. If the chemical contaminant is decontaminated effectively, there should be a significant reduction in potential exposure.
Technical factors influencing effectiveness of recovery option	The robustness of surfaces when exposed to high velocity reactive liquids (bleaches, detergents, foams and gels) should be considered. This option may be less effective where contamination has absorbed into porous surfaces or penetrated inaccessible surfaces (i.e. under a screw). This option may need to be repeatedly implemented to effectively decontaminate the affected surface.

Feasibility and intervention costs

Specific equipment	Seek specialist advice and guidance. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Monitoring equipment to determine efficacy of reactive liquids. Appropriate containers for temporary storage of waste products.
Utilities and infrastructure	Fuel and parts for transport vehicles, engines
Consumables	Chemicals (bleaches, detergents, foams and gels), brushes and equipment used in decontamination
Skills, personnel and operator time	Operator time and personnel requirements will vary depending on the size and scale of the chemical incident, and types of contaminated surfaces (i.e. floor tiles, bricks, upholstery or carpets). Specialist personnel and suppliers may be required to undertake this option.

(7) Reactive liquids (bleaches, detergents, foams and gels)

Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Factors influencing the cost of this option may include; • Type of reactive liquid involved (i.e. simple bleach or specialist foam or gel). • Specialist personnel (this option may require specialist suppliers to implement the option) • Chemical contaminant involved • Weather • Building size • Access to contaminated area • Proximity of water supplies • Use of personal protective equipment PPE Note: costs will increase if scaffolding is required, and if repainting walls is required.
Waste	
Amount and type	Waste is likely to be in liquid form, and may require abatement or treatment prior to being released into the environment, or transferred for disposal. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	In urban environments decontamination will mainly generate aqueous wastes or slurries which may contain high concentrations of the active decontamination agent (e.g. chlorine). The products of which could be hazardous both to people and the environment, and must be neutralised before it can safely be discharged into the sewage system. Contaminated waste effluent and liquids must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Factors influencing waste issues (i.e. cost)	Will depend on the reactive liquids used, size and scale of affected area and volume of contaminated waste produced.
Exposure	
Averted exposure	There should be a significant reduction in potential exposure to members of the public living in the affected area. However, it should be noted that these techniques will only reduce exposure to people while they are in particular environment. Averted exposure will be dependent on specific situations and the surfaces cleaned. Averted exposure may be influenced by the consistency in implementing this option effectively over a large area, and the time of implementation. The impact of cleaning the surfaces on the overall exposure will be reduced with time on outdoor surfaces due to natural weathering.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the implementation of reactive liquids as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant)

(7) Reactive liquids (bleaches, detergents, foams and gels)

	Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	There may be a risk to agricultural land due to leaching of contaminated water.
Compensation issues	There may be requests for compensation for loss of possessions, personal property, loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, produce. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Schecter A. The Binghamton State Office Building Pcb, Dioxin, and Dibenzofuran 85 Electrical Transformer Incident. *Chemosphere*. 1986; 9-12 Barkley NP. Pioneer Equipment Company - Superfund Site (pilot study for clean-up techniques) Control Technology. Update on building and structure decontamination. *J. Air Waste Manage. Assoc* 1990; 40 (8):1174-1178.
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident. 2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3. 201. Available; https://www.gov.uk/how-to-classify-different-types-of-waste
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(8) Physical decontamination techniques

Objective	To reduce potential exposure to chemical contamination by reducing concentrations on a variety of surfaces
Other benefits	This recovery option may decrease the need to carry out more destructive recovery options e.g. (14) Dismantling and disposal of contaminated material
Recovery option description	Physical decontamination relates to a number of measures that physically remove a contaminant from the environment using equipment (not chemicals) surface and includes neutral sorbent techniques. See also recovery option (12) Surface removal (buildings) **Neutral sorbent materials include;** clays (fullers earth), sawdust, resins, activated charcoal, dry powders (e.g. soap powder, earth, dirt and flour) zeolites and super absorbent polymers may be used to "mop up" liquid contamination. Neutral sorbent materials may be implemented during the response (emergency) phase as an early decontamination option. Additionally, saw dust has been found to bind fine volcanic ash particles, making the clean-up process easier. The material then may be collected and disposed of at a toxic landfill or by incineration. Specific examples include; • Phorate: May use activated charcoal, fullers earth or other absorbent • Sulphur Mustard: activated charcoal, fullers earth or bentonite. **Wet wiping** is a common physical decontamination method to remove chemically contaminated particle dust whilst preventing re-suspension on interior surfaces. Impermeable surfaces are wet-wiped, using a wet rag or mop after consultation with and approval by property owner. Wet wiping should not be conducted if there is the potential to cause damage to the surface (i.e. sensitive surfaces). Solid objects (i.e. electrical equipment and exercise equipment) can be wet wiped, or moved to allow cleaning of the underlying surface and returned to their original location. Wet-wiping also reduces the risk of inhalation exposure of recovery workers when compared to other methods such as sweeping.
Key information requirements	Seek specialist advice and guidance. It is likely that specialist advice would be needed to determine an appropriate absorbent material dependant on the chemical and quantity involved. Availability of skilled personnel, contractors and specialist equipment (as some physical decontamination techniques may require specialist equipment). What surface or type of building has been contaminated? (i.e. multi-storey, terraced, semi-detached) How will the contaminated waste generated by this option (i.e. wet-wipes, absorbent materials) be disposed of?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This technique may be used in conjunction with other techniques such as (6) Reactive gases and vapours; (7) Reactive liquids (bleaches, detergents, foams and gels); (11) Vacuum cleaning and (12) Surface removal to enhance the removal of contamination.
Target	Indoor/ outdoor surfaces and objects
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals (liquid/ solid) that can be removed by physical techniques. However, the physicochemical properties and physical form (solid/ liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, and ability to absorb to porous surfaces, partition coefficient and chemical toxicity (acute and chronic health impacts).
Scale of application	**Any**

(8) Physical decontamination techniques

Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out soon after a chemical incident when maximum concentration is still on the surfaces and before natural weathering can disperse contamination throughout the environment. This option is effective at any time after contamination for persistent liquid chemicals.

Considerations

Public health considerations	None
Legal implications and obligations	Seek specialist advice and guidance. There may be liability issues with regard to possible damage to property. There may also be issues with ownership and access to property or the affected site, or cultural heritage protection of listed and other historically important buildings or precious objects. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste', which is subject to control under legislation. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. For example, contaminated absorbent materials and wet-wipes may be classed as hazardous waste. Suitably marked bags or containers should ideally be handed over to a responsible person at the scene.
Social implications	Access to residential properties to carry out remediation, and possible damage to building surfaces and objects. Public acceptability of waste treatment and storage routes. There may be a positive benefit from cleaning houses.
Environmental considerations	Depending on the absorbent material used and the chemical contaminant(s) involved, the toxicity of waste by-products would need to be considered. The disposal of waste arising from the implementation of this option may have an environmental impact. However, this should be minimised through the control of any disposal route and relevant authorisations.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	If applied correctly, reduction in overall exposure should be significant.
Technical factors influencing effectiveness of recovery option	It may be difficult to apply certain adsorbents in powder form to vertical or downward facing surfaces. This option is unlikely to be applicable for sensitive surfaces (e.g. glass/ heritage) due to the risk of damage. Weather conditions may also affect the efficacy of this option (if outdoors) Correct application of absorbent material over the contaminated area. Type, evenness and condition of surface. Time of implementation, as natural weathering may reduce contamination over time so rapid implementation could improve the effectiveness of this option.

Feasibility and intervention costs

Specific equipment	Seek specialist advice and guidance as this option may require specialist suppliers to implement the option. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination

	operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service. Transport vehicles required for absorbent material and removal of waste. Monitoring equipment to determine efficacy of recovery option Appropriate containers for temporary storage of waste products
Utilities and infrastructure	Fuels and parts for transport vehicles, engines, water and electricity.
Consumables	Absorbent and adsorbent materials, spreading and removal equipment and wet-wipes. The cost of these consumables will vary depending on the size and scale of the contamination and area that requires remediation.
Skills, personnel and operator time	Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. floor tiles, bricks, upholstery and carpets). Specialist personnel and suppliers may be required to undertake this option.
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Factors influencing the cost of this option include; • Type of physical decontamination technique used (absorbent/ adsorbent material or wet-wipe). • Specialist personnel (this option may require specialist suppliers to implement the option). • Chemical contaminant involved • Weather • Building size • Topography and size of the affected area • Access to contaminated area (including tidiness of houses and amount of ‘contents’ that may require removal) • Amount of dust/ dirt on surfaces • Use of personal protective equipment PPE Note: the cost of equipment will vary depending on the size and scale of the contamination
Waste	
Amount and type	Waste is likely to be in solid form (wet-wipes and absorbent material), and may require abatement or treatment prior to being disposed of (i.e. via landfill or incineration). Many types of wastes that will be encountered during or after a chemical incident may come under the classification of ‘Hazardous waste’. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Options for packaging and conveying the waste, including treating the waste on site or at an off-site facility and the possibility of interim storage if final disposal is not yet available.
Factors influencing waste issues (i.e. cost)	Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	There should be a significant reduction in potential exposures to members of the public living in the affected area. However, it should be noted that these techniques will only reduce exposure to people while they in particular environment. Averted exposure will be

	dependent on specific situations and the surfaces cleaned. Factors influencing averted exposure include; Consistency in effective implementation of option over a large area Time of implementation. The impact of cleaning the surfaces on the overall exposure will be reduced with time on outdoor surfaces due to natural weathering.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e. transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving physical decontamination techniques as a remediation option. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	
Agricultural impact	None.
Compensation issues	There may be requests for compensation for personal property or possessions and loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, product. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Additional information	
Practical experience	Dunne A, Dobney A, and Hodgson G. Asbestos: The hidden hazard in domestic, educational and health care settings. Chemical Hazards and Poisons Report 2010;17:10 Health and Technical Assistance for the World Trade Centre (WTC) Dust Cleaning Program (Final Report) OSHA activity. 2003. Available at: https://archive.epa.gov/wtc/web/pdf/confirmation_cleaning_study.pdf
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident. 2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, 2011). Available; https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
Comments	

(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning)

Objective	To reduce exposure arising from contamination on internal surfaces of buildings and indoor objects within inhabited areas.
Other benefits	This recovery option may reduce contamination from indoor surfaces and objects in buildings.
Recovery option description	A variety of cleaning methods are available (e.g. washing, scrubbing, shampooing, steam cleaning). Water is one of the simplest decontamination techniques and can be used to dilute and flush an agent Seek specialist advice and guidance, as the most appropriate method will be determined by the chemical contaminant(s) and target surface. • Hard surfaces and objects may be washed and scrubbed with warm/hot water, detergents and decontamination additives such as bleach (surfaces should be rinsed to remove remaining contamination and detergent). • Upholstery can be washed with detergent solution and be vacuumed off. • Walls and ceilings can be cleaned using sheeting to prevent contamination of the floor with waste water. Shampoo/steam cleaning techniques use machines to spray hot or cold detergent solution onto upholstered surfaces, carpets, tapestries etc, and it is vacuumed off before the fabric becomes saturated. Washing machines can be used for removable items (i.e. clothing or cushion covers). Steam cleaning physically extracts contaminants from materials and equipment surfaces. The steam is applied by hand-held wands or automated systems, and the contaminated condensate waste is collected for treatment and disposal. Steam cleaners which use hot water are not suitable for silk, viscose or cotton velvet fabrics. Care should be taken to avoid spreading contamination via floating bubbles. This technique cannot be used on non-ferrous metals.
Key information requirements	Seek specialist advice and guidance. It is likely that specialist advice would be needed to determine the appropriate water based cleaning method (dependant on the chemical and quantity involved). Availability of skilled personnel, contractors and specialist equipment (as some water based cleaning methods may require specialist equipment). What surface or type of building has been contaminated? (i.e. critical facility or domestic property) How will the contaminated waste generated by this option (i.e. contaminated condensate or waste water and run-off) be managed?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. This technique may be used in conjunction with other techniques such as (8) Physical decontamination techniques; (10) Pressure hosing and (11) Vacuum cleaning to enhance the removal of contamination.
Target	Indoor surfaces of residential properties (and other buildings) and household objects that are robust enough to be cleaned with water.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals (liquid/ solid) that are water soluble. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, and ability to absorb to porous surfaces, partition coefficient, viscosity and chemical toxicity (acute and chronic health impacts).
Scale of application	Indoor surfaces in all types of buildings
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out soon after incident when maximum contamination is on surfaces and before natural weathering can disperse contamination throughout the environment.

Considerations

(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning)

Public health considerations	None-assuming the public have been evacuated.
Legal implications and obligations	Liabilities for possible damage to property There may be issues with ownership and access to property There may be issues with using this option in listed or other historic buildings and on precious objects.
Social implications	Public acceptability of waste treatment and storage routes Possible damage to building surfaces and objects Positive benefit of cleaning houses Maintenance of use of indoor spaces
Environmental considerations	The disposal or storage of waste arising from the implementation of this option may have an environmental impact. However, this should be minimised through the control of any disposal route and relevant authorisations. Potential for degradation products for chemicals that react with water. Potential run-off.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	Would vary dependent on the surface and chemical involved. If implemented successfully for a compatible chemical it is likely to remove nearly all contamination from a surface. However, steam cleaners, which use very hot water, are not suitable for all surfaces.
Technical factors influencing effectiveness of recovery option	Type of cleaning method used Water solubility of chemical(s) Time of operation (the longer the time between the incident occurring and implementation of the option the less effective it will be, as contaminated dust may have migrated over time). Amount of dust on surfaces at the time of contamination Whether any cleaning has already been undertaken Efficiency of equipment Weather at time of incident; less material is deposited indoors during wet conditions. Appropriate clean-up of other indoor surfaces and objects. Ability to clean surfaces and objects thoroughly.

Feasibility and intervention costs

Specific equipment	Seek specialist advice and guidance and specialist equipment may be required to undertake this option. Scrubbing machines with solution dispenser Steam cleaners Spray machines Wet vacuum cleaners Transport vehicles for equipment and waste. Sampling and monitoring equipment.
Utilities and infrastructure	Electricity supply Water supply Roads for transport of equipment and waste Waste storage/holding utilities.
Consumables	Fuel and parts for vehicles Water and detergent Decontamination reagents e.g. bleach

(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning)

Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel, contractors and specialist equipment may be required. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. floor tiles, bricks, upholstery) It is important that the specific objectives and potential problems associated with the cleaning techniques are fully explained. Some options (i.e. mopping) could be implemented by the local population as a self-help measure but may require appropriate safety equipment (gloves, overalls, boots and safety glasses).
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Appropriate PPE that may be required could include; Respiratory protection (may be required in highly contaminated areas). Gloves and overalls. Waterproof clothing Normal safety procedures for handling chemicals. Help and assistance may be required for storage areas, COSHH regulations etc.
Other limitations/factors influencing costs	Removable items are easier and cheaper to dispose of. Chemical(s) involved Type of surface contaminated Building size Type of equipment used Access to the property Tidiness of houses and amount of ‘contents’ Amount of dust/dirt on surfaces Disposal route – if waste is not sampled first, must assume same level of contamination remains so there will be limited disposal options.

Waste

Amount and type	Water based wash solutions; however waste is likely to vary according to the technique used. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of ‘Hazardous waste’. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance.
Factors influencing waste issues (i.e. cost)	This will vary depending on the water-based cleaning technique used, size and scale of contamination. Waste water contaminated with debris or material that in itself would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods

Exposure

Averted exposure	There should be a significant reduction in potential exposures to members of the public living in affected areas. However, it should be noted that these techniques will only reduce exposure to people while they are in particular environment. Averted exposure will be dependent on specific situations and the surfaces cleaned. Factors that may influence averted exposure include; Consistency in effective implementation of option over a large area; need to ensure edges and corners are cleaned properly. Application of appropriate clean-up to other indoor surfaces and objects. Time of implementation. The impact of cleaning surfaces on overall exposure will be reduced with time if clean-up is delayed (due to natural weathering). Care of application. Need to wash contamination off surfaces and not just move it around the surface or onto another surface. The amount of time spent inside contaminated buildings by recovery workers or members of the public if this is used as a self-help option should be considered.

(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning)

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident water based cleaning methods as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	Seek specialist advice and guidance. There may be a risk to agricultural land due to leaching of contaminated water.
Compensation issues	There may be requests for compensation for personal property or possessions and loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Health and Technical Assistance for the World Trade Centre (WTC) Dust Cleaning Program (Final Report) OSHA activity. 2003. Available at: http://www.osha.gov/nyc-disaster/wtc-final-residential-dust-cleanup-program.pdf
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident. 2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, 2011). Available; https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
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(10)	Pressure hosing
Objective	To reduce exposure arising from contamination on outdoor surfaces within inhabited areas (i.e. buildings, road and paved areas).
Other benefits	This recovery option may reduce contamination from external building surfaces, vehicles and roads/paved areas. This option may also improve the cleanliness of the general area.
Recovery option description	Pressure-washing equipment can be used to hydrolyse or physically remove chemical contamination from a surface and dilute, dependent on the contaminant involved. Seek specialist advice and guidance as the most appropriate method of pressure washing will be determined by the chemical contaminant(s) and target surface. There is the risk that high pressure hosing could push contamination deeper into a surface. The majority of pressure washing machines have the capability of introducing detergents or other chemicals into hot or cold water. Water temperature could also be modified as high temperature solutions may be more effective at removing chemical contamination. A continuous water flow is applied at high pressure of about 150 bar (2000 psi). For large areas such as railway stations 5000psi pumped water could be used with equipment mounted on a heavy trolley. Washing must start at the top of walls and roofs and it is particularly important to avoid lifting roof tiles by forcing water upwards. A pump is mounted on the ground and hoses are fed to a platform or scaffolding. **Roofs:** It should be practicable to collect the waste water used for high pressure hosing. Collection of water from roofs can be aided by modifying guttering and drainpipes, so that the collected waste is fed into collection tanks, where it may be disposed of appropriately. In some cases the procedure can be modified to deliver hot water with detergent for roofs as this may be more effective (dependant on the chemical involved). Use of high pressure jets at pressures significantly above 150 –200 bar is not advisable on most roofs as this may lead to the lifting of tiles. **Walls:** It is likely to be more difficult to collect the waste water and associated contamination. **Ground:** The implementation of recovery options to the surrounding ground surfaces should also be considered after high pressure hosing has been implemented, if run-off to ground surfaces has occurred. If the implementation of any other options to the surrounding ground surfaces is planned, high pressure hosing of walls and roofs should be implemented first. Installation of a water recycling system should be considered where large volumes of water are used, a toxic chemical is involved or no foul sewer is available.
Key information requirements	Seek specialist advice and guidance. It is likely that specialist advice would be needed to determine the most appropriate pressure washing technique (depend on the chemical and quantity involved). Availability of skilled personnel and specialist equipment. What surface or type of building has been contaminated? (i.e. critical facility or domestic property) How will the contaminated waste generated by this option (i.e. water and run-off) be managed?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This option could be combined with (7) Reactive liquids (bleaches, detergents, foams and gels).
Target	Outdoor environments, including external building surfaces (i.e. buildings, roads, paved areas).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals (liquid/ solid) that are water soluble. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, and ability to absorb to porous surfaces, partition coefficient, viscosity and chemical toxicity (acute and chronic health impacts).
Scale of application	Any scale (however, implementation on a large scale would require special considerations due to the generation of contaminated waste water).
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination

(10)	Pressure hosing
Time of application	Maximum benefit if carried out soon after incident when maximum contamination is on surfaces and before natural weathering can disperse contamination throughout the environment.
Considerations	
Public health considerations	None
Legal implications and obligations	Liabilities for possible damage to property from physical impact or other factors (e.g. flooding) There may be issues with ownership and access to property Disposal of contaminated water via public sewer system There may be issues with using this option on listed or other historical buildings
Social implications	Public acceptability of waste treatment and storage routes Acceptability of disposal of contaminated waste water into the public sewer system. High pressure hosing of buildings will make an area look clean; the visual implementation of this option may also provide public reassurance and restore public confidence. Repair work on some walls and roofs may be required.
Environmental considerations	Severe cold weather could reduce the effectiveness of this option (water would need to be heated) Walls must be waterproof Roof constructions must resist water at high pressure High pressure hosing will create contaminated waste water. However, this should be minimised through the control of any disposal route and relevant authorisations. Pressure hosing can be difficult to contain, if waste water is not collected, some of it will run onto other surfaces (roads, soil, grass etc), resulting in a transfer of contamination which may require subsequent clean-up (generating more waste). There is also the potential for contamination of groundwater from this procedure. It is important that high pressure hosing of buildings is implemented before the implementation of any recovery options to surrounding ground surfaces. High pressure hosing can remove aged mortar necessitating remedial painting.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	The effectiveness of this option will vary, depending on the chemical and surface involved. For more sensitive surfaces (e.g. glass) using water at lower pressure (e.g. fire hosing) could be considered although may be less effective at removing contamination.
Technical factors influencing effectiveness of recovery option	Dependent on the chemical contaminant high pressure hosing could push the contamination deeper into the surface contaminated Type, evenness and condition of surface, including the amount of moss on roofs. Water pressure; amount of water, water temperature (hotter water is more effective), use of detergent Time of operation; if carried out soon after incident when maximum contamination is on surfaces and before natural weathering can disperse contamination throughout the environment. Different heights may have different levels of contamination depending on incident. Also, the height of the building (e.g. high rise office blocks) may limit the applicability of this option. Consistent application of water over the contaminated area (i.e. operator skill). Care in application; care needed to wash contamination from walls and roofs and not just move the contamination around the surface; lower part of walls need to be cleaned very carefully as this is the surface that will provide the greatest exposure to an individual in the vicinity of the building; special care needed to clean roof gutters and drain pipes. Whether the ground surrounding the building and other surfaces onto which run-off may have occurred have been decontaminated after treating the building (if waste was not collected). Number of buildings in the area
Feasibility and intervention costs	
Specific equipment	The type of pressure washing equipment used will vary, and may require waste water to be collected and filtered prior to disposal. The cost of equipment will vary, depending on the size of contaminated area and scale of remediation required.

(10)	Pressure hosing
Utilities and infrastructure	Roads for transport of equipment and waste Water supply Public sewer system/ approved route to dispose of waste water.
Consumables	Fuel and parts for generators and transport vehicles Surface treatment for roofs (if required) Cost of consumables will depend on the size of contaminated area and scale of remediation required.
Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel, contractors and specialist equipment may be required (i.e. high pressure hoses and gully suckers). Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. roads, paved areas, buildings). The DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service
Safety precautions	Seek specialist advice and guidance as bio-aerosols could be produced from this procedure. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Specific safety equipment may include; Lifeline and safety helmets (for tall buildings) Water-resistant clothing (particularly in highly contaminated areas) Personal protective equipment (PPE) to protect workers from contaminated water spray Precautions are needed to ensure that people making connections to mains water supplies do not inadvertently contaminate the water supply, e.g. by back-flow from vessels containing chemical contamination, or operate hydrants in a way that disturbs settled deposits within the water main system.
Other limitations/factors influencing costs	Weather. Building size or type of surface requiring remediation (i.e. roads/ paved areas). Type of equipment used. Access to contaminated area. Proximity of available water supplies.
Waste	
Amount and type	Pressure washers may produce large volumes of effluent (50 – 900 litres of water per hour) at high temperatures. Traffic film removers or other cleaning chemicals may be added to increase the effectiveness of the operation and abrasive agents such as sand or grit are sometimes incorporated into the wash waters. Toxic by-products could be produced once they react with water, also dust and chemically contaminated water will require appropriate disposal. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of ‘Hazardous waste’. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance.
Factors influencing waste issues (i.e. cost)	This will vary depending on the pressure washing technique used, size and scale of contamination. Waste water contaminated with debris or material that in itself would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods.
Exposure	
Averted exposure	There should be a significant reduction in potential exposure to members of the public living in affected areas. Averted exposure will be dependent on specific situations and the surfaces cleaned. The production of bio-aerosols would also need to be considered for both recovery workers and people inhabiting the area.

(10) Pressure hosing

Potential increased worker exposure	Consistency in effective implementation of option over a large area Care in application. Care needed to wash contamination from walls and roofs and not just move the contamination around the surface; lower part of walls need to be cleaned very carefully as this is the surface that will provide the greatest exposure to an individual in the vicinity of the building; special care needed to clean roof gutters and drain pipes. Whether the ground surrounding the building and other surfaces onto which run-off may have occurred have been decontaminated after treating the building (if waste was not collected). Population behaviour in the area. Number of buildings in the area, i.e. environment type/land use. Time of implementation. The impact of cleaning the surfaces on the overall exposure will be reduced with time as there will be less contamination on the surfaces due to natural weathering.

Other considerations

Agricultural impact	Seek specialist advice and guidance. There may be a risk to agricultural land due to leaching of contaminated water.
Compensation issues	There may be requests for compensation for property or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Dunne A, Dobney A, and Hodgson G. Asbestos: The hidden hazard in domestic, educational and health care settings. Chemical Hazards and Poisons Report 2010;17:10
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste EA, SEPA, EHS. Pollution prevention guidelines. 2007. PPG13 Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015.
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(11) Vacuum cleaning

Objective	To reduce exposure arising from contamination on internal and external surfaces of buildings and objects within inhabited areas. HEPA and/or carbon filters will also filter the air to reduce cross contamination, condensation and increase evaporation of liquids from surfaces besides physically removing solid residues.
Other benefits	This recovery option may also remove contamination from indoor and external surfaces and objects in buildings. Implementing this option (i.e. sweeping roads and pavements) will make an area look clean; provide public reassurance and restore public confidence.
Recovery option description	A variety of vacuum cleaning machines are available. Seek specialist advice and guidance, as the most appropriate method will be determined by the chemical contaminant(s) and target surface material. **Indoor -** High Efficiency Particulate (HEPA) vacuuming can achieve significant reductions in the gross levels of chemical contaminants on surfaces. This approach is clean, does not damage materials, and does not generate waste by-products other than those present in the filters themselves. HEPA vacuuming also reduces the potential for re-aerosolisation of the chemical contaminant. It is preferable to use a vacuum cleaner fitted with a HEPA filter to prevent re-suspension. Machines are electrically operated from mains electricity. However; vacuum cleaning may give rise to dust (particularly in dusty environments). Using water to dampen the surface or the use of a fixative coating is unlikely to be practicable and so personal protective equipment (PPE) must be provided for the workers to reduce the re- suspension hazard **Outdoor -** Municipal vacuum sweepers can be used to clean paved areas. Different types of vacuum sweeper are used for large surface areas, such as roads, and for small surface areas, such as pavements. It is recommended that machines with the ability to dampen the surface with water sprays are used to reduce dust (and subsequently reduce the re-suspension hazard). Some road sweepers can operate in wet weather conditions.
Key information requirements	Seek specialist advice and guidance. Availability of specialist equipment and appropriately trained/ skilled personnel. What surface or type of building has been contaminated? (i.e. road, pavement or domestic property) How will the contaminated waste generated by this option (i.e. filters and collected debris) be managed?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This technique may be used in conjunction (8) Physical decontamination techniques; (9) Other water based cleaning methods (scrubbing, shampoo, steam cleaning) and (12) Surface removal (buildings) to enhance removal of contamination.
Target	Internal surfaces (particularly floors) and objects in buildings, external surfaces (roads, paved areas)
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent chemicals that may re-suspend in the environment. This option is unlikely to be useful for viscous chemicals. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, ability to absorb to porous surfaces and chemical toxicity (acute and chronic health impacts).
Scale of application	**Any.** HEPA vacuums are suitable for indoor surfaces in all types of building. Vacuum sweepers can be used on most outdoor surfaces but are unlikely to be used in close proximity to people's homes.
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit soon after an incident when maximum contamination is on surfaces and before natural weathering can disperse contamination throughout the environment. If there is a delay in implementing this option, consider the possibility that contamination may have been transferred into

(11)	Vacuum cleaning
	buildings or homes e.g. on the soles of shoes. Therefore, regular repeated applications may be required until contamination from the surrounding environment (including soil or grass verges) is effectively remediated.
Considerations	
Public health considerations	None
Legal implications and obligations	Liabilities for possible damage to property Ownership and access to property Use in listed or other historic buildings and on precious objects.
Social implications	Public acceptability of waste treatment and storage routes Possible damage to indoor building surfaces and objects Positive benefit of cleaning houses. Acceptability of active disposal of contaminated waste water into the public sewer system. Acceptability of disposal of filtered waste from contaminated water (i.e. incinerator or landfill).
Environmental considerations	**Indoor vacuuming;** should have a limited environmental impact if waste is disposed of appropriately. **Outdoor vacuuming;** this will be complicated by weather; Severe cold weather could result in chemical contamination becoming trapped under a layer of ice. Wet conditions will create additional contaminated waste water, which may require filtering prior to disposal. If waste water is not going to be collected, and the hard surfaces are not equipped with drains, this option should not be considered.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	If the chemical contaminant(s) are effectively removed by vacuuming, exposure reduction should be significant. For outdoor areas, chemical contaminant(s) will be removed rapidly from these surfaces through natural weathering; therefore the effectiveness of vacuum cleaning as a remediation method decreases over time.
Technical factors influencing effectiveness of recovery option	This will vary depending on the vacuum cleaning technique used, size and scale of contamination. Specific factors that should be considered include; • Type and condition of surface • Time of implementation (effectiveness as a remediation option decreases over time as contaminated dust may disperse from the affected area). • Consistent application over the contaminated area; need to ensure edges and corners are cleaned • Amount of dust on surfaces at the time of contamination • Ineffective removal of contamination around drains and in gutters • Removal of loose debris from surface • Amount of hard outdoor surfaces in the area. • Has decontamination is carried out on adjacent surfaces, or any other cleaning already been undertaken. • Efficiency of equipment (depends on aerosol size of contaminant) • Amount of furniture and furnishings in the buildings and ventilation rates.
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance as specialist equipment may be required. DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation

	service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service **Indoor**: Vacuum cleaner with brush attachment and upholstery cleaning attachment (preferably HEPA filtered industrial vacuum cleaner). Costs will be influenced by; building size, type of equipment used, access, use of personal protective equipment (PPE), tidiness of buildings and amount of 'contents' and amount of dust/ dirt on surfaces. **Outdoor:** Pavement cleaner, road sweeper, spate pumps, transport vehicles for equipment and waste. Costs will be influenced by; weather, topography, size of area to be treated and type of equipment.
Utilities and infrastructure	Electricity supply. Roads for transport of equipment and waste.
Consumables	Fuel and parts for equipment, generators and vehicles. Also, specialised filters.
Skills, personnel and operator time	Seek specialist advice and guidance as specialist equipment may be required. Only a little instruction is likely to be required to operate the equipment. Vacuum cleaning could be implemented by the population as a self-help measure, after instruction from authorities and the provision of safety equipment (PPE). Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. floor tiles, bricks, upholstery)
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). If this vacuum cleaning is implemented as a '**self-help'** option personal protective equipment (PPE), including respiratory protection, will be required due to potential dust production.
Other limitations/factors influencing costs	Outdoor surface, building and size of area to be cleaned will influence the cost of this option. The type of equipment required may also affect the cost of this option as a remediation technique.

Waste

Amount and type	Vacuum cleaners (including road sweepers) may produce large volumes of chemically contaminated dust. **Indoor** : Potentially large quantities of chemically contaminated dust *Amount:* $5\ 10^{-3}$ kg m^{-2} *Type:* Dust, contaminated filters (40 g m^{-2} per year) which may have high contamination levels **Outdoor:** Potentially large quantities of dust and sludge 10^{-1} – $2\ 10^{-1}$ kg m^{-2}. The amount depends on the dustiness of a surface. If cleaning done under wet conditions and water disposed of directly to drains, then the waste produced will be higher. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance.
Factors influencing waste issues (i.e. cost)	This will vary depending on the size and scale of contamination. Contaminated dust and debris or material that in itself would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods.

Exposure

(11) Vacuum cleaning

Averted exposure	There should be a significant reduction in potential exposures to members of the public living in affected areas. However, it should be noted that these techniques will only reduce exposure to people while they are in particular environment. Averted exposure will be dependent on specific situations and the surfaces cleaned.
Potential increased worker exposure	• Consistency in effective implementation of option over a large area; need to ensure edges and corners are vacuumed appropriately. • Population behaviour in the area (i.e. amount of time spent in buildings). • Number of buildings in the area. • Weather at time of incident; less material is deposited indoors during wet conditions. Initial contamination is also influenced by the amount of furniture and ventilation rates. • Time of implementation. The impact of cleaning the surfaces on the overall exposure will be reduced with time as there will be less contamination on the surfaces due to natural weathering. • Application of appropriate clean-up to other indoor surfaces and objects.

Other considerations

Agricultural impact	None.
Compensation issues	There may be requests for compensation for loss of property (i.e. carpets) or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Dunne A, Dobney A, and Hodgson G. Asbestos: The hidden hazard in domestic, educational and health care settings. *Chemical Hazards and Poisons Report* .2010;17:10 Fortunati, GU .The Seveso Lesson: Advances in reclamation and disposal techniques. In: Rappe C, Choudhary G. & Keith LH. (Eds). Chlorinated Dioxins and Dibenzofurans in Perspective. *Lewis.* 1986: 541-553 Health and Technical Assistance for the World Trade Centre (WTC) Dust Cleaning Program (Final Report) OSHA activity. 2003. Available at: http://www.osha.gov/nyc-disaster/wtc-final-residential-dust-cleanup-program.pdf
Key references	HSE. Asbestos: The licensed contractors' guide. 2006 DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste EA, SEPA, EHS. Pollution prevention guidelines. 2007. PPG13 Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(12)	Surface removal (buildings)
Objective	To reduce inhalational exposure from contamination on internal and external walls of buildings within inhabited areas.
Other benefits	This recovery option may remove other contamination from external building surfaces. There are positive benefits associated with this option, including cleaning houses and buildings.
Recovery option description	Surface removal (buildings) is a specialised recovery option that is likely to require expert advice, and may require specialist suppliers and contractors to undertake remediation of the affected area. Building surfaces include; concrete, stone or brick, which have a large surface area due to their porous nature. Paint or surface layers containing contamination can be removed from surfaces by commercially available paint removers and/or physical means (e.g. scraping, scabbling, scrubbing or abrasive blasting). Commercial sanders are likely to produce a lot of dust unless an improvised vacuum shroud is placed around the sander and connected to a HEPA filter vacuum cleaner. Many small scrubbing machines are available for domestic use, equipped with a solution dispenser and wet vacuum (squeegee) pick-up. **Scabblers:** The use of scabblers facilitates the removal of cracked or shattered concrete surfaces leaving a textured finish, which a new layer will key satisfactorily well too. Scabbling involves several pneumatic hammers shattering the top 6mm off the top layer of concrete. The surface **must** be kept wet during the process to prevent re-suspension and recontamination of surfaces. **Abrasive Blasting:** This technique uses abrasive material (i.e. sand, aluminium or glass beads) to facilitate the uniform removal of contaminated surface layers from materials and structures. Abrasive blasting of walls removes a thin layer, together with chemical contamination. To eliminate the risk of contamination spreading along the wall abrasive blasting must start at the top. Wet or contained methods are recommended to avoid the re-suspension of chemical contaminant(s). **Dry Ice (CO_2) blasting:** This technique is an industrial cleaning process for surfaces that uses carbon dioxide pellets as the blasting medium. The principle of dry ice blasting is that CO_2 gas returns to the atmosphere and leaves only the contaminant and particles removed from the surface as waste. Therefore, additional systems are required to collect and filter CO_2 gas and waste material and debris. If walls are sufficiently contaminated to require surface treatment, the ground surfaces surrounding the area (i.e. paving at the front of a building) are also likely to be heavily contaminated, and these areas will also require remediation. If the implementation of any other options to the surrounding ground surfaces is planned, abrasive blasting of walls should be implemented first.
Key information requirements	Seek specialist advice and guidance Availability of skilled personnel and contractors and specialist equipment. What surface or type of building has been contaminated? (i.e. critical facility or domestic property) How will the contaminated waste generated by this option (i.e. filters and collected debris) be managed?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This technique may be used in conjunction with (11) vacuum cleaning to enhance removal of contamination.
Target	Highly contaminated surfaces on interior and exterior of buildings, excluding glazed areas
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent chemicals that absorb onto porous surfaces. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence and chemical toxicity (acute and chronic health impacts).
Scale of application	**Any.**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination

(12) Surface removal (buildings)

Time of application	Maximum benefit if carried out soon after contamination. However, abrasive blasting of external walls of buildings can be effective up for many years after contamination occurs for persistent chemicals.
Considerations	
Public health considerations	Seek specialist advice and guidance as there is the potential for production of chemically contaminated dust from abrasive surface removal procedures.
Legal implications and obligations	Liabilities for possible damage to property (e.g. direct damage/ flooding) There may be issues with ownership and access to property Waste disposal legislation There may be issues with use on listed and other historically important buildings
Social implications	Public acceptability of waste treatment and storage routes. Possible damage to building surfaces. Repair work on some walls may be required.
Environmental considerations	The disposal or storage of waste arising from the implementation of this option may have an environmental impact. However, this should be minimised through the control of any disposal route and relevant authorisations. Sandblasting will create contaminated waste water so appropriate monitoring will be required in the sewage treatment plant. If waste water is not collected, some of it will run onto other surfaces (roads, soil, grass etc), resulting in a transfer of contamination which may require subsequent clean-up, generating more waste.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Would vary depending on the surface and chemical involved. If implemented successfully it is likely to remove nearly all contamination from a surface. Severe cold weather may influence the effectiveness of this option (water may need to be heated)
Technical factors influencing effectiveness of recovery option	This will vary depending on the surface removal technique used, size and scale of contamination. Specific factors that should be considered include; • Type and condition of surface (including evenness) • Time of implementation (effectiveness as a remediation option decreases over time as deposited contamination dust may disperse from the affected area). • Consistent application over the contaminated area; need to ensure edges all surface material is removed • Amount of dust on surfaces at the time of contamination • Removal and collection of loose debris and removed surface material from affected area • Has decontamination is carried out on adjacent surfaces (i.e. indoor surfaces and objects), or has any other cleaning already been undertaken. • Water pressure • Number of buildings in the area • Degree of glazing present (which will need to be cleaned carefully after surface removal has been undertaken).
Feasibility and intervention costs	

(12) Surface removal (buildings)

Specific equipment	Specific equipment will vary, dependant on the surface removal technique used. Seek specialist advice and guidance. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Other equipment may include; • Monitoring equipment to determine efficacy of surface removal. • Appropriate containers for temporary storage of waste products. • Scrapers • Steam strippers • Pneumatic chisels • Sandblasting equipment • Removing lino tiles from concrete: machine (long reach scraper) to remove tiles stuck to concrete floors • Saws for removing wooden floors • Transport vehicles for equipment and waste
Utilities and infrastructure	Roads (transport of equipment, materials and waste) Water supply Public sewer system
Consumables	Mains electricity (for indoor surface removal), water supply, sand, alumina, glass beads, dry ice, fuel and parts for generators and transport vehicles.
Skills, personnel and operator time	Skilled personnel essential to operate some equipment (e.g. sandblasting) but simpler techniques (e.g. paint removal) are relatively straightforward. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. floor tiles, bricks or concrete).
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers (recovery workers) will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Other safety equipment may include; • Gloves and overalls. • Personal protective equipment (PPE) may be required under dusty conditions to reduce the hazard from re-suspension (especially if asbestos is present). Precautions are needed to ensure that people making connections to mains water supplies do not inadvertently contaminate the water supply, e.g. by back-flow from vessels containing chemical contamination, or operate hydrants in a way that disturbs settled deposits within the water main system.
Other limitations/factors influencing costs	Chemical contaminant(s). Building size. Type of equipment used. Access to contaminated area, including tidiness of houses and amount of 'contents' Thickness of surface covering/layers of wallpaper and/or paint.
Waste	
Amount and type	It is likely that significant quantities of contaminated surface material will be produced. The remaining solid phase may be disposed at a hazardous waste landfill but will be influenced by the chemical (s) involved. There is the potential for degradation products to be produced for chemicals that react with water when undertaking water based methods (e.g. sandblasting). Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous

(12)	Surface removal (buildings)
	waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Options for packaging and conveying the waste, including treating the waste on site or at an off-site facility and the possibility of interim storage if final disposal is not yet available.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	There should be a significant reduction in potential exposure to members of the public living in affected areas. However, it should be noted that these techniques will only reduce exposure to people while they are in particular environment. Averted exposure will be dependent on specific situations and the surfaces cleaned. Averted exposure may be influenced by; Consistency in effective implementation of option over entire area. Weather at time of incident; less material is deposited indoors under wet conditions Application of appropriate clean-up to other indoor surfaces and objects. Time of implementation: maximum benefit is achieved if this option is carried out soon after initial contamination. However, abrasive blasting of external walls of buildings can be effective up for many years after contamination occurs for persistent chemicals. Care of application. Need to remove contamination from surfaces and not just move it around the surface or onto another surface. Amount of time spent inside buildings.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving surface removal as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	
Agricultural impact	None.
Compensation issues	There may be requests for compensation for loss or damage to property, or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

(12)	Surface removal (buildings)
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Other Considerations	Some options may have other side effects (e.g. rationing of water supplies or restrictions on the use of water).

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste EA, SEPA, EHS. Pollution prevention guidelines. 2007. PPG13 Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
Comments	
Document History	

(13) Fixative and strippable coatings

Objective	To reduce exposure arising from contamination on internal or external surfaces of buildings / vehicles and on paved / road surfaces within inhabited areas.
Other benefits	Any other necessary recovery options could be implemented more easily whilst fixative or strippable coatings are in place. Will also prevent the spread of contamination whilst the material is in place.
Recovery option description	Although surface contamination might be removed by other recovery options (e.g. cleaning) some chemical contaminant(s) may remain at appreciable levels within the pores of a surface material. Rather than attempt to remove them by destructive means, a better solution could be to seal them in by using an appropriate surface coating. The presence of any such chemicals would need to be taken into account if a building was to be altered or demolished in future, especially with regards to toxic, persistent chemicals. Fixative and strippable coatings is a specialised recovery option that is likely to require expert advice, and may require specialist suppliers and contractors to undertake remediation of the affected area. **Fixative coatings –** This technique will may protect the population from exposure by forming a barrier (permanent or temporary) between contamination and inhabitants. Alternatively, fixative coatings may reduce the re-suspension hazard of contamination prior to disposal of contaminated items or the implementation of other recovery options. Some fixatives (e.g. 10% glycerol in water) can just be applied as a temporary measure to prevent re-suspension of contamination whilst other recovery options are implemented. For hydrophobic chemicals a wetting agent (surfactant) can be used to increase their affinity for water and enhance the fixative process. Water, acrylic paint (Vinamul), or lignin (a non-toxic waste product from paper production) can be used for temporary fixing of contamination on grassed/soil surfaces. Paints have been used to seal contamination on a permanent basis but the presence of contamination would need to be taken into account if the building was to be modified or demolished in the future. **Strippable coatings –** Some fixative coatings can be strippable and can include absorbent materials or reactive chemicals to aid remediation. Compounds that bind with chemical contaminant(s) are mixed with a polymer and applied to a contaminated surface (usually applied as a liquid or gel). After curing, the polymer is removed by cutting with a sharp knife and peeling. Contamination adheres to the polymer that then requires disposal as a solid active waste. This technique is useful for removing contaminated particles hidden in the cracks, between skirting boards and the floor, as the liquids used are able to penetrate well and dry to an elastic solid. Application of polymer paste (based on PVA) may be considered for removal of contamination from metal surfaces. In particular it can be used for machinery and ventilation systems.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel and contractors and specialist equipment. What surface (i.e. vehicle/ road) or type of building has been contaminated? How will the contaminated waste generated by this option (i.e. solid active waste) be managed and disposed of?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This recovery option could be implemented with other active cleaning methods, including (6) Reactive gases and vapours; (7) Reactive liquids (bleaches, detergents, foams and gels); (10) Pressure washing or (12) Surface removal. (13) Dismantle and disposal of contaminated material
Target	External walls and roofs of buildings. Paved surfaces (roads, pavements, paths, etc) and soil.
Targeted chemicals and important physicochemical properties	This recovery option is most applicable to all persistent chemicals that absorb onto porous surfaces. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical

(13)	Fixative and strippable coatings
	contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, vapour pressure and chemical toxicity (acute and chronic health impacts).
Scale of application	**Varies.** Fixative coating may be applied over relatively large areas but strippable coatings are more suitable for small areas (e.g. houses, pavements, playgrounds). When used on large surface areas strippable coatings can be very difficult to remove intact.
Exposure pathway prevention	Inhalation / dermal (skin) contact / inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out soon after incident when maximum contamination is still on the surface before it can spread in the environment.
Considerations	
Public health considerations	Seek specialist advice and guidance. There is the possibility that the remediation agent may remain in the in environment and pose a public health risk
Legal implications and obligations	Liabilities for possible damage to property Use on listed buildings, historically important sites & conservation areas Solid waste will be subject to waste disposal legislation (for peel-able coatings) Ownership and access to property
Social implications	Potential damage to sensitive surfaces from carrying out this recovery option Access to property Public acceptability of waste treatment and storage routes There may also be issues with the acceptability of chemical contamination remaining in-situ, and public perception of potential future exposure. Method of disposing such a large quantity of contaminated waste may not be acceptable to local residents.
Environmental considerations	None.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Severe cold weather may impede the efficacy of this option Strippable/ peel-able coatings cannot be applied in wet weather
Technical factors influencing effectiveness of recovery option	Type of chemical involved Weather conditions and temperature Type, evenness and condition of surface Time of implementation: the longer the time between contamination occurring and implementation of the option the less effective it will be due to fixing of the contamination to the surface Consistent application of coatings over the contaminated area Viscosity of applied liquids Number of affected surfaces (i.e. buildings and paved areas) that require treatment in the affected area For soil contamination the speed of grass growth may influence the effectiveness, fixative coatings are only likely to be useful as a temporary measure

(13) Fixative and strippable coatings

Feasibility and intervention costs

Specific equipment	Seek specialist advice and guidance. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Other equipment that is likely to be required includes; • Monitoring equipment • Ladders, metal rakes, brushes, scaffolding • Airless spray pump and compressor • Appropriate containers for temporary storage of waste products (solid active waste). • Transport vehicles for equipment and waste.
Utilities and infrastructure	Roads for transport of equipment, materials and waste.
Consumables	Strippable (peel-able) and / or fixative coatings Water Fuel and parts for equipment and transport vehicles.
Skills, personnel and operator time	Seek specialist advice and guidance as specialist personnel and suppliers may be required to undertake this option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident, and types of contaminated surfaces (i.e. bricks, vehicles, ventilation systems).
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers (i.e. recovery workers) will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Weather (the efficacy of this option is influenced by cold or wet weather conditions). Building size/ height/ pitch of roof Type of equipment used Access Evenness of surface Size and scale of the area to be treated

Waste

Amount and type	Fixative coatings will not produce any waste whilst they are in place. However strippable coatings when removed are likely to be highly contaminated and require appropriate disposal. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Options for packaging and conveying the waste, including treating the waste on site or at an off-site facility and the possibility of interim storage if final disposal is not yet available.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods

(13) Fixative and strippable coatings

Exposure

Averted exposure	Whilst a fixative or strippable material is in place exposure should be significantly reduced for those inhabiting or working in the area. Factors influencing averted exposure include; • Consistency in effective implementation of option over a large area. • Population behaviour in area (i.e. amount of time spent indoors/ outdoors). • Weather (efficacy of this option is influenced by wet or cold weather conditions). • Amount of buildings in the area. • Time of implementation. The impact of cleaning the surfaces on the overall exposure will be reduced with time as there will be less contamination on the surfaces due to natural weathering. • Topography (soil)
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving fixative or strippable coatings as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	None.
Compensation issues	There may be requests for compensation for loss or damage to property, or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience

Key references

Comments

Document History

(14)	Dismantle and disposal of contaminated material
Objective	To remove contamination associated with buildings and other contaminated items ranging from cars, street furnishing and personal items.
Other benefits	Will prevent removal of contaminated materials for use elsewhere. Hand deconstruction diverts materials out of landfills redirecting them back into reuse and recycling.
Recovery option description	**Dismantling** refers to the physical removal of selected components (such as contaminated environmental control systems) from equipment. Dismantling could be the sole activity of decontamination efforts or removal of substructures prior to other clean-up techniques, or to expose inaccessible areas of decontamination. **Hand deconstruction** refers to hand dismantling of buildings for maximum salvage, and diverts building material from the waste stream by returning it to homeowners or redirecting it back to the marketplace (i.e. recycling). **Disposal** refers to the complete destruction and or disposal of equipment, parts of equipment or any other parts of the infrastructure by an appropriate disposal route. Significant preparation activities may be required, for example all surfaces may need to be washed down to minimise dust. Toxic residues may also have to be neutralised, stabilised, or removed prior to disposal activities to prevent emissions. Selective/ partial dismantling could take place where furniture or internal/external surfaces are contaminated and in removing components of the building the contamination is removed (doors, windows, wooden panels, soft furnishings etc). In extreme cases roofs could be removed and replaced to remove contamination. Removal of street furnishings would include items such as such as street signs, bus shelters, mainly formed of plastic and painted metal. This option may be expensive and labour intensive and should only be considered if other options are not appropriate for the level of contamination. **Building demolition** techniques used could range from using a ball and crane, controlled explosives, or by pneumatic chisel. In all cases emissions (i.e. dust and particulate matter) will need to be monitored and controlled. For more specialist demolition, buildings could be encapsulated in a scaffolding structure, faced with panels, equipped with a HEPA filtered ventilation system to control dust and particulate emissions. Foundations may be removed (by jack hammers or other means) depending on the size of the building, if required. **Vehicle disposal** any vehicles severely contaminated on external and/or interior contaminated would be stripped down and disposed of accordingly. This may involve towing the vehicle (possibly combined with fixing of contamination) to appropriate site for disposal. Another option could be to dismantle vehicles on site (hand deconstruction). **Internal objects** Internal objects/furnishings that could be considered for disposal include • Small materials removed from the building (e.g., books, papers, pictures, wall hangings) • Small equipment and office items (e.g., staplers, telephones, hand tools) • Large durable materials removed from the building (e.g., furniture, computers, copiers, fax machines, printers) • Building and decorating materials such as carpeting, draperies, window blinds, window air conditioners, ceiling panels, wallboard, and panelling • Mail suspected of contamination • Refuse, food, and other unwanted materials present at the site at the time of contamination. **Decontamination prior to disposal** If a decision is made to dispose of contaminated material / objects the implementation of other recovery options to reduce the amount of contamination in the final waste generated should also be considered
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel and contractors and specialist equipment. What surface (i.e. vehicle/ road) or type of building has been contaminated? How will the contaminated waste generated by this option be managed and disposed of?
Linked recovery options	This is a **remediation option** and should be linked to **protection options** such as (4) Temporary relocation from residential areas or (5) Permanent relocation from residential areas. This technique may be used in conjunction with other decontamination options such as (10) Pressure washing; (11) Vacuum cleaning and (13) Fixative/ strippable coatings to deduce the amount of contamination prior to disposal

(14)	Dismantle and disposal of contaminated material
Target	Highly contaminated buildings or surfaces (including vehicles and internal objects) in an area where exposure concentrations are too high for people to live or work.
Targeted chemicals and important physicochemical properties	This recovery option is applicable for chemicals that pose a risk to public health especially if persistent or toxic chemicals that are otherwise difficult to decontaminate. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, ability to absorb to porous surfaces and chemical toxicity (acute and chronic health impacts).
Scale of application	**Any**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	This recovery option is not time limited and can be implemented at any stage.
Considerations	
Public health considerations	Seek specialist advice and guidance. The dismantling process (e.g. demolishment of buildings) may result in release of contamination (including dust and particulate matter) into the environment.
Legal implications and obligations	The dismantling or demolition of non-residential properties does not require planning permission or prior approval. However, the dismantling or demolition of residential buildings may require approval from the local planning authority, which may impose conditions on the way dismantling or demolition is carried out. Use on listed and other historically important buildings Solid waste treatment and disposal legislation Responsibility for relocating residents or users where this is required.
Social implications	There may be issues with regard to the public acceptability of this option (i.e. people's homes, items vehicles being dismantled or demolished). Temporary relocation of residents in areas immediately surrounding the building in question may be essential during demolition. Public acceptability of waste production, treatment, storage and disposal routes Effects on business, this recovery option could have large financial implications Damage to an inhabited area Distress caused by loss of homes or amenities Public acceptability to aesthetic changes to area This option may not be appropriate for us on listed and other historically important buildings
Environmental considerations	The dismantling process (e.g. demolishment of buildings) can result in release of contamination into environment, and the use of (13) Fixative or strippable coatings should be considered in conjunction to limit this. The disposal or storage of waste arising from the implementation of this option may have an environmental impact. However, this should be minimised through the control of any disposal route and relevant authorisations. If wet weather is present there is the potential of chemical contaminants into groundwater should be considered.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

(14)	Dismantle and disposal of contaminated material
Effectiveness	
Recovery option effectiveness	If carried out effectively should eliminate further exposure to contamination.
Technical factors influencing effectiveness of recovery option	Type of chemical involved Weather conditions
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Specific equipment may vary (dependent on the technique and surface involved) but the following may be required: Monitoring equipment Tools for dismantling/disposing of contaminated material Appropriate containers for temporary storage of waste products. Transport vehicles for equipment and waste
Utilities and infrastructure	Roads for transport of equipment, materials and waste Power supply Water supply
Consumables	Water Fixative coatings (to prevent dust) Fuel and parts for equipment and vehicles
Skills, personnel and operator time	Seek specialist advice and guidance, as skilled personnel are likely to be required to undertake this recovery option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated surfaces (i.e. buildings, roads, paved areas, vehicles).
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Structural engineering reports may be required to assess safety of work. Additional demolition and waste implications may arise such as asbestos. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers (i.e. recovery workers) will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Appropriate safety equipment (hat, boots,) for large scale dismantling / demolition Respiratory protection would be important if there is a risk that dust and particulate matter would be generated. Appropriate safety measures and respiratory protection will be required if asbestos is present.
Other limitations/factors influencing costs	Costs and equipment required will vary according to the scale of contamination and size of structure that requires dismantling or disposal. Other factors influencing costs include; Property type and use (i.e. residential or commercial) Compensation for damage to building/property Weather Size of structure that requires disposal Type of equipment used

(14) Dismantle and disposal of contaminated material

Waste	
Amount and type	Likely to generate large amounts of contaminated material. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. Disposal of waste may be expensive as the assumption (in the absence of sampling and monitoring) will be that all associated waste is contaminated and will have to be disposed of as appropriate. This will have further implications on transport, treatment, disposal and storage.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Options for packaging and conveying the waste, including treating the waste on site or at an off-site facility and the possibility of interim storage if final disposal is not yet available. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required to aid forensic investigation as well as sorting large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	It is likely that individuals would not be inhabiting the area where dismantling or disposal is being implemented. If option is carried out effectively and waste disposed of accordingly it should prevent further public exposure.
Potential increased worker exposure	Consistency in effective implementation of option over entire area Appropriate decontamination of surrounding ground surfaces and vegetation
Other considerations	
Agricultural impact	None
Compensation issues	There may be requests for compensation for loss or damage to property, or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

(14) Dismantle and disposal of contaminated material

Additional information

Practical experience	Bennett S, Bolton P. Operation MSC Napoli. *Chemical Hazards and Poisons report, HPA*. 2009;14:15 . Dunne A, Dobney A, and Hodgson G. Asbestos: The hidden hazard in domestic, educational and health care settings. *Chemical Hazards and Poisons Report* 2010;17:10 Fortunati, GU .The Seveso Lesson: Advances in reclamation and disposal techniques. In: Rappe C, Choudhary G. & Keith LH. (Eds). Chlorinated Dioxins and Dibenzofurans in Perspective. *Lewis.* 1986: 541-553 Goodfellow FJL, Murray VSG. Chemical Incident Response Service, Medical Toxicology Unit, Guy's and St Thomas' Hospital Trust, London, UK. *Chemical incident report*. 2000 (12) 8-9
Key references	Department of health and human services USA. Response to a Ricin Incident: Guidelines for Federal, State, and Local Public Health and Medical Officials. 2006. DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste EA, SEPA, EHS. Pollution prevention guidelines. 2007. PPG13 Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste HM Government. Strategic National Guidance. The decontamination of buildings and infrastructure exposed to Chemical, Biological, Radiological or Nuclear (CBRN) substances or material.2011. Kukadia V, Upton S, Hall D. Control of dust from construction and demolition activities. BREPress.2003. Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(15)	Modify operation/cleaning of ventilation systems
Objective	To reduce exposure from contaminated ventilation systems in commercial and public buildings.
Other benefits	Removal of contamination from the area and prevent redistribution of contamination in buildings.
Recovery option description	**Reduce spread of contamination – interior release** Strategies for reducing the spread of contamination through building conditioning systems may include rapidly isolating all air handling unit (AHU) fans and closing all heating ventilation air conditioning (HVAC) dampers, including exhaust dampers. This could be implemented in the response (emergency) phase of a chemical incident to reduce the spread of contamination if an incident occurred inside a building . **Reduce spread of contamination – exterior release** Significant contamination of building interiors following an exterior airborne release may be relatively unlikely, except for large-scale events. HVAC systems can be shut down if an exterior release is identified, but some ingress can potentially occur through 'leaks' in the building envelope including the main and ancillary entrances **Ventilation** HVAC system operation can be maintained and flushed with fresh air to dilute the internal contamination. Gases and volatile liquids mainly contaminate building air and may be removed by appropriate ventilation within a few hours. This process can be combined with increasing the temperature within the building via the heating system (**enhanced ventilation**) to quicken this process and to desorb any chemicals from surfaces within the building. Would need to consider installing filters in HVAC system to limit spread of contamination outside building. **Underground transport networks -** Disabling ventilation systems may need to be considered if contamination has occurred on an underground transport network (i.e. London underground). Once evacuation has taken place, shutting down ventilation systems may prevent the spread of contamination to the outdoor environment (e.g. streets). **Cleaning -** Ventilation systems may become heavily contaminated and are not very easy to decontaminate or clean. Potential cleaning options will vary dependant on the chemical involved. A significant quantity of chemical contamination may be removed by exchanging the air filters from industrial buildings, mainly from ventilation systems and heaters.
Key information requirements	Are the HVAC plans for the building available? What is the size and scale of the incident? Are skilled personnel and specialist equipment required?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This recovery option could be used in conjunction with (7) Reactive gases and vapours; (9) Other water based cleaning methods (scrubbing, shampoo, steam cleaning) and (11) Vacuum cleaning to facilitate decontamination.
Target	Contaminated air handling unit (AHU) and heating ventilation air conditioning (HVAC) units within buildings.
Targeted chemicals and important physicochemical properties	This recovery option is applicable for persistent and toxic chemicals that could be dispersed via a buildings ventilation system (i.e. volatile liquids). However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, physical form, vapour pressure and chemical toxicity (acute and chronic health impacts).
Scale of application	Any.
Exposure pathway prevention	Inhalation of chemical contamination.

(15)	Modify operation/cleaning of ventilation systems
Time of application	Maximum benefit if carried out shortly after contamination. Can have a significant effect on reducing contamination levels even if applied at a late stage for persistent chemicals
Considerations	
Public health considerations	Seek specialist advice and guidance, as there may be a need to consider chemical contamination dispersal outside of the building
Legal implications and obligations	Liabilities for possible damage to property. In some cases, small-scale demolition may be necessary as part of the process of making building modifications. Most demolition of non-residential properties does not need planning permission or prior approval.
Social implications	It may be difficult for recovery workers to access ventilation systems to clean them effectively Reassurance of employees and users of the building that chemical contamination has been removed, and maintaining continuity of work.
Environmental considerations	Electronic parts may be damaged by water if not dismounted,
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	The effectiveness of this option will depend on which strategy is employed e.g. whether to use the ventilation system to induce fresh air into a building or to expel contaminated air out of a building. It will depend on the specification of the individual air ventilation system.
Technical factors influencing effectiveness of recovery option	HVAC systems can be shut down if an exterior release is identified, but some ingress is then likely to occur through ‘leaks’ in the building envelope including the main and ancillary entrances. Operator skills / knowledge of specific ventilation system. Technical difficulties in accessing and cleaning contaminated areas Pressure and amount of water for high pressure water treatment. Water temperature: because the air outlet channels, in particular may be greasy and contain dust; a high water temperature (>60 ºC) is required to ensure a high reduction in contamination levels. However, it should be noted that the inlet channels are usually the most contaminated. Need to be aware of potential build-up of flammable natural gases (e.g. methane and radioactive radon) in poorly ventilated underground spaces
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance, as skilled personnel are likely to be required to undertake this recovery option. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Other equipment that is likely to be required may include; Monitoring equipment Brushes, vacuum device Appropriate containers for temporary storage of waste products. Transport vehicles for equipment and waste 'Dust trap' filter and/or 'NORCLEAN' type industrial vacuum cleaner and/or high pressure water washer Grinding machines Other hand tools.

(15)	Modify operation/cleaning of ventilation systems
Utilities and infrastructure	Transport vehicles for equipment. Scaffolding or mobile lifts for tall buildings, where channels may be mounted under the ceiling.
Consumables	Water supply. Pressurised air supply.
Skills, personnel and operator time	Seek specialist advice and guidance, as skilled personnel are likely to be required to undertake this recovery option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of contaminated buildings or ventilation systems that require remediation.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers (i.e. recovery workers) will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Appropriate safety equipment (hat, lifelines, waterproof safety clothing, boots). Respiratory protection would be important if there is a risk that dust and particulate matter would be generated dust. Appropriate safety measures and respiratory protection will be required if asbestos is present.
Other limitations/factors influencing costs	Need for scaffolds/ mobile lifts, and potential need for different types of treatment (dependant on e.g., channel sizes and other ventilation system characteristics). Cost of specialist labour.
Waste	
Amount and type	Cleaning ventilation systems is likely to generate moderate amounts of contaminated waste material. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance. **Solid waste:** 50 – 100 g / m^2 **Dry waste:** is collected in vacuuming filters that are relatively easy to dispose. **Liquid waste:** from pressure washing can mostly be collected and filtered with the industrial vacuum cleaner, so that the water is cleaned and sludge is left.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Spent filters/ absorbent material may be collected as solid waste and disposed of via landfill or incineration.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	Inhalation of chemical contaminants. Factors influencing averted exposure include; Consistency in effective implementation of option throughout the affected ventilation system Appropriate decontamination of surrounding surfaces (i.e. walls, floors and ceilings)

(15) Modify operation/cleaning of ventilation systems

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the modification/ cleaning of ventilation systems as a remediation technique. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	N/A
Compensation issues	There may be requests for compensation for loss or damage to property, or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products and services. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Other considerations	The public perception (and that of work force) may be a larger and irrational issue that's difficult to overcome. Ongoing health monitoring and surveillance may be required to ease the public's mind or the addition of extra carbon filters etc.

Additional information

Practical experience	Health and Technical Assistance for the World Trade Centre (WTC) Dust Cleaning Program (Final Report) OSHA activity. 2003. Available at: http://www.osha.gov/nyc-disaster/wtc-final-residential-dust-cleanup-program.pdf
Key references	Communities and local government Good practise and guidance. Precautions to minimise effects of a Chemical, Biological, Radiological or Nuclear Event on Buildings and Infrastructure. 2004. Royal Society. Making the UK safer: detecting and decontaminating chemical and biological agents. 2004. DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(16)	Cleaning vehicle ventilation systems
Objective	To reduce potential exposure to chemicals that may contaminate a vehicles engine/ ventilation system during an incident
Other benefits	Decontaminating the internal and external parts of an engine may reduce the amount of other pollutants released by vehicles.
Recovery option description	Following a chemical incident chemical vapour or a chemical plume could contaminate a vehicles engine/ ventilation system. This would be potentially enhanced by a vehicle driving through a contaminated cloud as the vehicle's engine would be running and increase uptake via the ventilation system. If contamination occurs, there is a risk that the contamination could be released next time the vehicle is operated and therefore pose a health risk to the vehicles occupants. This recovery option could be implemented by opening all doors and windows of a vehicle and to run the engine with air conditioning on full power for an extended period of time until all contamination has dispersed. Ideally, ventilation systems should be cleaned prior to decontamination of the interior and exterior surfaces of the car to prevent repeated cleaning operations. The removal of air filters from car ventilation systems should also be considered as this can remove a significant quantity of contamination present in the ventilation systems.
Key information requirements	Are skilled personnel and specialist equipment required? How will the contaminated waste generated by this option be managed? What is the economic impact of this option? (i.e. is it more economical to replace the vehicle?)
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. Appropriate decontamination of internal and external surfaces of vehicle would be required following implementation of this option, see (6) Reactive gases and vapours; (8) Physical decontamination techniques and (9) Other water based cleaning methods. In more extreme cases a vehicle may need to be dismantled to clean the ventilation systems more extensively although; however, this would need to be balanced against the cost of disposing of the vehicle, see (14) Dismantling and disposal of contaminated material.
Target	Vehicle engines and ventilation systems
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all volatile chemicals and chemically contaminated dust. However, the physicochemical properties and the physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include physical form (solid, liquid or gas), persistence and volatility.
Scale of application	All vehicles potentially exposed to a chemical plume
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination
Time of application	As soon as possible after contamination to reduce the spread of contamination via vehicle ventilation systems
Considerations	
Public health considerations	None
Legal implications and obligations	Liabilities for possible damage to vehicle Ownership and access to vehicle

(16)	Cleaning vehicle ventilation systems
Social implications	It may be difficult for recovery workers to access ventilation systems to clean them effectively Acceptability of car being dismantled for decontamination purposes Damage may be caused to vehicle during the cleaning process
Environmental considerations	There is a risk of chemical contamination being released directly into the environment.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	If performed soon after contamination, this recovery option should prevent any further exposure to any users of the affected vehicle.
Technical factors influencing effectiveness of recovery option	Appropriate decontamination of internal and external surfaces of vehicle would be required following implementation of this option (see other recovery options) Technical difficulties in accessing and cleaning contaminated areas Time of implementation: The use of the vehicle may result in chemical being released into the environment or interior of the car. Cost and time to undertake sampling and monitoring to demonstrate effectiveness can delay the return of a vehicle asset. Also the cost may outweigh the benefit of implementing this option.
Feasibility and intervention costs	
Specific equipment	Transport vehicles for equipment, materials and waste. Appropriate equipment to dismantle engine
Utilities and infrastructure	Roads for transport of equipment, materials and waste.
Consumables	Potentially new engine parts, oil
Skills, personnel and operator time	Methods apart from running air conditioning are likely to require skilled mechanics to remove/ dismantle engine.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers (i.e. garages) will have to comply with the Health and Safety at Work Act to ensure that mechanics (recovery workers) use appropriate PPE and follow Standard Operating Procedures (SOPs). Appropriate safety equipment (overalls, gloves and boots) are provided. Respiratory protection may be required if the chemical contaminant is an inhalation hazard and health risk.
Other limitations/factors influencing costs	Type of vehicle requiring decontamination Cost of decontamination compared to the cost for disposal of the vehicle would have to be evaluated.
Waste	
Amount and type	This recovery option may generate liquid wastes from decontamination of ventilation systems. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of ‘hazardous waste’. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.

(16) Cleaning vehicle ventilation systems

Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Spent filters/ absorbent material may be collected as solid waste and disposed of via landfill or incineration.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	Will vary dependent on the surfaces contaminated within a car engine. If implemented effectively like to reduce potential exposure significantly. The consistency of how this option is implemented may influence averted exposure (as it could be quite complicated).
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). There could be Union involvement that may result in problems trying to return assets back to their former owners e.g. Fire and Rescue service, etc. Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving cleaning of vehicle ventilation systems as a remediation technique. Exposure pathways recovery workers could be exposed to are: Dermal /inhalation exposure from contamination in environment and equipment Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	
Agricultural impact	N/A
Compensation issues	There may be requests for compensation for loss or damage to property, or loss of earnings as this recovery option may restrict the movement of transport, e.g. goods, products and services. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk Vehicle insurance is unlikely to cover CBRN incidents. Business and first responders would need to check with their insurers as this may influence the appropriateness of this recovery option.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

(16)	Cleaning vehicle ventilation systems

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
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(17)	Storage, covering, gentle cleaning of precious objects/personal items
Objective	To reduce exposure arising from contamination on personal items (i.e. mobile phones, credit cards, and prosthetic limbs) and precious objects within inhabited areas.
Other benefits	Gentle cleaning will remove contamination from precious objects within buildings.
Recovery option description	It may not be possible or appropriate to carry out decontamination of precious objects, such as museum artefacts, tapestries, jewellery, paintings, due to the risk of damaging the objects during the cleaning process. Important personal items such as mobile phones, keys, credit cards, prosthetic limbs and jewellery also need to be considered. Several alternative options are available for such objects. Some precious objects, which do not require handling, could be placed in protective casing or covered. For instance, museum artefacts could be placed behind glass or Perspex; the objects can then remain on display, but the public would be protected from the contamination. Specialist gentle cleaning techniques could be considered for other objects and personal items. In some cases this option may be implemented for public reassurance purposes if the risk of adverse health effects arising from chemical contamination of personal and precious objects is likely to be low. A novel method is under development for decontamination of personal objects using radiofrequency (RF) Gas Plasma. This technique has been shown to be effective for removing malathion and halogenated phenols in experimental studies. This method involves placing personal items such as mobile phone, jewellery, spectacles, credit cards into a decontamination chamber for a specified period of time. Photochemical bleaching of items is a noted side effect. More information on radio-frequency gas plasma and other experimental techniques is available in the Appendix A.
Key information requirements	
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. In the case of extensive contamination that cannot be removed via gentle cleaning, appropriate disposal may need to be considered, see (14) Dismantling and disposal of contaminated material This recovery option could also be potentially linked to; (7) Reactive gases and vapours and (9) Other water based cleaning methods (scrubbing, shampoo, steam cleaning).
Target	Precious and personal objects within buildings.
Targeted chemicals and important physicochemical properties	This recovery option is applicable for persistent chemicals that are otherwise difficult to decontaminate. However, the physicochemical properties or physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, and ability to absorb to porous surfaces, surface tension and chemical toxicity (acute and chronic health impacts).
Scale of application	Small objects.
Exposure pathway prevention	Inhalation / skin contact / inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out soon after incident
Considerations	
Public health considerations	None
Legal implications and obligations	Liabilities for possible damage to objects Ownership and access to objects Use in listed or other historic buildings

(17)	Storage, covering, gentle cleaning of precious objects/personal items
Social implications	Potential damage to valuable items Decision to retain some objects and dispose of others could have social repercussions (i.e. credit cards, keys or prosthetic limbs). Possible damage of objects with particular heritage significance. Lack of access to objects and buildings by the public
Environmental considerations	None
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Will vary dependent on the chemical involved, size of the object and type of material contaminated.
Technical factors influencing effectiveness of recovery option	Type, condition and fragility of objects or personal items Value of object/item Time of operation (contamination migrates elsewhere over time) Consistent application of cleaning over entire object Amount of dust on the surface of the object at the time of incident Whether any cleaning has already been undertaken.
Feasibility and intervention costs	
Specific equipment	Specialist cleaning equipment for gentle cleaning.
Utilities and infrastructure	Power and water supplies Storage facilities
Consumables	Protecting materials (i.e. glass, Perspex, ziplock bags) Cleaning materials (swabs, cotton buds) Cleaning solutions (mild detergents or soap).
Skills, personnel and operator time	This recovery option may require specialist cleaning and handling skills. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident and types of personal items or precious objects that are contaminated.
Safety precautions	Gloves and overalls.
Other limitations/factors influencing costs	
Waste	
Amount and type	Waste water may be generated from cleaning; however unlikely to be a large quantity. Solid waste (i.e. cotton buds, swabs and cleaning clothes). Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Spent cleaning materials (i.e. cotton buds, swabs and clothes) may be collected as solid waste and disposed of via landfill or incineration.

(17)	Storage, covering, gentle cleaning of precious objects/personal items
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Solids should be transported in bulk transport units fitted with a liner that can be closed for transport or in sift-proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	Cleaning objects will only reduce exposure to people while they are indoors and will be very dependent on the specific situation and the objects and other surfaces cleaned. Factors influencing averted exposure include; • Weather at time of incident; less material from a chemical plume would be deposited indoors during wet conditions. • Appropriate clean-up of other indoor surfaces and objects.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the cleaning of personal items/ precious objects as a remediation technique. Exposure pathways recovery workers could be exposed to are: Dermal /inhalation exposure from contamination in environment and equipment Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.
Other considerations	
Agricultural impact	N/A
Compensation issues	There may be requests for compensation for loss or damage to personal property, or being displaced from home (i.e. credit cards, keys and prosthetic limbs seized by police). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Other considerations	Storage, containment and cleaning may be expensive and take time. Also, the cost to replace the item should be evaluated, as the uniqueness of the item may influence the applicability of this option.
Additional information	
Practical experience	Dunne A, Dobney A, and Hodgson G. Asbestos: The hidden hazard in domestic, educational and health care settings. Chemical Hazards and Poisons Report 2010;17:10

(17) Storage, covering, gentle cleaning of precious objects/personal items

Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(18)	Natural attenuation (with monitoring)
Objective	This is a passive option to allow the natural degradation or dispersal of a chemical naturally within the environment (e.g. internal building structure or external building surface) until it poses little or no hazard to inhabitants.
Other benefits	No active implementation required, therefore overall cost likely to be lower than many active remediation technologies. As this option involves monitoring, this can have a positive impact on the affected population.
Recovery option description	Natural attenuation processes include a variety of physical, chemical or biological processes that, under favourable conditions, act without human intervention to reduce the mass toxicity, mobility, volume or concentration of contaminants in the environment. These processes include; • **Destructive mechanisms**; biodegradation, destruction, oxidation and hydrolysis • **Non-destructive mechanisms**; sorption, dispersion, dilution, and chemical or biological stabilisation or transformation, and volatilisation. Monitoring of affected areas is required to confirm whether natural attenuation processes are acting at a sufficient rate to ensure that the wider environment is unaffected and that remedial objectives will be achieved within a reasonable timescale. However, allowing chemical contamination to attenuate within a building environment will be extremely restricted. Opening windows and doors may accelerate the clearance of volatile compounds but there would need to be consideration for the outdoor environment. In some cases, increasing the air flow within a building may accelerate clearance of a particularly volatile compound (see (15) Modify operation/ cleaning of ventilation systems) but in some cases (e.g. contaminated dust) this option could exacerbate contamination spread. The environment into which a chemical is released can also determine how feasible this recovery option would be. For instance, it may be more acceptable to let a persistent chemical degrade in the environment in a rural area that is rarely used whereas an important commercial district or critical facility may require more urgent remediation strategy due to social pressures.
Key information requirements	To properly evaluate this recovery option, it is necessary to know the location, concentration of the contaminant, and how the contaminants behave in the environment (i.e. physicochemical properties) • Are there sufficient site data to support monitored natural attenuation is a viable recovery option? • Do the site characterisation data and results of modelling demonstrate that natural attenuation is occurring and can achieve the risk management objectives? • Is the monitoring programme sufficiently robust? Do the results of the monitoring demonstrate that remedial goals have been achieved and monitoring can cease?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. This option can be used in conjunction with, or after, other remediation methods such as; (15) Modify operation/ cleaning of ventilation systems
Target	Potentially all surfaces but more effective in outdoor environments.
Targeted chemicals and important physicochemical properties	This recovery option is applicable for volatile organic compounds (halogenated and non-halogenated) but in populated areas should only considered for chemicals with short persistency. For instance this would not be a potential option for heavy metals, PCB's or dioxins. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility and chemical toxicity (acute and chronic health impacts). This option will be influenced by the nature of the environment in which the contaminant is found.
Scale of application	**Any**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination

(18)	Natural attenuation (with monitoring)
Time of application	This recovery option can be implemented from the early to late phase (hours – years) of a chemical incident. This recovery option may take several decades to arrive at a satisfactory outcome.
Considerations	
Public health considerations	Volatilisation can present some health risks, e.g. by migration of vapour through the vadose zone into buildings.
Legal implications and obligations	There is legislation linked to the enforcement and control of natural attenuation as a remedial option. Depending on the nature of the contamination, in consultation with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland or the Northern Ireland Environment Agency (NIEA) will be required. Some of the activities that are associated with monitored natural attenuation may themselves be subject to regulatory control.
Social implications	Acceptance of monitored natural attenuation requires liaison and agreement with various stakeholders (landowners, insurers, financiers and prospective purchasers) and the relevant regulators. Regular consultation is recommended throughout the screening, demonstration, assessment and implementation stages of this recovery option. Public may perceive this option as “doing nothing” which can have negative implications.
Environmental considerations	Unsuitable weather conditions e.g. lack of rain/ wind or sun. Degradation may lead to the generation of intermediate products with greater toxicity/ mobility than the parent compound. Potential for spread of contamination in environment.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Seek specialist advice and guidance. The effectiveness of this option is directly linked to the physicochemical properties of the chemical and behaviour in different environments and surfaces.
Technical factors influencing effectiveness of recovery option	This recovery option may take from hours several decades to arrive at a satisfactory outcome; therefore this potentially long-term time frame makes this recovery option susceptible to changes in various technical, economic and regulatory conditions, including land-use and legislative changes. These factors need to be considered in the design and application if natural attenuation (with monitoring) is selected as a long-term remediation strategy. Weather conditions, e.g. if a dry period (e.g. drought) effectiveness would be reduced. Temperature could affect the volatilisation of chemicals and hence their persistence. Also, if certain outdoor surfaces are protected from rainfall (e.g. bus shelter) contamination would potentially persist for longer. Similarly, chemicals may persist for different periods depending on the surface contaminated. In addition, the level of perceived or actual risk will influence the appropriateness of implementing this recovery option, including; • Sensitivity of the site (presence and proximity of vulnerable receptors); • Hazardous properties of the chemical contamination (mobility, persistence and toxicity, and the potential to degrade to other substances with these properties); • Seriousness of the pollution (e.g. List I and II substances under the EC Directives); The level of uncertainty in the definition of the conceptual model and in assessment/ monitoring data available.
Feasibility and intervention costs	
Specific equipment	Screening and monitoring equipment
Utilities and infrastructure	Capacity to analysis samples (i.e. laboratory facilities).

(18)	Natural attenuation (with monitoring)
Consumables	None
Skills, personnel and operator time	Seek specialist advice and guidance. Skilled personnel may be required to undertake monitoring and analysis.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance.
Other limitations/factors influencing costs	There is the potential for the long-term monitoring for many years (decades), which will require significant financial provision; other recovery options may provide a more favourable cost-to-benefit ratio; there is also a risk that data may confirm that active remediation is required after all. Finally, the cost of developing contingency plans may be prohibitive.
Waste	
Amount and type	No waste is generated using this option. However, note that contaminated land may be classified as waste (but excluded from most waste controls).
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	If chemical does not persist in environment, exposure may be reduced but maybe not as quickly as if cleaning techniques were used
Factors influencing averted exposure	Weather conditions, season.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers (i.e. specialist personnel undertaking sampling and monitoring) could be exposed to chemical contaminant(s) may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving natural attenuation. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included. Incremental exposure to the public will be influenced by their knowledge, understanding and compliance of associated advisory notices, warning about the incident.
Other considerations	
Agricultural impact	Potential for spread of contamination in environment
Compensation issues	There may be requests for compensation loss of earnings as this recovery option may restrict the movement of transport and tourism into an area (i.e. land is perceived as blighted). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.

(18) Natural attenuation (with monitoring)

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Acceptance of monitored natural attenuation requires liaison and agreement with various stakeholders (landowners, insurers, financiers and prospective purchasers) and the relevant regulators. Regular consultation is recommended throughout the screening, demonstration, assessment and implementation stages of this recovery option. Potential concerns could be raised due to the civil liabilities associated with migration of contamination between neighbouring properties; therefore communication of site monitoring is of key importance.
Other considerations	Some breakdown products may be more toxic than original contaminants, degradation rates may drop, contaminants may not behave as predicted, these factors call for a long term commitment to monitoring and a contingency plan.

Additional information

Practical experience	Bennett S, Bolton P. Operation MSC Napoli. Chemical Hazards and Poisons report, HPA. 2009;14:15
Key references	Communities and local government Good practise and guidance. Precautions to minimise effects of a Chemical, Biological, Radiological or Nuclear Event on Buildings and Infrastructure. 2004. DEFRA research project final report: contaminated land remediation. CL:AIRE. Nov 2010. EA- Guidance remediation position statements. 2007 HM Government. Strategic National Guidance. The decontamination of buildings and infrastructure exposed to Chemical, Biological, Radiological or Nuclear (CBRN) substances or material.2011. Home Office. The release of Chemical, Biological, Radiological or Nuclear Substances or Materials. Guidance for Local Authorities. 2003.
Comments	
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(19) Outdoor surface removal and replacement

Objective	To reduce exposure from contamination on roads, paved and other outdoor areas such as soil within inhabited areas.
Other benefits	Improvement in overall condition of outdoor surfaces. Removed hard surfaces can be treated or left to attenuate and then recycled e.g. as hardcore. Soil can be removed and cleaned e.g. thermal desorption or solvent systems, and replaced (as with the Olympic park, Stratford, London).
Recovery option description	The most common forms of hard outdoor surfaces include; tarmac or concrete slabs. **Roads/paved areas**: Standard machinery to remove asphalt surfaces is available in different sizes. They have a rotating drum with cutting teeth which conveys planed material (about 40 mm thick) to the middle of drum where it is pushed on to a conveyor belt and from there to flatbed truck. If machines do not have brushes for debris collection, this must be added or manual sweeping carried out. Water is sprayed continuously onto the drum to suppress dust. Typical highway maintenance machinery can remove a width of about 2 m per pass. Replacing/resurfacing asphalt and concrete roads can be undertaken using standard equipment. For replacement in small areas, manual methods are likely to be used, i.e. tarmac is deposited in several places and spread by shovel and rake, then tamped. For small surface areas it may also be possible to use a jackhammer to loosen existing tarmac and rubble can be shovelled into wheelbarrows. However, this has not been trialled. A small excavator/bob-cat can be used to remove concrete slabs. Concrete slabs are replaced by hand. The need to resurface asphalt and concrete surfaces will depend on the depth removed and other factors, such as acceptability. The area can be repaved with hot rolled asphalt or concrete paving machine to relay concrete. **Soil surfaces**: A layer of asphalt (or alternatives, e.g. concrete or paving stones) can be applied over small areas adjacent to buildings. This measure will provide protection from contamination on the ground area. It is likely to be considered for reducing exposure from residual contamination after removing a topsoil layer, as soil very close to a building may, in some cases, be contaminated to a greater depth, due to water run-off.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel, contractors and specialist equipment. What type of surface (i.e. roads or parklands) has been contaminated? How will the contaminated waste generated by this option be managed and disposed of?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. This option is likely to give rise to dust, so application of water to dampen the surface or the use of another temporary fixative is recommended prior to implementation to limit the re-suspension hazard, see; (12) Surface removal (buildings). Alternatively, fresh soil can be placed over an area of contamination potentially after topsoil removal see (21) Ploughing/ digging methods to act as a protective barrier from contamination. This technique could also be used as a temporary fixing method if there is volatile chemical contamination within the soil.
Target	Outdoor surfaces (roads, pavements, paths, soil, parks etc)
Targeted chemicals and important physicochemical properties	This recovery option is applicable for persistent chemicals and those that absorb to porous surfaces, or with a low mobility in soil. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, ability to absorb to porous surfaces, soil adsorption and chemical toxicity (acute and chronic health impacts).
Scale of application	Any size of road or paved area
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination

(19) Outdoor surface removal and replacement

Time of application	Maximum benefit if carried out soon after incident when maximum contamination is on the surfaces. However surface removal may be effective for long periods after chemical contamination (this is linked to physicochemical properties of the chemical contaminant and behaviour in the environment).
Considerations	
Public health considerations	This option is likely to give rise to dust, which may raise public health concerns within the local population of sensitive groups.
Legal implications and obligations	Liabilities for possible damage to property Ownership and access to property Use in conservation areas or at listed sites
Social implications	Damage to roads, soiled areas Damage can also confirm public perception of the seriousness of the incident. But, the damage also shows positive action which can reassure public. Effects on transport Aesthetic issues
Environmental considerations	Severe cold weather may affect asphalting technique (>5 degrees C) Acceptability of smothering flora and fauna Public acceptability of waste treatment and storage routes
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	Reductions in exposure received by a member of public living in the area will depend on the amount of contamination and the area covered by outdoor hard surfaces and the time spent by individuals on or close to these areas. Repeated application is unlikely to provide any significant increase in decontamination.
Technical factors influencing effectiveness of recovery option	Evenness and condition of roads/soiled areas Operator skill Ineffective removal of contamination around drains and in gutters Removal of loose debris from surface Consistency in effective implementation of option over a large area Whether decontamination is carried out on adjacent surfaces Thickness of soil layer used (when placed over contamination) Risk of chemical contamination of any nearby ground/surface waters, hydrogeology of area needs to be considered
Feasibility and intervention costs	
Specific equipment	Seek specialist advice and guidance as outdoor surface removal and replacement is likely to be undertaken by specialist suppliers and contractors. DEFRA maintains a framework of specialist suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service Specific equipment may vary (dependent on the technique and surface involved) but the following may be required: Monitoring equipment Small scale planer, shovel, tamper, wheelbarrow, lorry, Planer with conveyor, Paving machine, road sweeper, roller, JCB, lorry, rake, bobcat mini-bulldozer. Appropriate containers for temporary storage of waste products. Transport vehicles for equipment and waste

(19)	Outdoor surface removal and replacement
Utilities and infrastructure	Roads (transport of equipment, materials and waste)
Consumables	Tarmac or concrete or concrete paving slabs Tungsten carbide teeth Fuel and parts for equipment, generators and vehicles
Skills, personnel and operator time	Skilled personnel essential to operate equipment. Covering with clean soil could be implemented on a small scale by unskilled workers.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers (i.e. recovery workers) will have to comply with the Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs). Appropriate safety equipment (hat, boots, safety goggles and overalls) for large outdoor surface removal and replacement may be required. Respiratory protection would be important if there is a risk that dust and particulate matter would be generated.
Other limitations/factors influencing costs	Costs and equipment required will vary according to the scale of contamination and size of area that requires surface removal and replacement. Other factors influencing costs include; Compensation for damage to buildings/property Weather Topography of the area (evenness and condition of surface affects grinding depth) Size of area to be remediated Type of equipment used/ planer size, sweeping equipment Access to the affected site.
Waste	
Amount and type	Likely to generate large amounts of contaminated tarmac, soil or concrete (dependent on the area remediated), which may require decontamination and specialist equipment (i.e. JCBs) and disposal. Asphalt: about 15 kg m^{-2} per cm removed Paving slabs (concrete): about 30 kg m^{-2} per cm removed Waste depends on thickness removed and density of material Cover Grass/soil with asphalt: 15 m^2/team per hour (team size: 4 people) Cover with clean soil: Small areas: 2 10^1 m^2 h^{-1} per team (team size: 1) Large areas: 4 10^2 m^2/team.hr (team size: 2) Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required to aid forensic investigation as well as sorting large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is

	subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods

Exposure

Averted exposure	If this recovery option is implemented effectively contamination and further exposure is likely to be limited. However further re-development of contaminated surfaces (e.g. future road or building works) could result in re-exposure.
Factors influencing averted exposure	Consistency in effective implementation of option over a large area Behaviour of the population in the affected area (i.e. time spent indoors/ outdoors). Environment type / land use Whether decontamination is carried out on adjacent paved surfaces.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving outdoor surface removal and replacement. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	N/A
Compensation issues	There are likely to be requests for compensation for loss of earnings from measures which restrict the movement of transport, e.g. goods, produce and services. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	The Olympic site (Stratford, London) has used a lot of soil cleaning technologies.
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
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(20) Soil and vegetation removal

Objective	To reduce exposure from contamination on outdoor grassed and soil areas within inhabited areas.
Other benefits	Removal of contamination from grassed and soil areas. Removal of contaminant from grass areas in gardens may reduce subsequent contamination of soil used for growing food. This in turn may reduce up-take by food crops grown.
Recovery option description	There are a variety of techniques that could be used, dependant on the type of outdoor area involved and the level of contamination. ***Grass cutting and removal -*** Grass in the affected area is mown and cuttings collected. The grass cutting height should be as low as possible. This option is likely to give rise to dust. Temporary fixative coatings are not recommended prior to grass cutting and removal. ***Plant and shrub removal -*** A portable brush cutter or forage harvester (depending on the size of the area being remediated) is used to remove plant growth. Waste vegetation is removed by loading into trailers. Replanting is likely to be required. Temporary fixative coatings are not recommended prior to plant and shrub removal. ***Topsoil and turf removal -*** Turf and the top 50 mm (may vary according to chemical) of topsoil may be removed using a spade (manual) or by bobcat mini bulldozers (mechanical). Any plants and shrubs would need to be removed first. Temporary fixative coatings (such as water) should be considered prior to implementation to minimise dust. ***Turf Harvesting -*** Turf is removed, optionally followed by reseeding or re-turfing. Removal is carried out using a turf harvester which skims off a thin layer of soil/root mat (about 1 cm) with the turf in rolls or slabs, and machines are available in various sizes. ***Collection of leaves -*** Collection of leaves (deciduous trees & shrubs), needles and pinecones (coniferous trees). Leaves that have fallen from trees are collected and disposed of or composted. Additional decontamination may also be necessary for surfaces under trees/shrubs. ***Tree and shrub pruning/ removal -*** Removal or heavy pruning of trees and shrubs with the option of replacement. Most importantly, leaves must be removed. If tree felling is conducted on a small scale, incineration of the waste is an option. Temporary /fixative coatings are not recommended with this procedure. Smaller pruning and leaves can be shredded for composting.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel, contractors and specialist equipment. What type of outdoor environment (i.e. parkland or farmlands) has been contaminated? How will the contaminated waste generated by this option be managed and disposed of?
Linked recovery options	This is a **remediation option** and should be linked to **protection options** such as (1) restrict public access. Temporary fixative coatings (13) fixative/ strippable coatings such as water should be considered prior to implementation some of these techniques to minimise dust.
Target	Soil and vegetation in inhabited areas
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent chemicals, and those with low mobility in soil. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, water solubility, soil adsorption and chemical toxicity (acute and chronic health impacts).
Scale of application	On small to large scale dependant on technique used
Exposure pathway prevention	Inhalation, dermal (skin) and inadvertent ingestion of chemical contamination
Time of application	Maximum effectiveness will be achieved soon after contamination has occurred before natural weathering can occur. Can be applied later for chemicals that remain in the top layer of soil.

Considerations

Public health considerations	Seek specialist advice and guidance. There is a possibility of chemically contaminated dust and particulate matter being produced using some of these methods.

(20) Soil and vegetation removal

Legal implications and obligations	Part 2A (Environment Protection Act 1990) Contaminated land Liabilities for possible damage to property. Ownership and access to property. Appropriate recovery/ disposal of collected waste. Use on listed or conservation areas or sites of special scientific interest.
Social implications	Access/ acceptability for people's gardens/ recreational areas. Aesthetic issues
Environmental considerations	Extreme cold weather could reduce the effectiveness of this option Soil texture - turf harvesting equipment is very sensitive to stones and rocks. In extreme cases, the slope of the area may be a constraint. This option may also pose a soil erosion risk This option may have possible adverse impact on bio-diversity and ecology in the affected area (may cause loss of plants, shrubs and soil fertility).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	If recovery option is implemented effectively further exposure is likely to be reduced or eliminated.
Technical factors influencing effectiveness of recovery option	The depth to which chemical contamination has moved into soil Weather conditions, particularly those at the time of contamination and the amount of rain following contamination. Collection of leaves would be influenced significantly by the season. Correct implementation of option – all contaminated soil and vegetation should be collected to work effectively. For chemicals that have migrated below 50 mm in the soil, this option is less effective unless the depth of removal is increased. Soil texture: dry, crumbly soils will be more difficult to remove Topography of the affected area (i.e. evenness of ground) Amount of the area with grass/soil/vegetation coverage Time of operation (contamination migrates into the soil over time)

Feasibility and intervention costs

Specific equipment	Seek specialist advice and guidance, as specialist equipment may be required. Specific equipment will depend on the size of the area being treated and the technique employed, and may include; mower, brush cutter, tractor, rake, spade, motorised scraper, grader or bulldozer More specialist equipment may include; seeding machine, chainsaw, axes / cutters, ropes and ladders (for tall trees) and shredder. An incinerator may be used for waste from small areas Transport vehicles and containers for equipment and waste
Utilities and infrastructure	Roads (transport of equipment, materials and waste) Power supply
Consumables	Fuel and parts for vehicles and equipment Plants and turf or grass seed (if required).
Skills, personnel and operator time	Seek specialist advice and guidance. DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service For some of these techniques only a little instruction is likely to be required (e.g. grass cutting/ plant and shrub removal). However, they may require hard physical work, which not all persons would be capable of. They could, to some extent, be implemented by inhabitants of the affected area as a self-help measure, after instruction from authorities and provision of safety and other required equipment. Skilled personnel are required to operate brush cutters and forage harvesters and equipment for tree felling.

(20)	Soil and vegetation removal
Safety precautions	Under very dusty conditions respiratory protection and protective clothes/gloves may be recommended to reduce the hazard from re- suspended contamination (e.g. dust) PPE may be required dependent on the chemical involved and level of contamination.
Other limitations/factors influencing costs	The appropriateness of this recovery option is influenced by the physicochemical properties of the chemical contaminant; Requirement of skilled workforce (or not) Soil type, soil condition and depth removed, Amount of soil / vegetation to be removed Weather Topography (i.e. evenness of the affected surface). Size of affected area requiring remediation Type of equipment used/ required. Access to the contaminated area requiring remediation.
Waste	
Amount and type	Most of these techniques are likely to generate large quantities of chemically contaminated soil and vegetation that will require appropriate disposal in accordance with permit controls. In some cases incineration of trees or shrubbery could be considered on a relatively small scale although this will dependant on the chemical involved In rural environments decontamination will mainly generate solid wastes, such as soils and foliage which may be treated by incineration processes or sent to landfill as hazardous waste. Smaller volumes of secondary wastes, such as bags of contaminated clothing, will also be generated which may be disposed at a clinical waste incinerator. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required to aid forensic investigation as well as sorting large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. Debris contaminated with material that would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Exposure	
Averted exposure	Will vary dependant on the surfaces contaminated and the specific technique employed although there should be significant exposure reduction if employed effectively. Factors influencing averted exposure include; • Effective implementation of option over a large area. • Reductions in exposure received by a member of public living in the area will depend on the amount of the area covered by grass and the time spent by individuals on or close to grassed areas. • Time of implementation. The impact of removing the contamination on the overall exposure will be reduced with time as there will be less contamination on the surfaces due to natural weathering.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the

	wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving soil and vegetation removal. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	This is a risk of soil erosion, loss of plants, shrubs and biodiversity associated with the implementation of this recovery option.
Compensation issues	There are likely to be requests for compensation for loss of property or loss of earnings from measures which restrict the movement of transport, e.g. goods, produce and services. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Brunt H, Russell D, Brooke N. Sulphur mustard, Wales Swansea 2009. Chemical Hazards and poisons report, Incident response, Health Protection Agency. 2009;17:4 Goodfellow FJL, Murray VSG. Chemical Incident Response Service, Medical Toxicology Unit, Guy's and St Thomas' Hospital Trust, London, UK. Chemical incident report. 2000; 12 : 8-9 Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce.. Fondazione Lombardia per L' Ambiente.1998:32
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
Comments	
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(21) Ploughing / digging methods

Objective	To reduce exposure from contamination in outdoor areas covered in grass or soil within inhabited areas.
Other benefits	Ploughing methods will increase the surface area and may increase the rate of natural attenuation.
Recovery option description	Ploughing or digging methods can be used to mix contamination within the soil profile and lessen contamination on the surface where it is less likely to lead to significant exposure to inhabitants. Removal of plants, shrubs and trees may be necessary before ploughing or digging methods are implemented. Afterwards, replanting, replacing grass, rolling and fertilising of the land may be required. The mixing of contamination by these methods is irreversible and will severely complicate any subsequent removal of contamination. The Food Production Systems (Section 4) of the handbook contains more detailed instruction on implementing digging and ploughing methods that could be helpful in an inhabited area. **Manual digging -** Double digging, in which the top 15 cm of soil is inverted may be considered. This is a traditional method for digging vegetable gardens, particularly for potato crops. The top spade depth of soil is removed; the second spade depth is broken up, effectively mixing the soil to improve it. The top layer is then inverted and replaced. If the area is covered with turf, the top layer should be placed turf down if possible. If triple digging is implemented the thin top layer of soil and vegetation (about. 5 cm thick - optimised according to contamination depth) is inverted and buried at the bottom. The bottom layer (about 15 - 20 cm thick) is placed on top of this; and the intermediate layer (about. 5 – 15 cm thick), which should not be inverted to maintain fertility, is placed on the top. Contamination that was on the surface, or within the topmost few centimetres, is thereby well protected. **Shallow ploughing -** A standard mouldboard plough tills the soil to a depth of typically 25 – 30 cm, thereby mixing any contamination throughout the ploughed depth of soil. A significant amount of the contamination in the top few centimetres of soil is effectively buried. **Deep ploughing -** Deep ploughing with a standard single-furrow mouldboard plough to a depth of 45 cm effectively buries contamination in the top few cms of the soil and also mixes contamination throughout the ploughed depth of soil. Deep ploughing removes most of the contamination from the root uptake zone of plants. A special deep plough that tills the soil to a depth of 900 mm may also be available. Such ploughs require a more powerful tractor than is commonly available **Rotovating -** Soil and grass areas are tilled using power driven machines (rotovators) under manual control. The machines till to a depth of about 15 cm. Rotovating mixes the upper soil layers fairly uniformly within a relatively shallow depth. The mixing of contamination by rotovating is irreversible and will severely complicate subsequent removal of contamination. **Skim and burial ploughing -** A specialist plough is used, with 2 ploughshares: a skim coulter and the main plough. The coulter skims off the upper 5 cm of soil and places it in the trench made by the main plough in the previous run. Simultaneously, the main plough digs a new trench and places the lifted subsoil on top of the thin layer of topsoil now in the bottom of previous trench. This results in the top 5 cm of soil being buried at 45 cm and the 5 - 45 cm layer not being inverted. The effect on soil fertility is minimised, although it may be necessary to fertilise soil after implementation. The contamination is largely buried below the rooting zone for crops.
Key information requirements	Seek specialist advice and guidance as specialist equipment may be required. Availability of specialist equipment Geographical and topographical information on soil types, soil geology. Economic impact of implementing recovery option Proximity to environmentally sensitive sites or sites of scientific interest
Linked recovery options	This is a **remediation option** and should be linked to **protection options**.
Target	Grass and soil surfaces in gardens, parks, playing fields and other open spaces, which have not been tilled since contamination occurred.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are persistent or toxic, with low mobility in soil. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical

(21) Ploughing / digging methods

	contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts), persistence, soil motility and water solubility.
Scale of application	Suitable for large surface areas only (e.g. parks).
Exposure pathway prevention	Inhalation, dermal (skin contact) and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit is obtained if digging or ploughing is carried out soon after contamination. The effectiveness will gradually decrease with time for some chemicals as they naturally degrade or migrate in the soil.

Considerations

Public health considerations	None
Legal implications and obligations	Liabilities for possible damage to property Ownership and access to property Use on listed and historic sites or in conservation areas Possible application of waste controls
Social implications	Access/ acceptability to people's gardens/ recreational areas Aesthetic issues Public acceptability of waste treatment and storage routes Loss of public amenity Leaving contamination in-situ- likely to require excellent communication strategy. Access to public areas may need to be restricted temporarily before ploughing is implemented Restriction on subsequent tilling of the land may not be practicable or acceptable.
Environmental considerations	Need to consider possibility that chemical(s) may leach into ground or surface water Soil erosion risk (reduced by subsequent grass re-seeding) Bring contamination closer to groundwater Loss of soil fertility Land should not be used to grow food Acceptability of smothering flora and fauna and loss of plants and shrubs Severely complicates subsequent removal of contamination Soil may need to be rolled afterwards before use Severe cold weather may influence the effectiveness of this option In extreme cases, the slope of the area maybe a constraint
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	Likely to significantly reduce exposure if implemented effectively.

(21) Ploughing / digging methods

Technical factors influencing effectiveness of recovery option	Weather Correct implementation of option Soil texture (does the soil contain stones etc.) Whether the area has been tilled since incident Time of implementation. If contamination has migrated below the ploughing depth, the technique will be much less effective Consistency in effective implementation of option over a large area. Time of implementation: weathering will reduce contamination over time so quick implementation will improve effectiveness. Whether recovery options have been applied to other nearby ground surfaces. Risk of chemical contamination of any nearby groundwater/surfaces, hydrogeology of the area needs to be considered.

Feasibility and intervention costs

Specific equipment	Will vary dependant on the technique involved but could include the following: Spades, skim and burial plough, powerful tractor, rotovators, deep plough * Skim and burial ploughing equipment is not readily available throughout Europe at the present time
Utilities and infrastructure	Roads for transport of equipment.
Consumables	Fuel and parts for transport vehicles and tractor. Plants and replacement grass
Skills, personnel and operator time	Seek specialist advice and guidance. DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Personnel and skill level will vary (dependant on the technique required). Personnel must be instructed and briefed carefully about the objective of the recovery option.
Safety precautions	Under very dusty conditions respiratory protection and protective clothes may be recommended to reduce the hazard from re-suspended contamination.
Other limitations/factors influencing costs	Costs will vary significantly dependent on the technique employed

Waste

Amount and type	Advice should be sought from the environment agencies (EA, SEPA, NIEA) on whether ploughing/ digging methods would be subject to waste permitting controls. There is a risk that the ploughing equipment may have to be disposed of if it cannot be proven to be clean once this option has been implemented.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A

Exposure

Averted exposure	This recovery options do not remove contamination from the environment. Reductions in exposure will vary dependant on the physiochemical properties of the chemical involved and the specific technique employed. Factors influencing averted exposure include; • Consistency in effective implementation of option over a large area. • Population behaviour in area. • Amount of grass/soil in the area i.e. environment type/land use.

(21) Ploughing / digging methods

	• Time of implementation. The impact of ploughing on the overall exposure will be reduced with time as there will be less contamination on the surfaces due to natural weathering.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving ploughing and digging methods. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	Depending on the contaminant, this method may reduce exposure to humans but prevent the land being used for farming or similar e.g. persistence of sulphur mustard.
Compensation issues	There are likely to be requests for compensation for loss of property or loss of earnings from measures which restrict the movement of transport, e.g. goods, produce and services. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Many of these techniques will be carried out as part of standard farming methods.
Key references	Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(22)	Snow/ice removal
Objective	To reduce exposure from contamination on external walls and roofs of buildings and paved/road surfaces within inhabited areas.
Other benefits	Will remove contamination from outdoor surfaces. This option may restore public confidence and promote reassurance that the contamination has been removed.
Recovery option description	If contamination occurs in open areas covered by a thick layer of snow, the removal of the snow layer before the first thaw will prevent the contaminants from reaching the underlying ground surface. Generally, soil areas will be most important to treat, but the method could also be applied to external building surfaces (especially roofs) and paved/ road surface. The removal can be carried out by 'Bobcat' mini-bulldozers (easy to manoeuvre in small areas) or similar available equipment. Alternatively removal can be undertaken with spades, shovels, pokers or manual scrapers. However, these alternatives are much slower. For contamination arising on soiled areas the removal of trees/shrubs (recovery option 19
Key information requirements	What is the weather forecast?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This recovery option could be linked to (20) Soil and vegetation removal as cold/ freezing temperatures may immobilise the chemical (depending on physicochemical properties). Therefore as a precautionary measure it may be better to remove an additional layer "just in case".
Target	Snow covered open areas, buildings, roads, paved areas and particularly grassed areas and other areas of soil, e.g. parks, playing fields and gardens.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that are persistent or toxic. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include; chemical toxicity (acute and chronic health impacts), persistence and water solubility.
Scale of application	Any scale. Suitable for small areas (e.g. gardens) and large areas (e.g. parks, playing fields etc).
Exposure pathway prevention	Inhalation, dermal (skin) and inadvertent ingestion of chemical contamination
Time of application	Maximum benefit if carried out as soon as possible after contamination. Must be carried out before the first thaw following the contamination.
Considerations	
Public health considerations	None
Legal implications and obligations	Ownership and access to property. Liabilities for possible damage to property. Waste disposal legislation
Social implications	This option may restore public confidence and promote reassurance that the contamination has been removed. Adverse aesthetical effect, due to the use of relatively heavy machinery in garden areas.
Environmental considerations	Snow storms can make it very difficult to carry out the work. In extreme cases, the slope of the area may be a constraint (depends on operator skill). Obstacles e.g. trees/ shrubs. The disposal of the waste water from the implementation of this option will have an environmental impact. However, this should be minimised through the control of any disposal route and relevant authorisations. It is important to note that a pile of contaminated snow becomes a major pollution source when it melts

(22)	Snow/ice removal
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	If implemented promptly following contamination exposure reduction should be significant
Technical factors influencing effectiveness of recovery option	Effective and consistent application of option over a large area. Time of implementation. The impact of snow removal will be reduced with time as snow melt starts. Over time, snow may form drifts leading to pockets of condensed contamination. The snow layer must be sufficiently thick to allow complete removal of the snow surface. If, for example, human activity has compressed the snow, complete removal will be more difficult. Bunded or watertight storage areas to store contaminated snow would be required. Important to note that a pile of contaminated snow becomes a major pollution source when it melts.
Feasibility and intervention costs	
Specific equipment	Bobcat mini-bulldozer or similar equipment (e.g. tractor with scraper), or spades, shovels, and manual scrapers. Vehicles for transporting equipment and waste
Utilities and infrastructure	Roads for transporting equipment and waste. Storage or facilities to dispose of contaminated snow/ ice off site.
Consumables	Fuel and parts for vehicles
Skills, personnel and operator time	Little instruction is required. On a local scale, snow removal from the ground could by the inhabitants of the affected area as a **self-help measure**, after instruction from authorities and provision of safety and other required equipment. However, the manual work requires hard physical work, which not all people would be able to do.
Safety precautions	Waterproof clothing, boots and gloves. In case of dry frost / storm weather, respiratory protection should be considered if carrying out the procedure soon after contamination.
Other limitations/factors influencing costs	Weather Topography (evenness of the affected area) Size of area Thickness of snow layer to be removed Type of equipment used Access to contaminated area
Waste	
Amount and type	Depends on thickness of the snow layer. 5 cm snow = 0.5 kg m^{-2}. Waste
Possible transport, treatment, disposal and storage routes	Waste authorisations may be required for transport and/ or storage.
Factors influencing waste issues (i.e. cost)	
Exposure	
Averted exposure	Likely to be significant reduction in exposure if employed effectively
Factors influencing averted exposure	Population behaviour in area: the time spent by individuals on or close to snow covered surfaces. Amount of the area containing snow covered surfaces.

(22) Snow/ice removal

Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving snow/ ice removal. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	None
Compensation issues	N/A
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015
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(23)	Barriers to seal land contamination
Objective	Containment methods used to manage contaminated soil and groundwater using established engineering approaches.
Other benefits	Containment isolates the contaminated material or matrix, preventing exposure to the surrounding environment. This option can also be adapted to treat contaminated ground water in situ.
Recovery option description	Barriers are used to prevent the migration of contaminants. Available techniques include; • **Vertical barriers:** a physical wall constructed around a contaminant source to isolate contaminants, minimise the spreading of contaminants and restrict potential ground water contamination • **Horizontal barriers:** injection or placement of a physical impermeable construction above or beneath a contaminated volume. • **Cover systems:** an engineered horizontal layer of "uncontaminated" material placed on the surface or in the sub-surface. The cover may be single or multi-layered and may be used for forming a barrier between contaminated material and surrounding environment (people, animals and plants) or for controlling the upwards migration of contaminated water or gas. Covers may be soil or soil like material or synthetics. This option can also be adapted to treat contaminated groundwater, in which case it is referred to as a "permeable reactive barrier" (PRB). A permeable reactive barrier is an engineered treatment zone placed in the saturated zone of soil to remediate contaminated groundwater as it flows through. PRB can be designed to a variety of configurations depending on the contaminant to be treated. There are 2 basic types of PRB: • Funnel-and-gate: the contaminated ground water is directed to a permeable reactive zone (the gate) by a series of impermeable barriers (the funnel) • Continuous wall: a reactive treatment zone is placed across the complete flow path of the contaminated groundwater. The use of different reactive media within the reactive zone of a PRB allows the treatment of a wide variety of groundwater contaminants. Reactive media can include chelators, sorbents and microbes.
Key information requirements	What chemical(s) are involved? What is the layout of the area requiring remediation? What are the requirements of the land user(s)?
Linked recovery options	This is a **remediation option** and should be linked to **protection options**. This recovery options should be considered in conjunction with; (21) soil and vegetation removal; (22) ploughing/ digging methods and (24) burial in-situ
Target	Contaminated land/ contaminated groundwater
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all persistent and toxic chemicals are likely to pose an inhalational hazard (i.e. asbestos). However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other important physicochemical properties would include persistence, ability to absorb to porous surfaces and chemical toxicity (acute and chronic health impacts).
Scale of application	**Small/ Medium**
Exposure pathway prevention	Inhalation, dermal (skin) contact and inadvertent ingestion of chemical contamination.
Time of application	Not important (can be implemented decades after contamination occurred).
Considerations	
Public health considerations	None
Legal implications and obligations	There may be waste permitting implications associated with this option.

(23)	Barriers to seal land contamination
Social implications	There may be some social disruption due to noise complaints. Barriers may also pose an aesthetic issue. The public may also be sceptical of contamination not actually being removed and just sealed off.
Environmental considerations	Considerations of the geological and hydro-geological conditions at the affected site may influence whether or not this is a suitable remediation option.
Ethical considerations	This recovery option has the potential to improve the affected environment, either by being less of an eye-sore or improving ecology within the affected area. Barriers are likely to significantly impact the chemical and/or biological state of the groundwater/soil, e.g. pH, organic matter, which can in turn reduce soil biodiversity. Permeable reactive barriers (PRB's) can also disrupt local hydraulic patterns, and can potentially impact flood risk.
Effectiveness	
Recovery option effectiveness	Potentially very effective at reducing exposure to contamination.
Technical factors influencing effectiveness of recovery option	The barrier type will be dependent on soil and water characteristics. Modelling data will be required to assess and validate the performance of this option. Life span of barriers to seal contamination should also be considered.
Feasibility and intervention costs	
Specific equipment	Considerable resources utilised for construction of barriers: heavy plant machinery, plant tools, transport; excavation for permeable reactive barriers and absorbent materials to prevent contamination leaching. Monitoring equipment to determine contamination levels post intervention
Utilities and infrastructure	
Consumables	Barrier materials, fuel, parts for vehicles.
Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel and scientific support are likely to be required to monitor the effectiveness of this option at the remediated site. DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service
Safety precautions	Appropriate PPE and general safety precautions are required.
Other limitations/factors influencing costs	Type of barriers to be installed and duration of treatment. This option can be quite expensive, for example remediation of the Castlegate housing estate in Caerphilly (South Wales) cost £15 Million.
Waste	
Amount and type	Dependant on the volume of contaminated ground water or soil that requires treatment. The barriers may require replacement and disposal (10+ years) and would need to be disposed of via approved (permitted) routes. Many types of wastes that will be encountered during or after a chemical incident may come under the classification of 'hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A

(23) Barriers to seal land contamination

Exposure

Averted exposure	There should be a significant reduction in potential exposure to members of the public living in the affected area.
Factors influencing averted exposure	Some barriers (i.e. permeable reactive barriers lose reactive capacity over time). There is also a risk that permeability would be reduced due to precipitation of contaminants or breakdown products.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving barriers to seal land contamination. Exposure pathways recovery workers could be exposed to are: • Dermal /inhalation exposure from contamination in environment and equipment • Inadvertent ingestion of contamination from workers' hands (unlikely to be significant) Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	N/A
Compensation issues	Financial and legal advice relating to compensation can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	Russell J, Davies P and Russell D. The use of a novel technology in the remediation of a contaminated land site as a public health protection measure. *Chemical Hazards and Poisons Report* 2007;10; 11-14 Phillips W, Dobney A and Whittaker P. The Hampole Quarry. *Chemical Hazards and Poisons Report*. 2008;13: 4-6
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste EA Guidance Remediation Position Statements. 2007 version 1.
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(24)	Burial in-situ
Objective	To remediate the affected area and buildings by burying contaminated surfaces (e.g. buildings or large vehicles) in situ.
Other benefits	None
Recovery option description	In extreme cases following a large scale incident large basins can be excavated to provide a waste disposal route for chemically contamination and associated debris. The waste may be encased in specific barriers such as a polyethylene sheet and concrete. Following burial the basin can be covered with topsoil.
Key information requirements	Geology and hydrogeology of the area
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options**. This decontamination technique may be combined with (23) Barriers to seal contamination. Residents would require relocation from residential areas, therefore this option would need to be carried out in conjunction with (5) Permanent relocation.
Target	Chemically contaminated debris
Targeted chemicals and important physicochemical properties	This recovery option is more applicable to non-water-soluble chemicals that are persistent and difficult to decontaminate, to prevent leakage through membranes. However, the physicochemical properties and physical form (solid, liquid or gas) of the chemical contaminant will influence whether or not this option is a suitable alternative to other remediation techniques. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include; persistence, water solubility and chemical toxicity (acute and chronic health impacts).
Scale of application	Any scale.
Exposure pathway prevention	Inhalation, dermal (skin) and inadvertent ingestion of chemical contamination
Time of application	There are no restrictions on time with this option, and can be implemented at any stage after a chemical incident
Considerations	
Public health considerations	None
Legal implications and obligations	Seek specialist advice and guidance. There may be legislation or legal implications relating to waste and the pollution of groundwater.
Social implications	Potentially significant resistance from residents in the area against burial of contamination in-situ as well as transporting the waste through/ nearby the inhabited area. Aesthetic issues may be a social issue.
Environmental considerations	Potential leaching of contamination to soil/ groundwater
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	There should be a significant reduction in potential exposure if burial in-situ is implemented properly and the area sealed appropriately to prevent leaching into groundwater.

(24) Burial in-situ

Technical factors influencing effectiveness of recovery option	This method requires specialised engineering expertise and materials which depend on the nature of the contaminant in question, e.g. water solubility in order to construct an effective membrane to contain the chemical. A suitable and robust monitoring programme will also need to be implemented to ensure the membrane remains intact.
Feasibility and intervention costs	
Specific equipment	Large digging machinery Specialist membranes for sealing contamination
Utilities and infrastructure	Power and water supplies.
Consumables	
Skills, personnel and operator time	Personnel and scientific support to undertake the monitoring programme. Seek specialist advice and guidance. DEFRA maintains a Framework of Specialist Suppliers able to offer a practical decontamination or wider remediation service, capable of carrying out decontamination operations across the UK. For more information see https://www.gov.uk/government/groups/government-decontamination-service
Safety precautions	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers and specialist contractors and suppliers will have to comply with Health and Safety at Work Act to ensure that recovery workers use appropriate PPE and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	There should be a significant reduction in potential exposure to members of the public living in affected areas.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that recovery workers (i.e transport personnel) use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker

exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving burial in-situ.

Exposure pathways recovery workers could be exposed to are:

- Dermal /inhalation exposure from contamination in environment and equipment
- Inadvertent ingestion of contamination from workers' hands (unlikely to be significant)

Exposure routes from transport and disposal of waste are not included.

Other considerations

Agricultural impact	None.
Compensation issues	There may be requests for compensation for costs associated with loss or damage to property, or loss of trade and earnings (i.e. manufacturing processes). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Other considerations	Likely to be expensive due to transportation needs, specialised engineering expertise and the cost of the materials used to construct an effective membrane to line basins.

Additional information

Practical experience	Burial in-situ was implemented during the remediation of the Seveso (dioxin) incident (1979).
Key references	Ramondetta M, Repossi A. SEVESO: Vent' anni dopo. Dall' Incidente al Bosco delle Querce.. Fondazione Lombardia per L' Ambiente.1998:32.
Comments	
Document History	

8 Water environments

What is a water environment?

For the purpose of the handbook, water environments cover areas such as drinking water supplies (i.e. public, private and industrial water supplies), water in beverages, food production and controlled waters (i.e. surface waters, ground waters, recreational waters and coastal waters).

The types of water environments included in the handbook are described in Table 8.1 to Table 8.4 respectively.

When developing a recovery strategy for managing contaminated water environments, decision-makers need a framework for choosing between the many possible recovery options. Throughout this process, they will also require a significant amount of information to support decisions to implement timely and effective recovery measures. This Handbook provides a decision framework and a compilation of information to help users evaluate the available recovery options following a chemical incident.

For small-scale, single chemical releases the recovery strategy may comprise of one or 2 recovery options that could be applied over the first few days or weeks following the incident. For a wide-scale, multi chemical release involving persistent chemicals the recovery strategy is likely to be more complex, comprising a series of recovery options that could be implemented over different phases of the incident response and affecting several types of water environments. Some aspects can be considered in advance of an incident as part of contingency planning. A series of checklists are provided in Section 3 to highlight the type of information that can be gathered under non-crisis conditions to help manage the pre-release and early phases of an incident. Expert input and guidance will also be needed to supplement this information, particularly to provide decision-makers with expert advice on the suitability of recovery options for the particular chemical, and the practicability of their implementation.

Table 8.1: Types of sub-areas in drinking water supplies and water environments

Area	Description
Drinking water supplies	Water supplied under statutory legislation as being wholesome to drink. **Public water supplies -** those delivered by statutorily appointed water companies. **Private water supplies -** those not provided by a statutorily appointed water company.
Controlled waters	**Surface waters –** Lakes, lochs, canals, rivers, streams, reservoirs etc. **Ground waters –** This is all water contained underground and includes groundwater as well as water above the saturated zone (i.e. the bottom of aquifers)
Food Production (including water in beverages)	See Food Production systems section of the handbook (Section 4)

8.1 Drinking water

Drinking water can come from one of 3 main types of water supply, and these are defined in Table 8.2.

Table 8.2: Definition of drinking water supply categories in the handbook

Water supply	Description
Public	Public water supplies are those delivered by statutorily appointed water companies to the majority of properties including private houses, commercial and public buildings, industrial premises and other properties*. Public water supplies come from both surface water and ground water sources. Surface water sources include reservoirs, lakes and rivers, while ground water sources are from aquifers, which are natural underground geological formations that store rainwater. The ground water is drawn through wells or boreholes drilled into the aquifers by the water companies. Ground water can also supply impounding reservoirs. The water supplies delivered by water companies are subject to strict regulation regarding their quality. To comply with the water quality regulations, the water is treated at water treatment works prior to being delivered. The water companies take regular samples of the water throughout the treatment process and distribution systems to ensure the provision of high quality water that meets the required standards[1].
Private	Private water supplies are defined as any regular supply of water that is not provided by a statutorily appointed water company and where the responsibility for its maintenance and repair lies with the owner or person who uses it. Private water supplies only account for a small percentage of water usage. Less than 1% of the population of the UK obtain their water from an entirely private supply either on an individual or multiple property basis. However, the number of private water supplies can be significant. For example, the Northern Ireland Environment Agency website states that there are 1,269 private water supplies; data collected by Defra indicate that there are about 42,000 private supplies in England, with about 60% of these being individual supplies to single private dwellings, typically drawn from a private well or borehole on the premises. Private water supplies can come from a variety of sources including: wells, boreholes, springs, rivers, lakes and ponds. The majority of private supplies are likely to be for dwellings and farms situated in remote or rural areas. However, there may be some private supplies in urban areas, particularly those used for industrial purposes such as brewing. Private water supplies may also be found supplying places such as hospitals, hotels, schools or campsites. Unlike public supplies, many private water supplies are not treated to remove impurities that affect the quality of the water such as pesticides, nitrates or cryptosporidium[1]. They are however regulated by the local authority under Private Water Supplies Regulations and should meet the levels which define them as wholesome for chemicals and microbiological concentration.
Un-regulated	Unregulated water supplies are defined as those drinking water supplies that are not maintained as public or private water supplies. The use of these water supplies will generally be confined to people using water from springs or collected rainwater whilst in recreational areas (e.g. campers and hikers).
Inset appointments	In some circumstances, a water company can replace the incumbent as the appointed water and/ or sewerage company for a specified area. As such, the replacement appointed water company takes on the same duties and responsibilities as the previous statutory water company for the specified area.

* Water companies may have several minor water supplies, typically in rural areas that may have simple water treatment (e.g. disinfection)

If drinking water supplies do become contaminated in the event of an incident, it is possible that some of the contaminated water will be consumed. Consequently, potential chemical exposure and the risks associated with drinking such water should be communicated effectively. This applies irrespectively of whether the water contains chemical concentrations below relevant water quality standards or whether the concentrations are above these levels for a limited period. This could be, for example where there are odours and taste issues associated with a chemically contaminated water supply. Public perception may also drive the need to provide ‘clean’ drinking water. This may conflict with other public health requirements and may not be justified purely on health protection grounds.

8.2 Water used in food production

See food production systems section of the handbook (Section 4).

8.3 Non-regulated water

Some of the issues that should be considered regarding un-regulated water supplies following a release of chemical contamination to the environment are given below:

If an incident has occurred in a rural area, campers and hikers etc in the affected area may be unaware of the incident. Warnings about consuming or using open water sources should be circulated through the media, although this may be insufficient to warn everybody that may potentially be affected. If an event continues for several days or more, new issues of warnings may be required. New technologies such as communication via mobile phones (e.g. text messaging) could be considered as a suitable communication medium. Additional measures such as displaying clear warnings in remote areas may also be required in the longer term.

8.4 Controlled waters

Controlled water encompasses all fresh and saline natural waters up to the UK offshore territorial limit. As such, by definition, they include all surface water, ground water, recreational waters and coastal waters within the UK. The definition of controlled waters is presented in Table 8.3. For ease of references, controlled waters have been divided into 4 sub-areas, described in Table 8.4.

8.5 Health protection criteria for Water environments

Any health protection criteria aimed at reducing the risks of adverse health effects, i.e. skin irritation, liver damage, cancer or birth outcomes, must consider all the wider consequences of the proposed protective measure. Hence, for example, costs and disruption to implement the measure must be balanced against the expected benefits, which include public reassurance. This balance needs to take account of the specific circumstances of the event which are likely to vary between different types of incidents and contamination 1. At present there are no international or national regulations outlining clean-up criteria that could be used directly following an incident involving chemical release in the UK, although it should be noted that the agencies involved in protecting drinking, recreational, and marine waters will have their own emergency and clean-up procedures for use during events and incidents.

Table 8.3: Definition of controlled water categories in the Handbook

Water supply	Description
Controlled waters	All fresh and saline natural waters up to the UK offshore territorial limit, including rivers, streams, lochs, estuaries, reservoirs, coastal waters and groundwater. The statutory definition of controlled waters is given in the Water Resources Act 1991 s 104(1) [2] and the Control of pollution Act 1974, s 30A (d) [3]. The Water Resources Act defines the Environment Agency's role in water pollution, water resources management, flood defence, fisheries and navigation. It covers discharges to surface and ground waters, estuaries and coastal waters, and controls abstracting and impounding water. The Act affects all businesses in England and Wales that discharge substances to controlled waters. Persons must not cause or knowingly permit and poisonous, noxious or polluting material or solid waste to enter controlled water unless they have consent from the Environment Agency. Industrial operators have to pay the cost of repairing damage caused by their polluting discharges, largely be reimbursing the Environment Agency for the anti-pollution works it has carried out [4].

8.1 Estimating exposure in water environments

The exposure to an individual from a given amount of chemical contamination following an incident can vary widely, depending on the chemicals involved, the spread of the contamination within the water environment and the time spent by the individual at locations with different levels of contamination. The total exposure of an individual living in a contaminated environment is the sum of the exposures arising from the differing levels of contamination through different pathways (e.g. inhalation, ingestion and dermal) at a variety of locations (e.g. at home or within a recreational water environment). The total exposure received by an individual is therefore determined by the time spent in each location and the exposure rate at that location, which is likely to decrease with time as the level of the chemical decreases.

In its published advice for radiation, PHE recognises that some clean-up techniques are considerably more resource-intensive and disruptive than others [7]. This principle, in part, could also be applied to chemical releases. In its advice, PHE recognises that it is difficult to specify numerical clean-up criteria in advance of an incident and that other aspects of planning for a response are important and should be given due consideration (see Section 3). PHE therefore advises that, following an incident, assessments should be undertaken of all the likely consequences of a range of clean-up strategies. These consequences should include cost, timescales, public acceptability and the availability of the necessary resources, as well as the expected reduction in risks of health effects. Clearly, collection in advance of information relevant to these assessments, such as the likely efficacy and resource requirements of different clean-up options, and prior identification and preparation of appropriate equipment and contractors, would facilitate the timely completion of such assessments in the event of an incident. Potential strategies that involve high levels of cost and disruption should only be undertaken if the expected reduction in risk of adverse health effects is also high, thereby maintaining a balance between the expected harms and benefits of the strategy.

Table 8.4 Definition of sub-areas con controlled waters in the handbook

Water supply	Description
Surface waters	Water present above ground, associated with freshwater resources, e.g. rivers, streams, springs, reservoirs and lakes. Discharge of clean surface water run-off (rain run-off from roofs, yards and roads) may be made to surface waters or ground waters without consent. If there is any risk of run-off being contaminated, for example by oil drips from cars or roofs contaminated by chimney emissions, then persons must have a discharge consent or groundwater regulations permit (England and Wales) or a groundwater authorisation (Northern Ireland). In Scotland, an offence would be committed if an activity was carried out that was likely to cause water pollution without SEPA's authorisation. If there is a risk of run-off being contaminated an authorisation must be obtained under the Controlled Activities Regulations.
Ground waters	Ground waters is all water that is found underground in the cracks and spaces in soil, sand and rock. Groundwater is stored in and moves slowly through layers of soil, sand and rocks (aquifers). Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone, which are permeable due to the large connected spaces that allow water to flow through. Hazardous substances that are damaging and toxic must be prevented from directly or indirectly entering groundwater, and include: • many pesticides (including sheep dip) and herbicides • many solvents • mineral oils and hydrocarbons • cadmium and mercury • radioactive substances • discharges from septic tanks
Recreational waters	Coastal and freshwater recreational water environments are defined, for the purposes of these Guidelines, as any coastal, estuarine or freshwater area where any type of recreational usage of the water is made by a significant number of users. While uses may be diverse and the Guidelines are intended to be applicable to all types of use, most concern relates to uses entailing water contact and, in the case of water quality, significant risk of water ingestion[5].
Marine waters	Natural maritime saline waters up to the UK offshore territorial limit. The Merchant Shipping Act 1995 covers at sea activities but also covers estuarial pollution in certain cases. The Maritime and Coastguard Agency (MCA) exercises Central Government's statutory responsibilities for acting when oil or hazardous and noxious substances emanating from any at-sea activity threaten the UK or its surrounding waters (MCA web site). The appointed regulatory body for each piece of legislation has a general duty to carry out enforcement activities when necessary. They have statutory powers to serve notices and take prosecutions (National contingency plan for maritime pollution plan for marine pollution from shipping and offshore installations [6]. Local authorities (Environment and Heritage Service in Northern Ireland) - Have accepted the non-statutory responsibility for shoreline clean-up [6].

8.2 Constructing a recovery strategy for water environments

Selecting an appropriate recovery options is a multistage process and an overview of the decision framework is given in the flowchart in Figure 8.1. it should be noted that the decision framework is not a substitute for expert specialist advice, but provides a framework for requesting, recording and evaluating the advice (Step 1 to 3). The selection of the most appropriate subset of recovery options is a 6-step process, involving the elimination of inappropriate options using a series of selection figures, look up tables or checklists.

Step 1 describes the initial identification of the chemical and the nature and extent of the incident. Step 2 of the framework leads the user to the decision tree in Figure 8.2. This decision tree guides the user through the different types of water environments and appropriate options. Steps 3 to 5 then provide a methodology for eliminating options that are unsuitable or ineffective by evaluating their characteristics.

From the remaining options, a recovery strategy can be determined (Step 6), a template table is provided (Table 8.9) that could be used to help record the decisions made during the recovery option elimination process. Implementation of the recovery strategy then follows, and if monitoring confirms that acceptable levels have been reached then it is possible to return to normality. If monitoring indicates that acceptable levels have not been reached, then the user returns to the decision tree in Step 2.

The final step is to document the incident and evaluate the response, including the effectiveness of the Handbook. Further details of the steps are given in the following sections.

The water environments decision framework does not include a strategy for performing a risk assessment or for designing or implementing a monitoring strategy following a chemical incident. This falls outside the scope of the UK Recovery Handbook for Chemical Incidents.

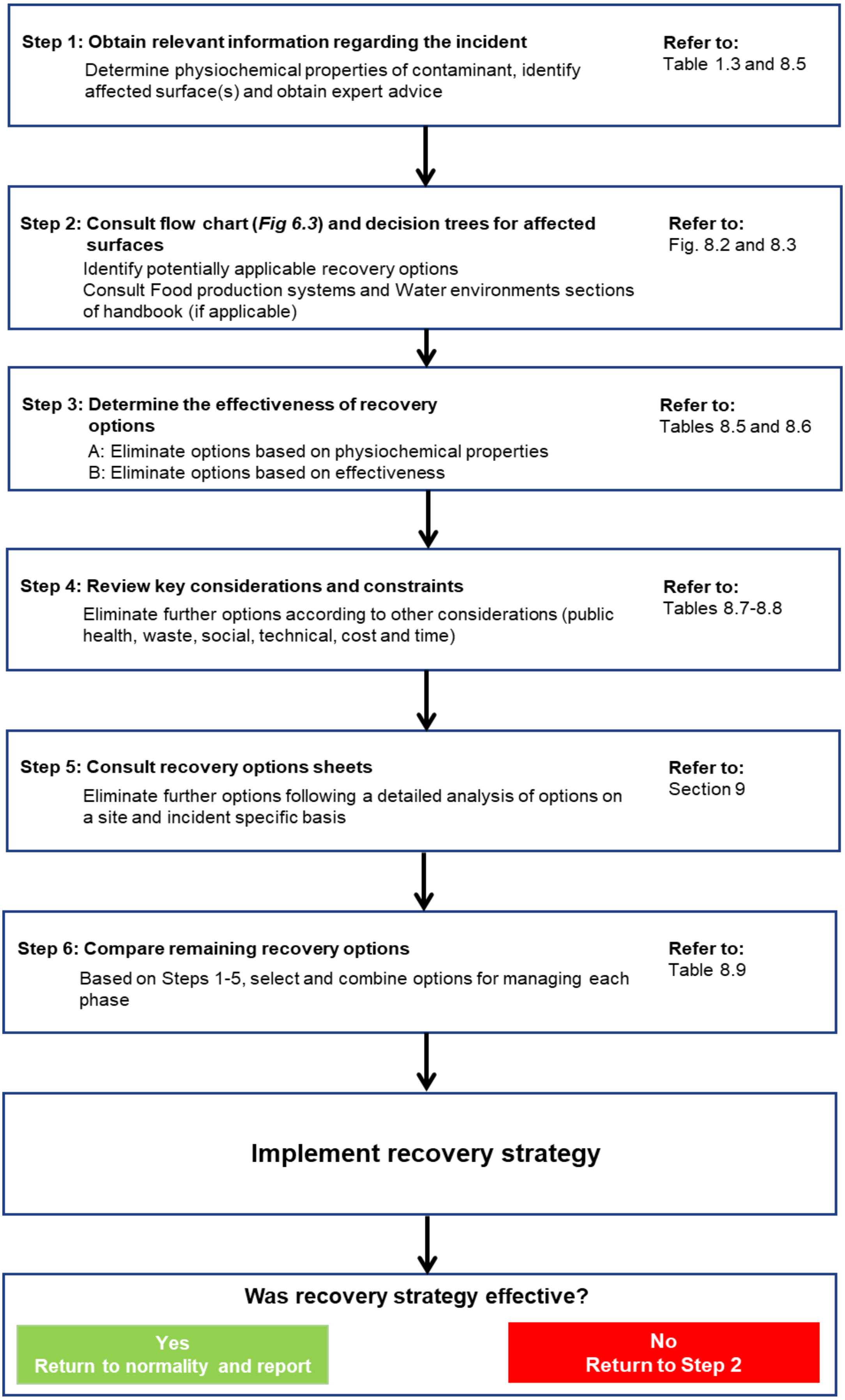


Figure 8.1 Key considerations for recovery

8.2.1 Step 1: Obtain relevant information regarding the incident

When a chemical incident occurs, the initial step is to identify the affected water environment as this may allow for a quicker response i.e. if it is a public or private water supply that has become contaminated and it is feasible to do so, the supply may be isolated quickly without affecting the general water supply

Information should then be sought to identify the chemical(s) involved and seek technical (chemical) expertise. Information should then be collected on its physicochemical properties, for example water solubility, persistency and toxicity amongst others. The Handbook has identified a subset of physicochemical and toxicological properties that should be considered which are outlined in Table 8.5 and Table 1.3 (Section 1). These properties will then be used to eliminate options in Step 3 of the decision-making process. Only when this information is available can an appropriate recovery strategy be developed.

Particular attention must be taken when an incident involves a mixture of chemicals as it is not only necessary to look at the individual chemicals but also to assess the potential interactions between the chemicals themselves. This will have a direct influence on the recovery options selected. Implementation of an option should ideally not cause more harm than good (i.e. further damage or worry) and unnecessary complications should be avoided.

Table 8.5 :Important physicochemical properties

Physical characteristic	Description	Interpretation			
				Value/ Description	Interpretation
Physical form (solid/liquid gas)	**Gases** and vapours spread out in the environment until they are equally distributed throughout the space available to them. **Liquids** will flow with gravity when released and therefore require safe containment to stabilise the incident and prevent further risk to persons, property and the environment. **Solids** need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion				
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. For instance, a volatile compound such as kerosene may volatilise from a water surface and pose an inhalational hazard Interpretation (Units = Pascals) $< 1.3 \times 10^{-4}$: Unlikely to volatilise Between 1.3×10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	**High VP** Likely to; be an inhalational risk and evaporate quickly	**Low VP** Unlikely to be; an inhalational risk		
Density of liquid (D Liquid)	The density (specific gravity) of a liquid is determined by comparing the weight of an equal amount of water. (Water = 1.0). If the specific gravity is less than 1.0 then it will float, if greater than 1.0 it will sink. This is likely to be an important factor following release to water where the use of certain recovery options (e.g. use of adsorbent booms/mats) could be considered for chemicals that float on water.	**D > 1** Will sink in water	**D < 1** Will form a surface film on water		
Persistence	The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.	**Short persistence**: Hours to days **Moderate persistence:** Weeks to months **Long persistence:** Months to Years			

Table 8.5 :Important physicochemical properties

Physical characteristic	Description	Interpretation		Value/ Description	Interpretation
Water solubility	The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread along the surface and be carried by the flowing water. Interpretation: Units ppm (mg/l) <10: Negligible solubility Between 10 and 1000: Increasing likelihood of solubilising >1000: Likely to solubilise	**High solubility** Likely to be; Mobile Unlikely to be; Volatilised or persistent	**Low solubility** Likely to be; Immobilised by adsorption and persistent Unlikely to be; Mobile		
Partition coefficient between water and octanol (K_{OW})	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = $\mathbf{K_{Ow}}$) > 1,000: Likely to bio accumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bio accumulating < 500: Unlikely to bio accumulate (hydrophilic)- Low	**High K_{ow}** Likely to be; Bio-accumulated (sorbed in soil or sediments) Unlikely to be; mobile	**Low K_{ow}** Likely to be; Mobile, soluble, biodegraded Unlikely to be; Bio-accumulated		
Henry's Law Constant	Describes the partitioning of a compound between a solution and the air above it. Tendency for chemicals to move from the aqueous phase to the gaseous phase.				
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.				
Permeation potential	Describes the permeation potential of chemicals to pass through and potentially contaminate some polymeric media (e.g. fuels and some solvents can permeate some plastics and taint the water).				
Toxicity	Sum of adverse effects or the degree of danger posed by a substance to living organisms. It is expressed generally as a dose response relationship involving the quantity of substance to which the organism is exposed and the route of exposure skin (absorption), mouth (ingestion), or respiratory tract (inhalation).				

8.2.2 Step 2: Consult decision trees/diagram for Water environments

Consult Figure 8.2 (decision tree 1 parts 1, 2 and 3) for potentially contaminated drinking water supplies. Follow Figure 8.3 (decision tree 2) for other water environments that are potentially contaminated.

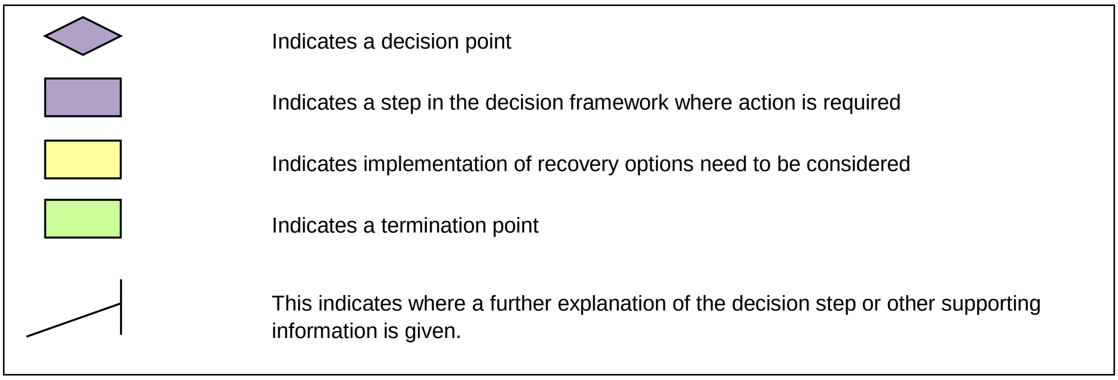
The decision trees identify recovery options that are specific for the type of contaminated water environments (e.g. drinking water/controlled water). Recovery options include **protection** (actions taken to protect the population) and **remediation** (return the area back to normal), which include waste disposal options.

Following a large-scale incident that affects drinking water, both decision trees (Figure 8.2 and Figure 8.3) should be consulted. Recovery options specific to decision tree 2, e.g. (20) Containment: Use of dams, booms and absorbent booms materials, could be considered for impounding contamination with reservoirs to subsequently reduce contamination in water to be used for drinking water.

This step is essentially an ‘inclusive’ step, identifying potential recovery options. Elimination of options is carried out in Steps 3 to 5.

The remediation of food production systems (e.g. crops of livestock) are covered in the Food production systems (Section 4) of the handbook. The remediation of inhabited areas is covered in Inhabited areas (Section 6). Where there may be cross-over between sections of the Handbook (food production systems/inhabited areas) these are highlighted in Figures 8.2 and Figure 8.3).

The decision trees (Figure 8.2 and Figure 8.3) should be used in the following way:



Where further information or guidance is available on the topic described in the ‘box’ in the decision tree, the link to the information is indicated in blue. This information should be read in conjunction with the decision tree.

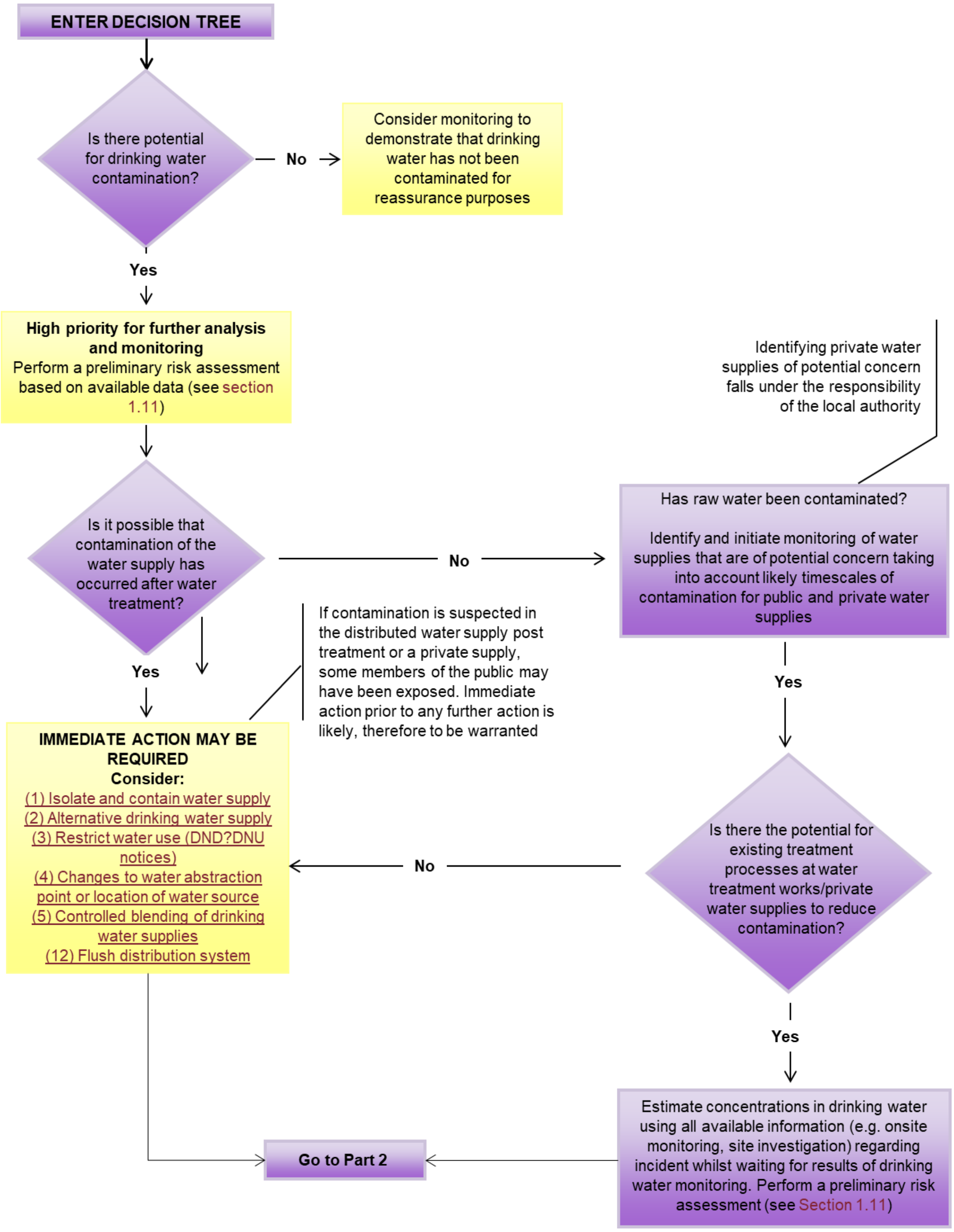


Figure 8.2 Decision Tree 1 - Drinking Water part 1

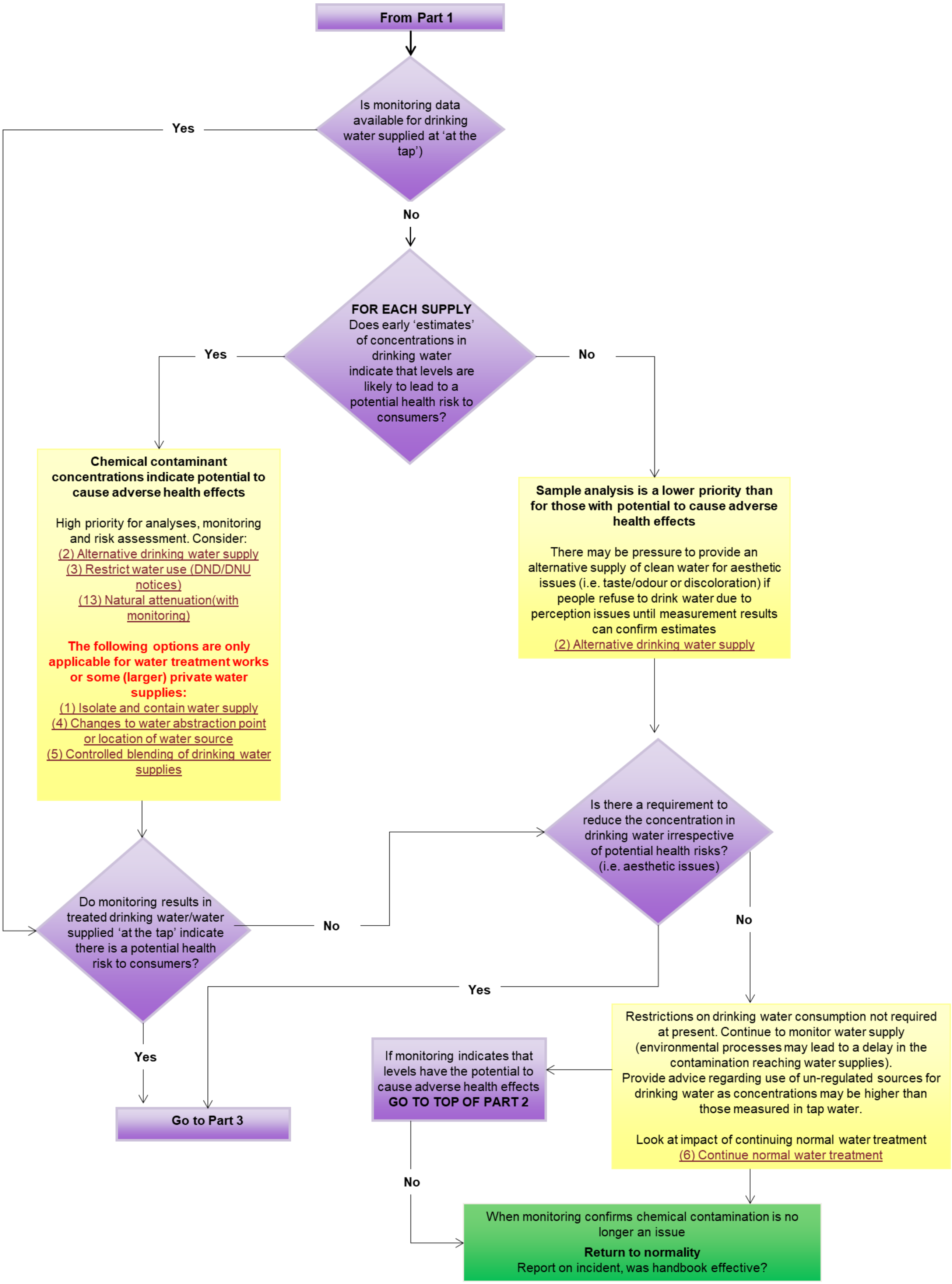


Figure 8.2. Decision tree 1 - Drinking water part 2

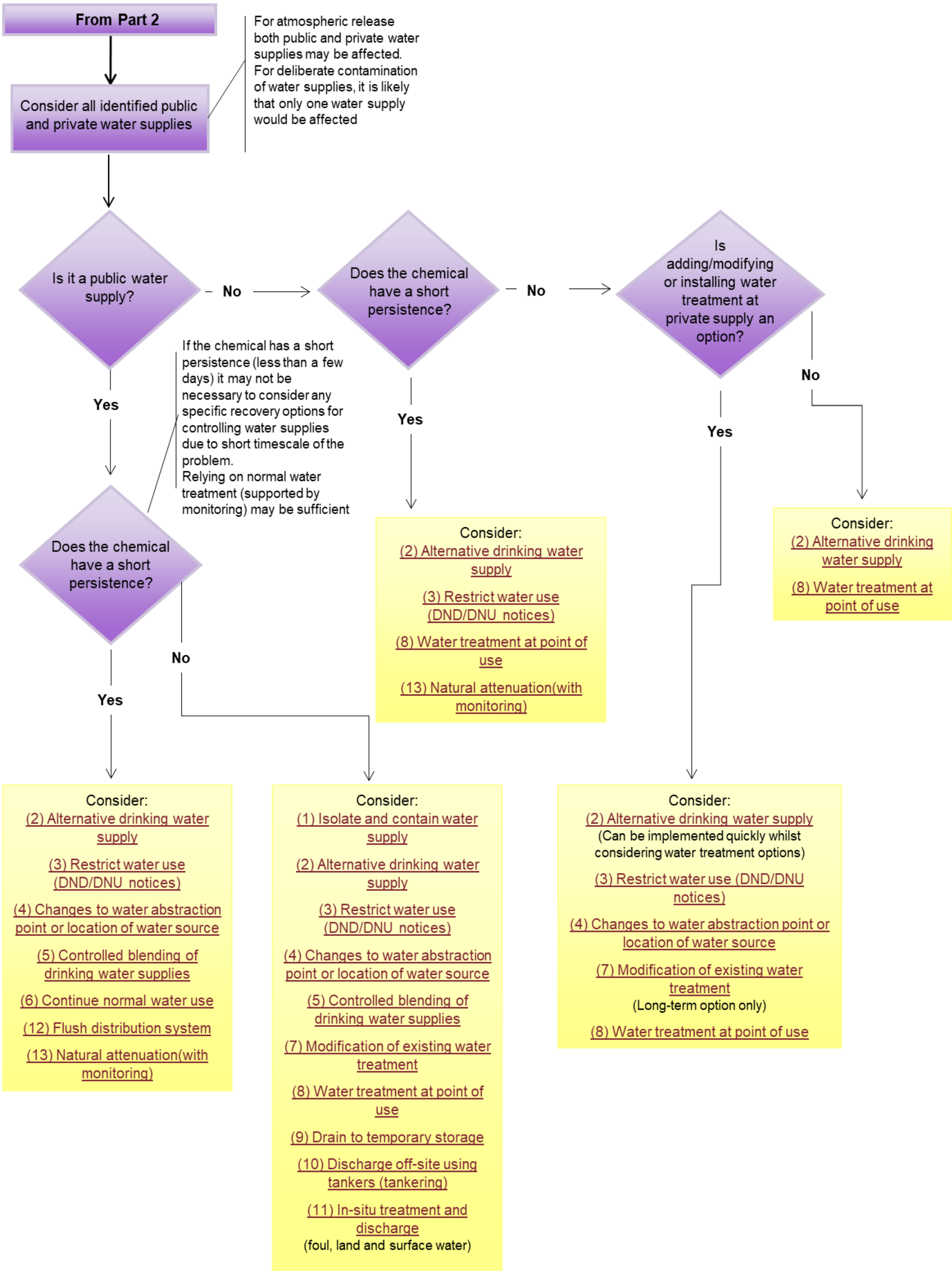


Figure 8.3. Decision tree 1 - Drinking water part 3

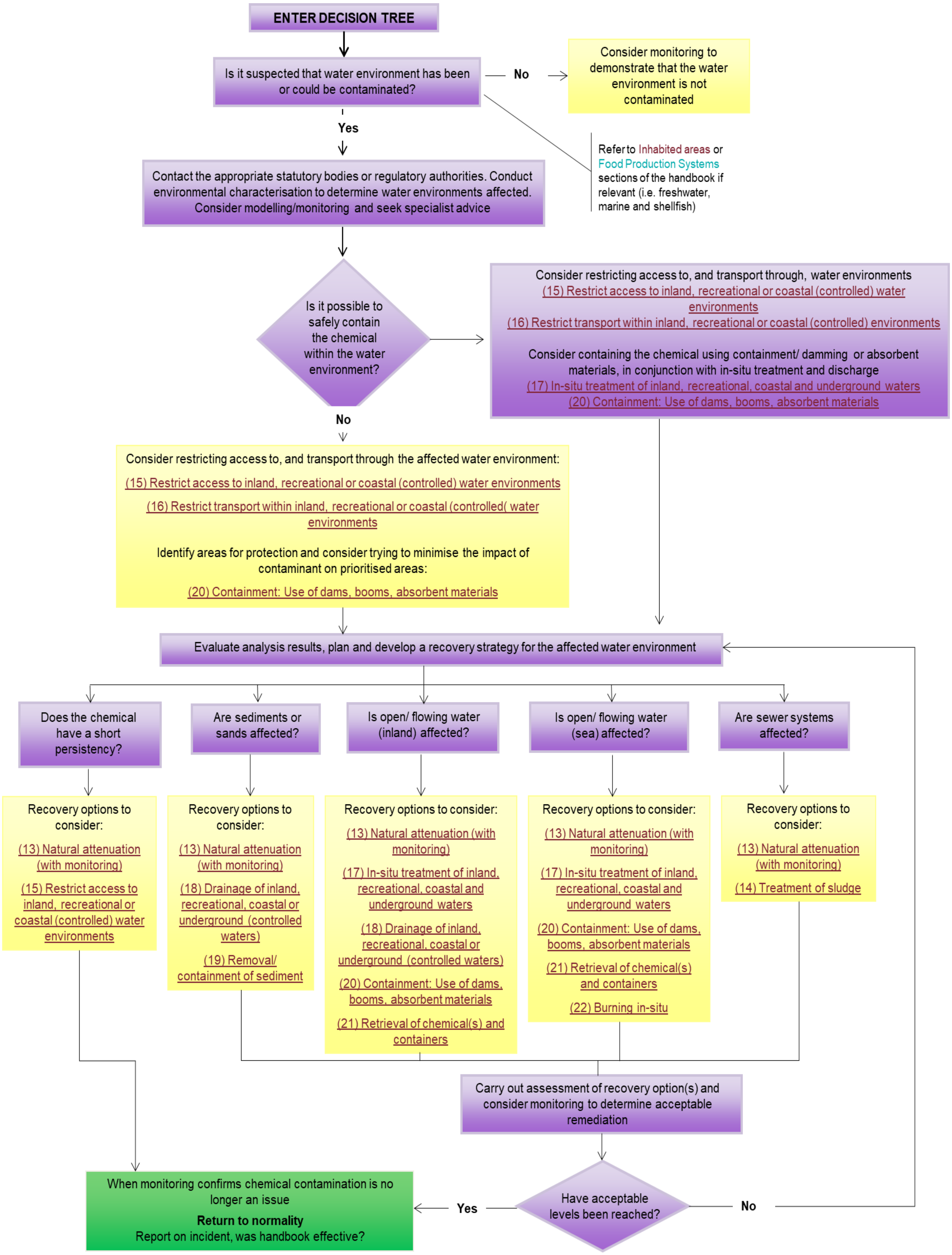


Figure 8.3. Decision tree 2 – Other water environments

8.2.3 Step 3: Review effectiveness of recovery options

A: Elimination of recovery options based on physicochemical properties only

Working through Figure 8.2 and Figure 8.3 has identified potential recovery options that may be applicable for contaminated water environments.

At this stage expert advice (e.g. EA/ SEPA/ NIEA/ DWI/ PHE) should be sought to determine and interpret the physicochemical properties of the chemical(s), using data identified in Table 8.5 (Step 1) to assist in eliminating recovery options. For example, if information obtained in Table 8.5 indicates that a chemical has a short persistence, the recovery option (7) Modification of existing water treatment could be eliminated at this stage. Particular attention must be taken when an incident involves a mixture of chemicals as it is not only important to look at the individual chemicals, but also to assess the potential interactions between chemicals themselves.

PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is openly available at:

https://www.gov.uk/government/collections/chemical-hazards-compendium

B: Elimination of options based on effectiveness

Determining which recovery options may be further eliminated can be achieved by considering the effectiveness of the recovery option in more detail (Table 8.6).

The colour-coding in Table 8.6 gives an indication of whether options would fall into “up to 100% effective”, “potentially effective” or “limited effectiveness”. The classification used in the selection tables is intended to be a generic guide and is not chemical specific.

The colour coding in Table 8.6 is based on an evaluation of the evidence base, stakeholder experience and advice or ongoing decontamination research within the UK. Therefore, Table 8.6 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (see Table 8.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. EA/ SEPA/ NIEA/ PHE/ DWI) and water companies. Due to their expertise and experience, water companies will usually be able to provide advice on the recovery strategy on a site and incident specific basis. If it is not possible to readily eliminate a recovery option at this stage, then it should be retained for consideration in Step 4.

A recovery option should only be eliminated if it is deemed to be ineffective for the affected water environment. All other recovery options should be retained. However, if the option is ‘potentially effective’ it should be recognised that there may be potential technical difficulties in implementing the option, or it may be that the option would only partially remove any residual contamination. Therefore, options are applicable if:

- There is direct evidence that it would be effective for the chemical (known applicability)
- The mechanism of action is such that it would be highly likely to be effective for the chemical (probable applicability)
- An option is taken as not being applicable if one or more of the following criteria are met:
- There is direct evidence that the option would not be applicable to the chemical.

- The chemical's properties are such that the option would not be expected to have any effect.
- The hazard posed by the chemical would not be reduced.
- The time taken to implement the recovery option would be longer than the chemical's persistence in the environment.
- There is a risk that implementing the recovery option should make the hazard worse (i.e. volatilization).
- Implementation of this option would place operatives at an unacceptable risk.

If it is not possible to readily eliminate a recovery option at this stage, then it should be retained for consideration in Step 4.

Table 8.6 Overview of recovery option effectiveness

Recovery option	Effectiveness				
	Drinking water		Other water environments		
	Public	Private	Sewage Treatment	Inland and underground waters	Marine and coastal water
(1) Isolate and contain drinking water supply			N/A	N/A	N/A
(2) Alternative drinking water supply			N/A	N/A	N/A
(3) Restrict water use (DND/DNU notices)			N/A	N/A	N/A
(4) Changes to water abstraction point or location of water source			N/A	N/A	N/A
(5) Controlled blending of drinking water supplies			N/A	N/A	N/A
(6) Continuing normal water treatment				N/A	N/A
(7) Modification of existing water treatment				N/A	N/A
(8) Water treatment at the point of use [tap]			N/A	N/A	N/A
(9) Drain to temporary storage		N/A	N/A	N/A	N/A
(10) Discharge to off-site disposal (tankering)		N/A		N/A	N/A
(11) In-situ treatment and discharge		N/A		N/A	N/A
(12) Flush distribution system			N/A	N/A	N/A
(13) Natural attenuation (with monitoring)					
(14) Treatment of sludge		N/A			
(15) Restrict access to inland, recreational or coastal (controlled) waters	N/A	N/A	N/A		
(16) Restrict transport within inland, recreational or coastal (controlled) waters	N/A	N/A	N/A		
(17) In-situ treatment of inland, recreational coastal and underground (controlled) waters	N/A	N/A	N/A		
(18) Drainage of inland, recreational, coastal and underground (controlled) waters	N/A	N/A	N/A		
(19) Removal/ containment of sediment	N/A	N/A	N/A		
(20) Containment: Use of dams, booms absorbent materials		N/A	N/A		
(21) Retrieval of chemical(s) and containers		N/A	N/A		
(22) Burning in-situ	N/A	N/A	N/A	N/A	

* (17) In situ-treatment of inland or coastal (controlled) waters could also be applicable to reservoirs used for drinking water.

Effectiveness	Up to 100% effective	Potentially effective	Limited effectiveness	Not applicable(N/A)

8.2.4 Step 4: Review key considerations and constraints

Recovery options invariably have other considerations or constraints associated with their implementation. A detailed description of these considerations is provided in the recovery option sheets (Section 9). To further assist in eliminating unsuitable options some of the key considerations for each option are described in Table 8.7 and summarised Table 8.8. These tables can be used in conjunction with the recovery option sheets (Section 9) to reduce the subset of options that may require more in-depth review.

To further assist in eliminating unsuitable options some of the key considerations for each option are described in Table 8.7 and summarised in Table 8.8 for public health, waste, social, technical, cost and time issues for each option. These tables can be used in conjunction with the recovery option sheets (Section 9) to reduce the subset of options that may require more in-depth review.

The colour coding in Table 8.7 and Table 8.8 is based on an evaluation of the evidence base, stakeholder experience and advice or ongoing decontamination research within the UK. The colour-coding gives an indication of whether options have “none of minor”, “moderate” or “important/key” constraints or considerations associated with their implementation. The classification used in the selection tables is intended to be a generic guide and is not chemical specific. Therefore, Table 8.7 and Table 8.8 should be evaluated in conjunction with the physicochemical properties of the chemical under consideration (Table 8.5). This is likely to be in conjunction with expert advice from relevant agencies (e.g. (e.g. EA/ SEPA/ NIEA/ PHE/ DWI).

The numbers in the brackets in Table 8.8 refers to the recovery option number. If an important (key) constraint is identified, it does not indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis (Step 5).

Table 8.7: Overview of key considerations of recovery options *Classification is based on evaluation of evidence base and stakeholder input

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(1) Isolate and contain drinking water supply	Public health - An alternative drinking water supply would have to be available. There are depressurisation risks for the network if rezoning cannot be carried out. Time - This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard.	Social - Disruption is likely to be upsetting to members of the public. People will also need information on where restrictions are in place, where alternative water distribution points are and how long the situation will last. Technical - The considerations associated with this option will vary depending on what other options are implemented with it. If the water supply is isolated but the area which is served by the supply is rezoned, impacts will be minimal, however, if alternative temporary supplies are required (i.e. tankers/ bowsers) then the technical, social and cost aspects will be increased. Waste - There may be significant amounts of contaminated water, which may require disposal and/ or storage under a waste transfer licence. Environment Agency should be consulted. Cost- The costs associated with other options which would need to be implemented alongside this.
Practical experience	Incident: Buncefield (2005) [8, 9]. Incident: Bromate contamination of raw water supply at Hatfield (2000) [10].	
(2) Alternative drinking water supply	Social - People will not want to travel too far to water distribution points. Older people and people with disabilities will require assistance in getting water to their homes. It should be noted that water companies do keep records of vulnerable customers and key users in their region and would therefore deliver water directly to these people. However, the customer list is voluntary (i.e. depends on people registering themselves with their water companies) therefore these companies may need to work with local authorities to identify other vulnerable customers. Bulk buying at shops is likely to lead to shortages of bottled water supplies. Technical - Separate individual supplies would need to be provided for hospitals, schools, office buildings and any other large premises containing large numbers of people. If bowsers are used, there is a requirement to sample the water in them every 48 hours and analyse for a full suite of contaminants or to refresh the water on a regular basis. This would involve several personnel and significant resources in the laboratory depending on the number of bowsers/ tanks required and tankering requirements. Cost - May be high, considering; vehicle hire (tankers and bowsers); consumables (fuel, bottles or containers for transporting water) and personnel (i.e. travelling time for drivers, possibly unsociable hours).	Public health - Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bath in, but not safe to drink or cook with may be difficult i.e. compliance. This can also have implications for lack of hygiene practices such as hand washing (as people are concerned about using the water, and they may reduce hand washing or stop altogether). The same applies to food hygiene and preparation. Clear public health messages should be given alongside any instructions about the water supply. Waste- Providing bottled water would produce bottle plastics waste.

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
	Time - This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard. It should be noted that mobilisation of tankers/bowsers and bottled water can take time depending on the location of stores and the affected area, and whether locations for bowsers/tanks/bottled water have been pre-agreed, or not.	
Practical experience	Incident: River Severn contamination (1998) [7]. Incident: Cyanide spill at Baia Mare Romania (2000) [8]. Incident: Long term leakage of heating oil into soil, UK (1996) [9]. Incident: Nickel in Care home (2008) [10]. Incident: Styrene in water, Whitechapel (2009) [11]. Incident: River Rhine contamination, Switzerland (1986) [12].	
(3) Restrict water use (DND/ DNU notices)	Public health - This recovery option should only be implemented if alternative water is available/ provided. Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bath in, but not safe to drink or cook with may be difficult i.e. compliance. A clear communication plan is required to ensure the water advice reaches the customers it needs to in a timely manner. Social - Reluctance of affected population to comply with and adhere to the restriction being imposed. Additionally, the social implications of providing an alternative water supply would also need to be considered for this option (see above). Cost - May be high considering options that will need to be implemented alongside this. I.e. for alternative water supplies the following cost factors would need to be considered: vehicle hire (tankers and bowsers); consumables (fuel, bottles or containers for transporting water) and personnel (i.e. travelling time for drivers, possibly unsociable hours).	Technical - Ensuring the affected population are aware that restrictions are in place and that an alternative supply is available. Shortages of alternative supplies could lead to people drinking contaminated water, and if the area affected involves large numbers of people, the supplies might not meet demand. The technical implications of providing an alternative water supply during restriction of water use also need to be considered (see above). Time - This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard. It should be noted that when providing alternative water supplies following the implementation of this option, mobilisation of tankers/bowsers and bottled water can take time depending on the location of stores and the affected area, and whether locations for bowsers/tanks/bottled water have been pre-agreed, or not. Waste- Providing bottled water would produce bottle plastics waste.
Practical experience	Incident: River Severn contamination (1998) [11]. Incident: Kerosene in drinking water (2004) [17]	
(4) Changes to water abstraction point or location of water source	Time - This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard.	Social - There may be problems regarding the acceptability of any remaining contamination in water supplies; there may also be concerns over the availability of alternative supplies. Where rezoning is used, or an alternative raw water source, acceptability may be an issue as customers may not like or be used to the alternative supply (e.g. upland water versus lowland; hard groundwater versus soft water).

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
		Technical - Priorities also need to be decided depending on the vulnerability of water supplies to the chemical emergency. Surface water supplies, such as rivers and reservoirs are likely to be of higher priority than boreholes in the short-term and this should be considered when formulating a monitoring strategy and identifying drinking water supplies of potential concern. In the longer term, monitoring and the implementation of this option may need to focus more on ground water sources, such as boreholes. The effectiveness of this measure depends on a programme of testing new abstraction points. Testing apparatus must be accurate. Rezoning carries a risk of discolouration of supplies if not carried out carefully – this is caused by the disturbance of iron and manganese deposits in water mains caused by a change in flow.
Practical experience	Incident: Arsenic contamination Bangladesh (1990's) [18]. Incident: Taste and odour to drinking water supplies within North East London (2010) [19].	
(5) Controlled blending of drinking water supplies	Time - Blending could be used as soon as contamination of a water source had been confirmed and would need to be implemented quickly. Blending would be required until the contamination is within the UK Water Quality Standard, or if raw water blending/mixing of supplies is used, until the water treatment works can deal with the concentration of the contaminant(s) present.	Public health – Controlled blending of drinking water supplies or changes in treatment processes may give rise to increased exposure to water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment. Social - Public perception would be an issue when implementing this option, even if water companies blended water to an acceptable standard, customers may still be concerned. Rezoning also applies here as a blending option – so the discoloration risk applies.
Practical experience	Incident: Bromate contamination of raw water supply at Hatfield (2000) [10]. Incident: Cyanide spill at Baia Mare Romania (2000) [11]. Incident: Taste and odour to drinking water supplies within North East London (2010) [19].	
(6) Continuing normal water treatment (supported by a monitoring programme)	Technical: Continuing normal water treatment may require enhanced surveillance to evaluate the effectiveness of this option.	Public health – Continuing normal water treatment may give rise to increased exposure to water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment. Social - There may be problems regarding the acceptability of any remaining contamination in water supplies; this is also likely to be related to the availability of alternative supplies such as bottled water. Waste – Although the works might remove the contamination, contamination may be concentrated in certain processes or in waste streams/ sludges. Disposal of these wastes would also carry costs and may require disposal and/ or storage under a waste transfer licence.
Practical experience		
(7) Modification of existing water treatment	Technical - Infrastructure needs to be in place to support the expansion of or changes to water treatment works if additional treatments are required (increased frequency of operations, 'new build', space requirements for new kit, etc).	Public health - Changes to water treatment processes may give rise to increased exposure to water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment.

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
	Cost - May be high, considering; infrastructure (adaption of current treatment plant or installation of a 'new build'); equipment; technology and personnel (builders, specialist engineers); timescale (could take months – years to install or build); disposal of contaminated water (availability of suitable disposal route). Time – it may take a long time (months – years) to implement this option.	Waste - There may be significant amounts of contaminated water, which may require disposal and/ or storage under a waste transfer licence. Social - Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There are also issues around the acceptability of residual levels of contamination by the public and the availability of alternative supplies (i.e. bottled water). There is also an aspect of disruption if modifications to existing water treatment require construction (i.e. 'new build').
Practical experience	Incident: Kerosene in drinking water NE London (2004) [16]. Incident: Love canal New York (1952) [19].	
(8) Water treatment at the point of use [tap]	Technical: This practicality of this option will be influenced by the availability of and installation of appropriate equipment	Social - This option relies upon individuals purchasing units, or arranging installation, as well as using them in an appropriate manner (e.g. not removing parts/ bypassing, etc). Technical - Reverse osmosis units require specialist engineers to install them and maintain/service them – if these activities are not carried out frequently, there are water quality risks Cost – Depends on the size of the area affected, and may be high, considering; equipment (jug filters are relatively inexpensive (<£40) whereas reverse osmosis units are more expensive (>£300); installation and maintenance (specialist engineers) and consumables (additional filters or pumps, if needed). Time: This option may take some time to implement considering the components required.
Practical experience	Incident: Arsenic Ground water contamination (1990's) [23].	
(9) Drain to temporary storage	Waste - There may be significant amounts of contaminated material generated from water treatment (e.g. sand from filter beds and sludge) that will require a suitable disposal route and may require disposal and/ or storage under a waste transfer licence. Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment. Costs - May be high, considering; equipment; skilled personnel to undertake the recovery measure and volume of waste requiring disposal.	Public health - There may be increased exposure of water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment. Technical - The volume/ capacity of contaminated material generated from water treatment that the water treatment facility can store is a technical consideration. It could also take days – weeks to drain (and then clean if required) the affected area. Time: There might be a delay in notifying relevant agencies. This option should be implemented early. The draining process may take some time depending on the amount of contaminated water.
Practical experience	Incident: Petrol fuel leak, Islington (2009) [25].	
(10) Discharge to off-site using tankers (tankering)	Technical - Equipment and skilled personnel to undertake the recovery measure (i.e. transport of raw materials and waste to and from treatment works). Waste - There may be significant amounts of contaminated water that will require a suitable disposal route and may require disposal and/ or storage under a waste transfer licence. Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment.	Public health - There may be increased exposure of water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment.

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
	Costs - May be high, considering; equipment; personnel and volume of waste requiring disposal.	
Practical experience	Incident: Petrol fuel leak, Islington (2009) [25].	
(11) In-situ treatment and discharge (foul, land, surface water)	Waste - There may be significant amounts of contaminated water that will require a suitable disposal route and may require disposal/ discharge under a waste transfer licence. Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment. Technical - Equipment and skilled personnel to undertake the recovery measure. Cost - May be high, considering; equipment; personnel and volume of contaminated water requiring treatment and disposal.	Public health - There may be increased exposure of water treatment operatives, either from direct exposure to contaminated water or through the accumulation, storage or discharge of contaminated waste water from treatment.
Practical experience	Incident: Wheal Jane Mine (1980's) [22]. Incident: Germany Bitterfield - regionally contaminated aquifers [24].	
(12) Flush distribution system	Public Health - An alternative drinking water supply (and appropriate water notifications) would have to be available while the system is being flushed. Waste - There may be significant amounts of contaminated water to be flushed through the water distribution system, which could potentially lead to the spread of low levels of contamination in the environment.	Time - This option could take some time to implement depending on the size of the distribution system.
Practical experience	Incident: Industrial water supply ethylene glycol (2009) [33]. Incident: Kerosene in drinking water NE London 2004 [17].	
(13) Natural attenuation (with monitoring)	None	Social - This option may be perceived as doing "nothing" by the public, which has negative implications. However, some may argue that continuing with normal water treatment is a positive message to the public. Technical - Monitoring equipment, skilled personnel to take samples. May take prolonged period of time for contamination to be broken down in the environment Cost - May be high, considering; monitoring equipment; consumables; skilled personnel (including laboratory analysis) and time (natural attenuation can take months – years).
Practical experience	Incident: Gannet oil spill, Scotland (2011) [26]. Incident: Petrol plume over England (1997) [27].	
(14) Treatment of sludge	Waste - There may be significant amounts of contaminated water and material generated from treatment of sludge. Contaminated waste will require a suitable disposal route and may require disposal and/ or storage under a waste transfer licence. Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment. Cost - May be high, considering; volume of contaminated sludge requiring treatment, monitoring equipment; consumables; skilled personnel (including laboratory analysis, loading and driving).	Public health - There may be increased exposure of water treatment operatives, either from direct exposure to contaminated water or sludge, through the accumulation, storage or discharge of contaminated waste water from treatment. Technical - Monitoring in the treatment works and of operatives may be required to ensure that operator exposure limits are not exceeded, and to confirm that treatment of sludge is effective in removing the chemical contamination.
Practical experience	Incident: Buncefield (2005) [8, 9].	

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(15) Restrict access to inland, recreational or coastal (controlled) water environments	Time - The recovery option will need to be in place quickly, with cordons and signage to prevent access to the contaminated water environment.	Social - Possible disruption and access may not be well received by members of the public. Technical - There may be difficulties in enforcing cordons depending on the size and nature of the affected water environment.
Practical experience	Incident: Happy lady shipwreck (2009) [28]. Incident: MSC Napoli (2007) [29].	
(16) Restrict transport within inland, recreational or coastal (controlled) waters	Technical - This option may be difficult to implement and control access and transport within the affected water environment.	Social - There may be issues with compliance and pressure to allow access to the affected water environment. Time: There might be a delay in notifying relevant agencies. This option should be implemented early and continue until the contamination reaches acceptable levels.
Practical experience	Incident: Braer Oil spill, Scotland (1993) [30]. Incident: MSC Napoli (2007) [29].	
(17) In-situ treatment of inland, recreational, coastal or underground waters	Time - This recovery option will have to be implemented quite quickly (early phase) as the effectiveness may depend on environmental conditions (i.e. weather/ depth of water). Waste - There may be significant amounts of contaminated water that will require a suitable disposal route (i.e. discharge to sea). Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment. Cost - May be high, considering; equipment; personnel and volume of contaminated water requiring treatment.	Public health - There may be increased risk of exposure to recovery workers. Technical - The volume of contaminated water requiring treatment and the suitability of techniques to remediate the affected water environment is a technical consideration.
Practical experience	Incident: Germany Bitterfield - regionally contaminated aquifers [24]. Incident: Songhua River spill, China (2005) [31]	
(18) Drainage of inland, recreational, coastal and underground (controlled) waters	Waste - There may be significant amounts of contaminated water or sediment that require disposal. Contaminated water will require a suitable disposal route and may require disposal and/ or storage under a waste transfer licence. Disposal routes for waste water and solid wastes could lead to the spread of low levels of contamination in the environment. Technical - The volume of contaminated water being drained and the availability of specialist equipment and skilled personal are technical considerations. It may also take a prolonged period of time for equipment to be installed and for the process to be implemented successfully. Cost - May be high, considering; equipment (high velocity pumps); infrastructure (installation); personnel; volume of contaminated water being drained.	Public health - There may be increased exposure of recovery operatives, either from direct exposure to contaminated water, or through drainage process. Social - Local communities may not find it acceptable for local waters to be drained. Compensation for loss of revenue for recreational/ business users.
Practical experience		
(19) Removal/ containment of sediment within inland, recreational, coastal and underground water environments	Waste - There may be significant amounts of contaminated sediment that require disposal. Contaminated sediment will require a suitable disposal route and may require disposal and/ or storage under a waste transfer licence. Disposal routes for solid wastes (i.e. contaminated sediment) could lead to the spread of low levels of contamination in the environment.	Public health - There may be increased exposure of recovery operatives, either from direct exposure to contaminated sediment through containment, removal or disposal.

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
	Technical - The volume of contaminated sediment and the availability of heavy specialist machinery, equipment and skilled personal are technical considerations. It may also take a prolonged period of time and be resource intensive to successfully remove all contaminated sediment. Cost - May be high, considering; equipment (heavy specialist machinery); skilled personnel; volume of contaminated sediment being removed/ contained.	Social - Issues with compliance a there may be pressure to re-open a site depending on what function it had previously (for example sailing clubs, recreational water areas, surfing, etc).
Practical experience	Incident: Love canal New York (1952) [20]. Incident: Minamata Japan (1968) [32]	
(20) Containment: Use of dams, booms absorbent materials	Waste - There may be significant quantities of contaminated adsorbent material/ booms or mats that require disposal. Contaminated materials will require a suitable disposal route and may require a waste transfer licence or be classified as hazardous waste. Technical - This recovery option may not be effective in containing the contamination, for example, in a marine setting this technique seldom reaches above 20% effectiveness. May take several days or weeks for contamination to be captured or contained. Time - This recovery option will have to be implemented quite quickly (early phase) as the effectiveness may depend on environmental conditions (i.e. weather conditions/ depth of water).	Public health - There may be increased exposure of recovery operatives to contamination through direct exposure with the chemical contaminant during the implementation of this option. Cost - May be high, considering; equipment (containment materials such as adsorbent booms/ mats); skilled personnel; volume of affected water and size/ scale of contamination.
Practical experience	Incident: Cyanide spill at Baia Mare Romania (2000) [12]. Incident: Braer Oil spill, Scotland (1993) [30].	
(21) Retrieval of chemical(s) and containers	Technical - This option is likely to require specialist equipment and skilled personnel (i.e. specialist diving team). This recovery option may not be effective in retrieving all of the chemical contamination (i.e. if chemical containers are leaking). It may take several days or weeks to retrieve chemical containers.	Public health - There may be increased exposure of recovery operatives to contamination through direct exposure with the chemical(s) or contained chemicals during the implementation of this option. Cost - May be high, considering; equipment; skilled personnel; size of affected area and spread of contamination. Time: This process may take a prolonged period of time depending on the number of chemical containers.
Practical experience	Incident: Tetrakalkyl lead accident at sea (1974) [33]	
(22) Burning in-situ	Public health - There is a significant risk of flash-back and secondary fires that could threaten human life in nearby settlements, as well as recovery workers. Additionally, combustion by-products (i.e. smoke and particulates) also have the potential to cause adverse health effects. Waste - There may be significant quantities of contaminated water that require further treatment (i.e. in-situ treatment and discharge). Discharge of contaminated water could lead to the spread of contamination in the environment. Social - Public perception of risk would be a major concern.	

Recovery options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
	Technical - The effectiveness of this recovery option depends on the physicochemical properties of the chemical contaminant (for example, thickness of oil slick (as not all crude oil spills burn)); prevailing metrological and oceanographic conditions (wind speed, wave conditions, water depth), as physical changes in the chemical contaminant can make it difficult or impossible to burn, and will require specialist personnel to implement this option. Cost - May be high, considering; equipment (i.e. booms to contain the spread); skilled personnel; volume of affected water and size/ scale of contamination. Time - This recovery option would have to be implemented in the early stages of a chemical spill due to weathering, dispersal and volatilisation.	
Practical experience	Incident: Buncefield (2005) [8, 9]	

Table 8.8 Overview of recovery option considerations ***Classification is based on evaluation of evidence base and stakeholder input**

Recovery options considerations	Public Health	Waste	Social	Technical	Cost	Time
(1) Isolate and contain water supply	Key	Low	Medium	Medium	Medium	Key
(2) Alternative drinking water supply	Medium	Medium	Key	Key	Key	Key
(3) Restrict water use (DND/DNU notices)	Key	Medium	Key	Medium	Key	Key
(4) Changes to water abstraction point or location of water source	Low	Low	Medium	Medium	Low	Key
(5) Controlled blending of drinking water supplies	Medium	Low	Medium	Medium	Low	Key
(6) Continuing normal water treatment	Medium	Medium	Medium	Low	Low	Low
(7) Modification of existing water treatment	Medium	Medium	Medium	Key	Key	Medium
(8) Water treatment at the point of use [tap]	Low	Low	Medium	Medium	Medium	Medium
(9) Drain to temporary storage	Medium	Key	Low	Medium	Key	Medium
(10) Discharge off site using tankers (tankering)	Medium	Key	Low	Key	Key	Low
(11) In-situ treatment and discharge	Medium	Key	Low	Key	Key	Low
(12) Flush distribution system	Key	Key	Low	Low	Low	Medium
(13) Natural attenuation (with monitoring)	Low	Low	Medium	Medium	Medium	Low
(14) Treatment of sludge	Medium	Key	Low	Medium	Key	Low
(15) Restrict access to inland, recreational or coastal (controlled) waters	Low	Low	Medium	Medium	Low	Key
(16) Restrict transport within inland, recreational or coastal (controlled) waters	Low	Low	Medium	Medium	Low	Low
(17) In-situ treatment of inland, recreational, coastal (controlled) waters	Medium	Key	Low	Medium	Key	Key
(18) Drainage of inland, recreational, coastal (controlled) waters	Medium	Key	Medium	Key	Key	Low
(19) Removal/ containment of sediment	Medium	Key	Medium	Key	Key	Low
(20) Containment: Use of dams, booms absorbent materials	Medium	Key	Low	Key	Medium	Key
(21) Retrieval of chemical(s) and containers	Medium	Low	Low	Key	Medium	Medium
(22) Burning in-situ	Key	Key	Key	Key	Key	Key

Considerations	**None or minor (Low)**	**Moderate (Medium)**	**Important (key)**
Time **(when to implement recovery option)**	**No restrictions on time**	**Weeks to months/ years**	**Hours – days**

8.2.5 Step 5: Consult recovery option sheets

Refer to individual recovery option sheets (Section 9) for all remaining options that have been identified in the selection process and note any other relevant constraints. This step involves a detailed analysis of all remaining options by careful consideration of the information on the relevant recovery options. This step can only be completed on an incident specific basis and in close consultation with local stakeholders to take into account local circumstances.

8.2.6 Step 6: Compare the remaining recovery options

Once options have been eliminated from the selection tables, if appropriate, the next step is to identify all the remaining options that could be considered for the type of affected water environments. These options need to be evaluated on a site and chemical incident specific basis using detailed information provided, for example, resources necessary, costs and amounts of waste generated, which may help to identify options that are not worth pursuing.

To aid with this selection strategy, a table could be designed to compare remaining recovery options. Table 8.9 gives an example of a template that could be used for such a purpose. Key questions that must also be considered include;

- What are the potential risks?
- What are the associated/ linked recovery options?

Once a recovery strategy has been implemented then the remaining steps are to monitor to determine if the recovery strategy has been effective, and to report on the incident and the response, including the effectiveness of the handbook (see Figure 8.2 and Figure 8.3). These steps are outside the scope of the handbook and are not discussed further.

Table 8.9: Further analysis of identified recovery options

Option number	Recovery option name	Step 1 Obtain information regarding the incident (refer to Table 8.5)	Step 2 Identify preliminary options for affected water environment (refer to Figure 8.2 – 8.3).	Step 3 – Review effectiveness and applicability of options (refer to Table 8.6)	Step 4- Review key considerations and constraints (refer to Tables 8.7 and 8.8)	Step 5- Consult recovery option sheets (Section 9).	Option applicable?	Reason for elimination?

8.3 References

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9 Recovery options for water environments

(1) Isolate and contain water supply
(2) Alternative drinking water supply
(3) Restrict water use (Do Not Drink / Do Not Use notices)
(4) Changes to water abstraction point or location of water source
(5) Controlled blending of drinking water supplies
(6) Continuing normal water treatment (supported by a monitoring programme)
(7) Modification of existing water treatment
(8) Water treatment at the point of use [tap]
(9) Drain to temporary storage
(10) Discharge off site using tankers (tankering)
(11) In-situ treatment discharge (foul, land, surface water)
(12) Flush distribution system
(13) Natural attenuation (with monitoring)
(14) Treatment of sludge
(15) Restrict access to inland, recreational or coastal (controlled) water environments
(16) Restrict transport through inland, recreational or coastal (controlled) water environments
(17) In-situ treatment of inland, recreational, coastal and underground waters
(18) Drainage of inland, recreational, coastal and underground (controlled) waters
(19) Removal/containment of sediment within inland, recreational coastal and underground water environments
(20) Containment: use of dams, booms absorbent materials
(21) Retrieval of chemicals
(22) Burning in-situ

(1) Isolate and contain water supply

Objective	To prevent and reduce exposure to contaminated drinking water supply.
Other benefits	None
Recovery option description	Water supplies would be isolated (turned-off) in only the most extreme circumstances. Ideally, this option should only be considered for a very short time (hours) to allow an initial flush of contamination to pass through the water supply system or to allow for very short-lived chemicals to degrade. It may also result in a large quantity of contaminated water requiring disposal.
Key information requirements	What is the source of contamination? What are the population demographics and size of the affected area? Will sensitive groups or populations be affected? (i.e. hospitals, schools) Are alternative drinking water supplies available? How difficult is it to isolate the supply?
Linked recovery options	This is a **protective option** and may need to be linked to **remediation options**. This recovery option should also be considered in conjunction with; (2) Alternative drinking water supply; (3) Restrict water use (Do Not Drink / Do Not Use Notices); (4) Changes to water abstraction point or location of water source; and (12) Flush distribution system. Storage / treatment of contaminated water (post treatment) would also need to be considered and options include; (9) Drain to temporary storage; (10) Discharge off site using tankers; (11) In-situ treatment and discharge (foul, land, surface water)
Target	Water supply and subsequent water use (i.e. drinking, food preparation, washing)
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access: https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties would include chemical toxicity (acute and chronic health impacts).
Scale of application	Any scale.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option would need to be implemented in the **early phase (hours to days)** of a chemical incident. The recovery option will need to be in place for the duration of the contamination, or until contamination is within water quality standards.

Considerations

Public health considerations	This option should only be considered for a very short time (hours). If this option is likely to be required for some time (i.e. days) then an alternative source of potable water would need to be made available.
Legal implications and obligations	Drinking water standards are regulated by the drinking water inspectorate (DWI). Chemical contamination would have to be within regulated limits before the isolated supply could be turned back on and comply with UK Drinking Water Standards. Refer to Appendix A for more information.
Social implications	Disruption likely to be upsetting to members of the public. There may also be issues with regards to disruption and access to people's homes/ residential areas.
Environmental considerations	None.

(1) Isolate and contain water supply

Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). An alternative supply of potable drinking water would have to be provided.

Effectiveness

Recovery option effectiveness	Up-to 100% effective in reducing exposure (i.e. ingestion/inhalation and dermal contact) of contaminated water.
Technical factors influencing effectiveness of recovery option	Access to water source to isolate the supply may be difficult. Depressurisation of system could lead to leaching of residual contamination from pipes when supply is turned back on.

Feasibility and intervention costs

Specific equipment	None
Utilities and infrastructure	None
Consumables	None
Skills, personnel and operator time	None
Safety precautions	None
Other limitations/factors influencing costs	None

Waste

Amount and type	None unless contaminated water requires treatment and disposal. See (7) Modification of existing water treatment for potential wastes arising from water treatment of contaminated water.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N.A

Exposure

Averted exposure	Ingestion/ inhalation or dermal contact with contaminated water (i.e. drinking, food preparation, washing).
Potential increased worker exposure	None.

Other considerations

Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.

(1) Isolate and contain water supply

Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. People will need information on: where restrictions are in place and that alternative water is available; where alternative water distribution points are; times when water will be distributed; how long the situation will last.

Additional information

Practical experience	
Key references	A. Nisbet, J. Brown, A. Jones, H. Rochford, D. Hammond and T. Cabianca. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [April 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015 Health Protection Agency. Health advice - coping without mains (2010). Available [April 2012] at; https://webarchive.nationalarchives.gov.uk/20120902110902/http://www.hpa.nhs.uk/webc/HPAwebFile/HPAweb_C/1194947340948 The Drinking Water Inspectorate. Drinking Water Safety. Guidance to health and water professionals (2009). Available [April 2012] at; http://dwi.defra.gov.uk/stakeholders/information-letters/2009/09_2009Annex.pdf
Comments	
Document History	

(2) Alternative drinking water supply

Objective	To reduce exposure to consumers by providing an alternative supply of potable drinking water in the event of chemical concentrations in supplied (treated) water exceeding UK Water Quality Standards.
Other benefits	Reduce dermal exposure from washing and impact on gardens from watering
Recovery option description	If restrictions were placed on the use of drinking water supplies due to chemical concentrations exceeding UK Water Quality Standards, alternative sources of water would need to be provided for drinking water and water used for food preparation. This Recovery option sheet considers the use of: • alternative mains water supply • reservoir/ aquifer rezoning • bottled water • water provided by water companies via tankers and bowsers at distribution points from other drinking water sources Advice is likely to be given that continued use of the water supply for sanitation is expected (see (8) Water treatment at point of use [tap]) and this will not give rise to any significant hazard. If the level of contamination was sufficiently high, then, in extreme cases, the water supplies could be isolated completely (1) Isolate and contain drinking water supply. Although water may not be acceptable for use as drinking water, it may still be suitable for sanitation. However, water supplies could be turned off completely in the most extreme circumstances. Ideally, this recovery option should only be considered for a very short time (hours) to allow an initial flush of contamination to pass through the water supply system or to allow for very short-lived chemicals to degrade.
Key information requirements	What are the population demographics and size of the affected area? Will sensitive groups or populations be affected? (i.e. hospitals, schools) Details of responsibilities for providing alternative water to private supply users Monitoring/ sampling analysis to confirm water is fit for consumption. Seek specialist advice and guidance (i.e. DWI/ Water Utility providers) as this recovery option may require bowsers, tankers and transport vehicles.
Linked recovery options	This is a **protective option** and may need to be linked to **remediation options.** This recovery option should also be considered in conjunction with; (1) Isolate and contain drinking water supply; (3) Restrict water use (DND/DNU notices) and (4) Changes to water abstraction point or location of water source;
Target	Water supply and subsequent water use (i.e. drinking, food preparation, washing)
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physiochemical properties include: chemical toxicity (acute and chronic health impacts), water solubility, density and partition coefficient.
Scale of application	**Small/medium scale.** Sufficient drinking water would need to be provided to sustain the population affected by any restrictions to their normal drinking water supply. Also sufficient drinking water would need to be provided to meet any legal obligations placed on the supplier and comply with UK Drinking Water Standards. In general, the supply of alternative water could only be maintained for a short period (days) and then only to relatively small numbers of people in local or regional communities. Distribution of bottled water or water via tankers and bowsers is likely to take at least 8 hours to plan and arrange. It is important, therefore to encourage use of existing water supplies for sanitation purposes to avoid other public health issues.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).

(2) Alternative drinking water supply

Time of application	This recovery option would need to be implemented in the **early phase (hours to days)** of a chemical incident. The recovery option will need to be in place for the duration of the contamination, or until contamination is within water quality standards.

Considerations

Public health considerations	None expected if water supplied is of sufficient quality. However some mineral waters on sale in the high street have a high concentration of sodium that can cause adverse health effects if used in baby feed. Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bathe in, but not safe to drink or cook with may be difficult. The season (summer or winter) will affect the amount of drinking water required due to human physiology.
Legal implications and obligations	Alternative drinking water supplies would need to meet the quality standards for normal drinking water supplies. Sufficient water would need to be provided to meet any legal obligations placed on the water supplier. In the UK, the Security and Emergency Measures Direction (SEMD) requires that 10 l d^{-1} per person should be provided if piped water supplies fail. Water companies in the UK have contingency plans to provide an alternative supply of drinking water during emergency situations (SEMD). These plans specify a daily amount of 10 l d^{-1} of drinking water per capita must be supplied for the first 5 days, then 20 litres per day after this period, and a time limit in which this alternative supply is provided. Refer to Appendix A for more information.
Social implications	There would be a short-term social impact as people would have to make provisions for collecting alternative drinking water supplies. Rationing may be needed to extend available supplies. Social unrest (due to real or perceived shortages in supplies), could lead to problems at distribution points. There is evidence to suggest that people are more likely to move out of their homes due to loss of water supply than electricity. Loss of confidence in the quality of water provided by water companies to the public (and other parties for private supplies). People will not want to travel far to distribution points. Older people and people with disabilities will require assistance in getting water to their homes. Bulk buying at shops is likely to lead to shortages of bottled water supplies. Separate individual supplies would need to be provided for hospitals, schools, office buildings and any other large premises containing large numbers of people. There is the potential issue of bottled water theft (water is an important commodity), and vandalism of bowsers, therefore security may be required. The public may decide to boil water provided via an alternative supply regardless of the public health message sent out. Generally, members of the public prefer bottled water to bowsers/ tanker water.
Environmental considerations	Inclement weather could lead to disruption in the provision of alternative supplies. Remote areas may not receive alternative supplies. Widespread contamination could mean alternative supplies are limited. Drought conditions may mean alternative supplies are limited. If undue pressure was put on a particular source of water such as rivers or reservoirs, then there could be an environmental impact. This would be exacerbated during the summer when water levels are generally at their lowest. Potential impact from requirement to dispose of large quantities of plastic bottles. Large quantity of heavy tankers to supply water could worsen air pollution in an area.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).

Effectiveness

Recovery option effectiveness	If the alternative supply was free from contamination, and the restricted water not used, then this recovery option will be up to 100% effective. An alternative supply may be less contaminated but still acceptable for use as drinking water; in this case the reduction in contaminated concentrations will be lower. Bottled water from shops should be free from contamination, as the source is generally not local and it could have been bottled for some time prior to any incident. In addition, bottled water has already gone through screening to meet quality control requirements.

(2) Alternative drinking water supply

Technical factors influencing effectiveness of recovery option	Some people may ignore restrictions and continue to drink the contaminated water. Some people may not be aware that restrictions are in place and that an alternative supply is available. Shortages of alternative supplies could lead to people drinking the contaminated water. If the affected area involved large numbers of people, the supplies might not meet demand. Suitable storage is required for the storage of large quantities of water. Sufficient staff to hand out large quantities of bottled water In some circumstances narrow roads may affect distribution of tankers/ bowsers via large vehicles/ tankers Separate individual supplies would need to be provided for hospitals, schools, office buildings and any other large premises containing large numbers of people. Instructions on DND notices could be supplied with bottled water.

Feasibility and intervention costs

Specific equipment	Equipment used for the transport of water (lorries, tankers and bowsers). Large storage facilities for the stockpiling of water. Containers for the transport of water from the distribution point to homes. Pallets for appropriate storage of bottled water.
Utilities and infrastructure	Co-ordination of distribution of supplies. Forward planning to determine how long capacity can be maintained.
Consumables	Fuel for vehicles and bottles or containers for transporting water. Bottled water from shops/warehouses.
Skills, personnel and operator time	Sufficient number of drivers to transport the water. Travelling time for drivers, possibly unsociable hours (weekends or outside normal working). If bowsers are used, there is a requirement to sample the water in them every 48 hours and analyse for a full suite of contaminants. This would involve a number of personnel and significant resources in the laboratory depending on the number of bowers/tanks required. In extreme circumstances, a police presence (or security) may be required at water distribution points.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water company workers use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Possible crowd control may be required at water distribution points. The water distributor (i.e. tanker or bowser) may require protection (from vandalism), and there may be the need for security at water storage areas.
Other limitations/factors influencing costs	Availability of tankers and bowsers. Some water companies may have their own tankers or bowsers or may have service level agreements with companies to provide such equipment in the event of an emergency. In both cases the equipment will be available locally, although may be not on the required timescales if large numbers are required. In large scale incidents, resources beyond those available to individual or groups of Water Companies may be needed. Mutual aid agreements may be necessary.

Waste

Amount and type	Many types of waste that will be encountered during or after a chemical incident may come under the classification of 'Hazardous waste'. To help determine if a waste is hazardous or not, seek expert opinion (Environment Agency) and consult available national guidance. No direct waste is generated unless contaminated water supply is isolated and requires treatment and prior to disposal. If contaminated water has already been treated, wastes arising from water treatment may also be contaminated. Indirect waste may also be generated, for example the disposal of large quantities of empty plastic bottles following the supply of an alternative supply.

(2) Alternative drinking water supply

Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance as contaminated water may require disposal and/or storage under authorisation via a suitable disposal route (Environment Agency). For any contaminated water, the following recovery options may apply; (9) Drain to temporary storage; (10) Discharge offsite using tankers (tankering); and (11) In-situ treatment and discharge (foul, land, surface water) Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) for disposal.
Factors influencing waste issues (i.e. cost)	Contaminated waste must be transported in suitable tank-vehicles or leak proof receptacles. The Environment Agencies (EA/ SEPA/ NIEA) have special powers to respond to waste issues during major incidents and should be consulted to determine an appropriate disposal route for contaminated waste although they are not responsible for removing the waste. Costs will be influenced by- volume of water requiring disposal and contaminant concentrations in the water.
Exposure	
Averted exposure	Ingestion/ inhalation or dermal contact with contaminated water (i.e. drinking, food preparation, washing).
Potential increased worker exposure	N/A
Other considerations	
Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at: www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.
Additional information	
Practical experience	Water companies have experience in providing drinking water using tankers or bowsers in emergency situations and natural disasters (e.g. floods). There are extensive bottled water resources in the UK.
Key references	A. Nisbet, J. Brown, A. Jones, H. Rochford, D. Hammond and T. Cabianca. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [April 2012] at;

(2) Alternative drinking water supply

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Comments

Document History

(3) Restrict water use (Do Not Drink / Do Not Use notices)

Objective	To prevent potential adverse health effects from exposure to contaminated water.
Other benefits	This recovery option also avoids exposing the affected population to risks in the initial and possibly later stages of a chemical incident where water supplies have been contaminated.
Recovery option description	**DND- Do Not Drink** or **DNU- Do Not Use Notices** These 2 notices differ but both have important outcomes. There might be cases in which water may not be potable as it may cause adverse health effects but the same water might be acceptable for washing items or bathing.
Key information requirements	What are the population demographics and size of the affected area? Will sensitive groups of populations be affected (i.e. hospitals, schools?). Are alternative drinking water supplies available?
Linked recovery options	This is a **protective option** and may need to be linked to **remediation options.** This recovery option should also be considered in conjunction with; (1) Isolate and contain water supply; (2) Alternative drinking water supply; (4) Changes to water abstraction point or location of water source; Storage / treatment of contaminated water (post treatment) would also need to be considered; (9) Drain to temporary storage; (10) Discharge off site using tankers (tankering); (11) In-situ treatment and discharge (foul, land, surface water) and (12) Flush distribution system.
Target	Water supply and subsequent water use (i.e. drinking, food preparation, washing).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Important physicochemical properties include: chemical toxicity (acute and chronic health impacts), water solubility, density and partition coefficient.
Scale of application	It is recommended that DNU notices are reserved for use only in those circumstances where there is unequivocal evidence of persistent contamination of the water supply with a substance at a level where short term exposure is known to give rise to adverse health effects in the otherwise healthy population, and measures to restore the water supply to normal are likely to be protracted (weeks, rather than hours or days). Another relevant scenario would be where the contaminant cannot be detected by a change in appearance, taste or smell of water (meaning consumers would not be alerted to the problem and thus unlikely to take avoiding action without being warned).
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option would need to be implemented in the **early phase (hours to days)** of a chemical incident. The recovery option will need to be in place for the duration of the contamination, or until contamination is within water quality standards.

Considerations

Public health considerations	This recovery option should only be implemented if alternative water is available/ provided. Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bathe in, but not safe to drink or cook with may be difficult i.e. compliance.

(3) Restrict water use (Do Not Drink / Do Not Use notices)

Legal implications and obligations	Ability of authorities to control the compliance with instructions and advice; people cannot be forced to comply, may not understand the instructions or be able or willing to follow them. Refer to Appendix A for more information.
Social implications	Reluctance of community to adhere to the restriction being imposed. It is recommended that DNU notices are reserved for use only in those circumstances where there is unequivocal evidence of persistent contamination of the water supply with a substance at a level where short-term exposure is known to give rise to adverse health effects in an otherwise healthy population, and measures to restore the water supply to normal are likely to be protracted (weeks, rather than hours or days). Generally, the type of circumstances when a DNU notice might be considered are those where there is a major chemical pollution incident which cannot be contained by the water supplier through stopping abstraction at the treatment works and/or the contamination has entered the treated water distribution system and the extent of the contaminated water cannot quickly be identified and contained/removed. Local authorities have the responsibility for making decisions about the continued operation of premises manufacturing or serving food and drink, and for public buildings such as schools and leisure centres. PHE is responsible for initiating contingency arrangements for hospitals and other health services.
Environmental considerations	Inclement weather could lead to disruption in the provision of alternative supplies. Remote areas may not receive alternative supplies. Widespread contamination could mean alternative supplies are limited. Drought conditions may mean alternative supplies are limited.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). It must be clear that issuing DND / DNU notices are a sufficient response to the incident.
Effectiveness	
Recovery option effectiveness	This recovery option may be up to 100% effective in preventing exposure, although it is possible that some members of the community will not adhere to the notice or understand the instructions. The efficacy of the recovery option depends on efficiency of the communication medium and compliance of the community to adhere to the warning notice.
Technical factors influencing effectiveness of recovery option	Implementing this option will depend on the nature of the incident. In a large scale event, the hazards posed by issuing a wide scale warning notice need to be balanced carefully against the nature of the water supply. Experience has shown that it is often preferable to implement enhanced health surveillance of the affected community instead of issuing a warning notice. Each situation has to be judged on its merits, taking into account local knowledge and whether or not water supplies can be returned to normal quickly or an alternate piped supply provided (by rezoning). If a decision is taken to issue 'do not drink' or 'do not use' advice or notices, the basis for lifting the advice must be agreed at the same time. Experience has shown that significant problems can arise if the criteria for lifting the notice have not been decided when it is first issued. The public may ignore restrictions and continue to drink the contaminated water. The public may also not be aware that restrictions are in place and that an alternative supply is available. Shortages of alternative supplies could lead to the public drinking contaminated water. If the area affected involved large numbers of people, the supplies might not meet demand. The key issues associated with this recovery option are compliance of individuals and length of time this notice would be enforced for. DND /DNU notices pose a significant challenge to a water supplier due to the need to make 100 per cent provision of alternative water supplies for drinking and food preparation (i.e. cooking). These logistical problems are magnified and further compounded in the case of a DNU notice because of the hygiene issues implicit in restricting the public's access to piped water for showering and bathing.
Feasibility and intervention costs	
Specific equipment	Mechanism of communication, leaflets, loud hailer, local radio, television.

(3) Restrict water use (Do Not Drink / Do Not Use notices)

Utilities and infrastructure	See linked recovery option (2) Alternative drinking water supply.
Consumables	Possibly bottled water/ bowsers (see linked recovery option (2) Alternative drinking water supply)
Skills, personnel and operator time	Operators disseminating warning notification, enforcing the message. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident.
Safety precautions	Appropriate educative/ informative material for the affected community.
Other limitations/factors influencing costs	Compliance by the public. Costs will be influenced by the length of time for which the restriction will remain in place
Waste	
Amount and type	None.
Possible transport, treatment, disposal and storage routes	None
Factors influencing waste issues (i.e. cost)	None
Exposure	
Averted exposure	Ingestion/ inhalation or dermal contact with contaminated water (i.e. drinking, food preparation, washing or bathing). Averted exposure will be influenced by public compliance with this recovery option.
Potential increased worker exposure	N/A.
Other considerations	
Agricultural impact	There may be an agricultural impact that could lead to a shortage of water for irrigation or impact on other farming practises, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementing this recovery option would require a clear communication strategy to ensure the public are kept informed, address health concerns and ensure compliance. All responding agencies should ensure that public advice is provided in an agreed and common format such as:

Frequently Asked Questions (FAQ) and provided to their staff in call centres or placed on their websites.

Additional information

Practical experience	Members of the public are familiar with boil water advisory (BWA) notices. Whilst these notices cause inconvenience in the home and can be disruptive to certain businesses (food and drink retailers and manufacturers) and public buildings (health care premises), the water industry has substantive experience of the practical aspects which are manageable, and the public is familiar with the concept.
Key references	A. Nisbet, J. Brown, A. Jones, H. Rochford, D. Hammond and T. Cabianca. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [April 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015 Health Protection Agency. Health advice - coping without mains (2010). Available [April 2012] at; https://webarchive.nationalarchives.gov.uk/20120902110902/http://www.hpa.nhs.uk/webc/HPAwebFile/HPAweb_C/1194947340948 Health Protection Agency. Heating oil incidents: action card for public health practitioner's v1.0 (2010). Available [April 2012] at; http://www.npis.org/PHE/CHaP_Report_No__20_Final__with_links_.pdf Rundblad G, 'The semantics and pragmatics of water notices and the impact on public health'. Journal Of Water And Health. 2008; 6: 77-86. The Drinking Water Inspectorate. Drinking Water Safety. Guidance to health and water professionals (2009). Available [April 2012] at; http://dwi.defra.gov.uk/stakeholders/information-letters/2009/09_2009Annex.pdf
Comments	
Document History	

(4) Changes to water abstraction point or location of water source

Objective	To reduce chemical contamination in drinking water in the event of chemical contaminant concentrations in normal water supply (treated) exceeding UK Drinking Water standards.
Other benefits	None
Recovery option description	This recovery option considers changes in abstraction points from; within a reservoir and rivers; the use of alternative water sources and movement of water within distributed water networks (usually referred to as re-zoning). It may take several days (dependent on physiochemical properties of chemical) or more for contamination to be evenly distributed through the water column of reservoirs due to their size and depth or climate (e.g. ice cover, hydrological cycling). It may be possible to use water from deeper parts of a reservoir (before contamination has reached it) by opening lower sluice gates and using water that has not yet been contaminated. It may also be possible for water companies to use other reservoirs under their responsibility that have not been contaminated. For rivers, water could be abstracted upstream of any contamination if several abstraction points are available. Water could also be used from downstream of the contamination if the abstraction point is sufficiently far enough away that the contamination has not reached there yet. It may be possible to change to alternative sources of water (e.g. change from river abstraction to bore holes). It may be possible for other nearby water companies to share uncontaminated water, if there is sufficient spare capacity and distributed networks exist to transfer the water to the desired location.
Key information requirements	Potential for contamination of other water sources. Is there capacity for supply from alternative water sources? Where is the river catchment area?
Linked recovery options	This is a **remediation option** and may need to be linked to **protective options.** This recovery option should also be considered in conjunction with; (1) Isolate and contain drinking water supply; (2) Alternative drinking water supply; (3) Restrict water use (Do Not Drink / Do Not Use notices) and (13) Natural attenuation (with monitoring)
Target	Public drinking water supplies. Not likely to be appropriate for private drinking water supplies in general (technical factors influencing effectiveness of recovery option).
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate drinking water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Small - medium scale:** Water companies or water suppliers could apply this option as long as sufficient drinking water supplies can be maintained, or until the contamination has been sufficiently dispersed or diluted.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option would need to be implemented in the **early phase (hours to days)** of a chemical incident. The recovery option will need to be in place for the duration of the contamination, or until contamination is within water quality standards.

Considerations

Public health considerations	None

(4) Changes to water abstraction point or location of water source

Legal implications and obligations	Any drinking water supplies would need to comply with the UK Drinking Water Standards. Refer to Appendix A for more information.
Social implications	There may be problems regarding the acceptability of any remaining contamination in water supplies; this is likely to be related to the availability of alternative supplies, such as bottled water. Demand for bottled water may increase sharply if people prefer drinking bottled water (for any reason).
Environmental considerations	Widespread contamination or water shortages during periods of drought could result in fewer opportunities for changing abstraction. Management of abstraction would need to be monitored more closely than usual to ensure that permanent damage to natural water sources is avoided. For example, changes in the manipulation of reservoir water may affect downstream biota. Potential for release of discoloured water into distribution system
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). This option may lead to possible water shortages in other areas. Water from a new abstraction point may also be contaminated, but to a lesser extent. Any increase in exposure compared with that prior to the incident would need to be weighed against the need to supply drinking water to the affected population.

Effectiveness

Recovery option effectiveness	If the water at the new abstraction point or water source is uncontaminated then this recovery option would be up to 100% effective in reducing concentrations in drinking water. The effectiveness of this measure depends on a programme of testing new abstraction points. Testing apparatus must be well calibrated and accurate.
Technical factors influencing effectiveness of recovery option	Priorities need to be decided depending on the vulnerability of water supplies to the chemical emergency. Surface water supplies, such as rivers and reservoirs, are likely to be of higher priority than boreholes in the short term, and this should be taken into account when formulating a monitoring strategy and identifying supplies of potential concern. In the longer term, monitoring and the implementation of this option may need to focus more on ground water sources, such as boreholes. Changes to abstraction or water sources could be implemented as soon as contamination of a water source is confirmed (and would need to be implemented quickly). This recovery option can only be used for a few days or weeks, until contamination is fully mixed (e.g. in reservoirs, or until contamination has spread to the new abstraction point, such as rivers, except where the new abstraction point is upstream of the release). This option is unlikely to be used in the longer term unless switching to deep boreholes unaffected by surface water contamination is an option. Changes made to water supply sources need to be linked very closely to a detailed monitoring programme to ensure the optimal timing of the changes to water abstraction points or location of water source. The effectiveness of this option will also be influenced by the extent to which water at the new abstraction point or water source is contaminated. For reservoir abstraction, water will need to be drawn from a sufficient depth to ensure that abstracted water has a lower chemical contamination concentration. The effectiveness of implementing this recovery option for surface reservoirs is likely to be low, and have limited acceptability. The time taken for contamination to reach abstraction points or new water supply should also be considered (e.g. water from a borehole would require monitoring). Changing from river abstraction to deep boreholes may only be an option in the short-term if the boreholes only have a limited water capacity compared to rivers. Changing the water source or abstraction point is unlikely to be an option for private water supplies since it is unlikely that a second source of uncontaminated water would be available. However, some private water supplies do have an additional source of supply where one source

	can dry up during the summer. It should be noted that the water from the alternative source is often not very palatable and so probably couldn't be used in the long term.
Feasibility and intervention costs	
Specific equipment	None in the short-term other than monitoring equipment. However, if this countermeasure was being considered as a longer-term option (switching to deep boreholes) then pipe work/infrastructure may be required. Additional monitoring may be needed at abstraction points to ensure contamination has not reached the new abstraction point or water source, or is below UK Water Quality Standards.
Utilities and infrastructure	Water companies or suppliers would have to have a sufficiently flexible and integrated system of water supply control to allow them to change abstraction points and/or water sources. This would mean that probably only the larger suppliers would be able to implement this option.
Consumables	None
Skills, personnel and operator time	No specific skills are required other than those already employed by the water company / supplier. There will be no additional time costs for the operator as any actions can be done during the course of normal work practices, with the exception of monitoring at the abstraction points.
Safety precautions	None.
Other limitations/factors influencing costs	Cost will vary depending on the size and the scale of the chemical incident.
Waste	
Amount and type	This option will not produce any contaminated waste water directly.
Possible transport, treatment, disposal and storage routes	N/ A.
Factors influencing waste issues (i.e. cost)	N/ A.
Exposure	
Averted exposure	Ingestion/ inhalation or dermal contact with contaminated water (i.e. drinking, food preparation, washing and bathing).
Potential increased worker exposure	None
Other considerations	
Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	None

(4) Changes to water abstraction point or location of water source

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Routes already in use by the water companies / suppliers could be used to give instructions to their operators. However, communication with the affected communities about the rationale for choosing this option would be desirable and should form part of a wider communication and information strategy.

Additional information

Practical experience	
Key references	Caldwell BK, Caldwell JC, Mitra SN, Smith W. Arsenic contamination Bangladesh 1990's. Searching for an optimum solution to the Bangladesh arsenic crisis. Social science & Medicine. 2003; 56: 2089-2096 Goodfellow FJL, Murray VSG. Chemical Incident Response Service, Medical Toxicology Unit, Guy's and St Thomas' Hospital Trust, London, UK. Chemical incident report. 2000; 12 : 8-9
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(5) Controlled blending of drinking water supplies

Objective	To reduce exposure to consumers by diluting chemical contamination in drinking water in the event of activity concentrations in the supplied (treated) water exceeding UK Water Quality Standards.
Other benefits	None
Recovery option description	Contaminated water could be mixed with uncontaminated or less contaminated water if more than one supply is available at the point of water treatment or post treatment. This is an effective method of reducing chemical concentrations in water to below UK Water Quality Standards and is done when required for other contaminants.
Key information requirements	Access to other water distribution networks Capacity of water supplies from other water supplies (e.g. service reservoirs)
Linked recovery options	This is a **remediation option** and may need to be linked to **protective options.** This recovery option should also be considered in conjunction with; (4) Changes to water abstraction point or location of water source; (6) Continuing normal water treatment (supported by a monitoring programme); (7) Modification of existing water treatment; (8) Water treatment at point of use [tap] and (13) Natural attenuation (with monitoring)
Target	Public drinking water supplies. This recovery option is generally **not** appropriate for private drinking water supplies.
Targeted chemicals and important physicochemical properties	This recovery option is applicable to all chemicals that could contaminate drinking water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Medium/ large scale** This recovery option could be used on a medium/ large depending on what options there are for blending different water sources either before or after water treatment, and the size of water distribution networks in place. Blending should not reduce the amount of drinking water produced or supplied to homes.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option should be implemented in the **early/ medium phase (hours – weeks)** of a chemical incident. Blending could be used as soon as contamination of a water source had been confirmed and would need to be implemented quickly. Blending would be required for the duration of time that a contaminated water source was above the UK Water Quality Standard.
Considerations	
Public health considerations	None if implemented correctly.
Legal implications and obligations	Blended drinking water supplies would need to meet the quality standards for normal drinking water supplies and comply with UK Drinking Water Standards. Refer to Appendix A for more information.
Social implications	There may be problems regarding the acceptability of residual levels of contamination in water supplies by the public, which may lead to loss of confidence in drinking (tap) water supplies. This could result in the demand for bottled water to increase sharply. Blending contaminated water with uncontaminated water means that chemical contamination is diluted. This will need to be carefully explained to the public, who might find this practice unacceptable, particularly if people

(5) Controlled blending of drinking water supplies

	who would have had a 'clean' supply now receive water contaminated with low levels (within acceptable limits) of chemical contamination.
Environmental considerations	Widespread contamination or water shortages during periods of drought could result in fewer opportunities for blending. If undue pressure was put on a particular source of water such as a river or a reservoir, may lead to an environmental impact. This would be exacerbated during the summer months when water levels are generally at their lowest.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). This option may possibly result in water shortages in other areas. The public may also be inadvertently exposure to chemical contamination from blended drinking water that otherwise they would not. Any increase in exposure to the affected population would need to be balanced against the need to supply drinking water for the larger population.

Effectiveness

Recovery option effectiveness	The effectiveness of this option in reducing contamination levels in water depends on the extent of contamination, chemical and level to which the contamination has been diluted. The effectiveness of this option relies on a programme of testing and monitoring water after the point of blending/ mixing to ensure that contamination levels have been reduced sufficiently. Therefore, testing apparatus must be calibrated and accurate.
Technical factors influencing effectiveness of recovery option	The availability of alternative (less contaminated) drinking water sources and the extent to which the cleaner source of water (i.e. free from contamination) and the speed with which blending can be implemented. There can be problems associated with mixing very soft and very hard water. Restrictions on the use of water may be required where there are shortages.

Feasibility and intervention costs

Specific equipment	No cost implications in the short- term. If this option is being considered as a long-term remediation measure, existing infrastructure may need to be upgraded (i.e. new build).
Utilities and infrastructure	The water company/provider must have access to different water sources/supplies and be able to adjust the amount of water from each source that enters the drinking water supply.
Consumables	None
Skills, personnel and operator time	No specific skills are required other than those already employed by the water company. It may be possible to undertake blending during the course of normal work practices. However, there may be additional time costs for the operator due to the need to undertake a full risk assessment to ensure that re-zoning supplies (to enable blending) would not create another problem, such as the supply of discoloured water or causing bursts in distribution pipes.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	None

Waste

Amount and type	None. This option will not produce any contaminated waste water.

(5) Controlled blending of drinking water supplies

Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A

Exposure

Averted exposure	Ingestion/ inhalation or dermal contact with contaminated water (i.e. drinking, food preparation or washing, etc.)
Potential increased worker exposure	None

Other considerations

Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	Unlikely to be applicable.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. Communication with the affected communities about the rationale for choosing this option would be desirable. This information must be developed in partnership with other experts, government agencies and departments. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Experience also confirms the need to ensure that other measures are put into place to keep the community informed of developments when regular briefings have been terminated. Previous incidents and exercises suggest weekly or monthly newsletters; site boards or banners around sites can be effective ways of achieving this.

Additional information

Practical experience	Water companies already have experience in blending and mixing water supplies. Water companies would have to decide if the contaminated source could be diluted sufficiently, given their available water sources.
Key references	UNEP/OCHA assessment Mission. Spill of liquid and suspended waste at the Aurul S.W retreatment plant in Baia Mare. Cyanide spill at Baia Mare Report. (2000) Available [April 2012] at: http://reliefweb.int/sites/reliefweb.int/files/resources/43CD1D010F030359C12568CD00635880-baiamare.pdf
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(6) Continuing normal water treatment (supported by a monitoring programme)

Objective	Continuing the use of normal water treatment as a mechanism to remove or partially remove chemical contamination in drinking water.
Other benefits	No changes to existing practices.
Recovery option description	There are several processes used routinely at water treatment plants to remove impurities from drinking water, all of which will remove chemicals (to some extent), including; flocculation or clarification, slow or rapid gravity sand filtration, carbon filtration, membrane filtration, ion exchange and reverse osmosis. A full monitoring programme would be needed to support this option and to confirm that water treatment is effective for the chemicals of concern and that normal water treatment will maintain chemical concentrations in the treated water below the UK Drinking Water Standards. It should be noted that chemical concentrations higher than UK Drinking Water Standards may be acceptable in the short-term particularly for short-lived chemicals. Refer to Appendix A for further guidance.
Key information requirements	Seek specialist advice and guidance. Where are the water sources treated, and what water treatment methods are used? Is there information on the efficacy of water treatment processes in reducing the chemical contamination?
Linked recovery options	This is a **remediation option** and may need to be linked to **protective options.** This recovery option should also be considered in conjunction with; (5) Controlled blending of drinking water supplies; and (13) Natural attenuation (with monitoring) Storage/ treatment of contaminated water (post treatment) may also need to be considered; (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge.
Target	Public drinking water supplies. This option is also appropriate for private drinking water supplies if water treatment is undertaken.
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals (to some extent) that could contaminate drinking water supplies. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Large scale:** All drinking water supplied by water companies undergoes treatment to some extent. Private water supplies may undergo localised treatment or treatment at point of tap.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing, etc.).
Time of application	This recovery option can be implemented in the **early to late phases (hours – months)** of a chemical incident. This recovery option does not require any amendments or changes to existing water treatment practices; normal water treatment may be sufficient to remove/reduce chemical contamination levels.

Considerations

Public health considerations	Continuing normal treatment of contaminated water may give rise to increased exposure to water treatment operatives. This could be as a direct result of exposure to contaminated water or to the accumulation and storage of contaminated waste from treatment (see Appendix A)

(6) Continuing normal water treatment (supported by a monitoring programme)

Legal implications and obligations	Drinking water undergoes treatment normally to comply with water quality standards (and would comply with the UK Drinking Water Standards). Any waste arising from treatment may need a new authorisation. Refer to Appendix A for more information.
Social implications	Loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). There may be the potential for an increased demand for bottled water. Possible loss of public confidence that the problem of contamination is being managed effectively. For aesthetic type incidents where there is no significant public health risk, it is important to consider the public's perception of risk and potential loss of public confidence.
Environmental considerations	If normal disposal routes for waste water and other solid wastes are used, there may be a risk of spreading low levels of contamination in the environment, e.g. in natural water courses.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Consideration should be given to possible exposure to operatives. There may be inequity between beneficiaries (water consumers) and those living close to waste facilities.
Effectiveness	
Recovery option effectiveness	Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. Generally, treatments used to remove a high content of solids (which lead to colour or turbidity in treated water) from surface water sources would be particularly effective at removing solid chemical contamination because many chemicals will adsorb to particulate material in the water. Physical filtration is very effective at removing particulate matter. Membrane filtration is a physical process used for 'clean' water sources with a very low content of solids and there are no chemical processes involved. 'Clean' ground water sources (i.e. some boreholes and aquifers) only undergo minimal treatment and this recovery option would be less effective at removing contamination in these water sources.
Technical factors influencing effectiveness of recovery option	Effectiveness will be dependent on the types and number of treatment processes used and also the chemicals(s) involved and their physicochemical properties. 'Normal' water treatment practises and processes may vary between different water companies.
Feasibility and intervention costs	
Specific equipment	No additional specific equipment would be required to implement this recovery option, as it involves continuing normal water treatment practices and processes.
Utilities and infrastructure	None if using existing facilities, however infrastructure would need to be in place to support the expansion of, or changes to water treatment works if additional treatments are to be brought 'on-line' (increased frequency of operations, 'new build', etc.)
Consumables	Increased frequency of replenishing treatment materials (e.g. filter beds and resins will give rise to additional costs).
Skills, personnel and operator time	No specific skills are required other than those already employed. However there could be additional operator time if operations were performed more frequently. Monitoring will be required (additional personnel) and therefore result in some increased costs.

(6) Continuing normal water treatment (supported by a monitoring programme)

Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring at the water treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded. Changes to other working and safety practices may be required to minimise exposure to operatives.
Other limitations/factors influencing costs	Costs could increase if operations were performed outside normal working patterns/shifts.
Waste	
Amount and type	Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from normal water treatment processes may come under the classification of ‘Hazardous waste’. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Large quantities of waste material could be generated (e.g. contaminated sand and activated charcoal from filter beds and sludge) that is above levels permitted for normal use, which may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to recovery or disposal and may require an environmental permit or a registered waste exemption. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from normal treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Disposal of contaminated material generated from water treatment may be expensive as large quantities of contaminated waste could potentially be generated (e.g. sand from filter beds and sludge). Cost can also be influenced by: the availability of a suitable disposal route; the cost of hazardous waste treatment/disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.
Exposure	
Averted exposure	N/A
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and

(6) Continuing normal water treatment (supported by a monitoring programme)

	Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring at the water treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded. Changes to other working and safety practices may be required to minimise exposure to operatives.

Other considerations

Agricultural impact	Sludge may not be acceptable for amendment of agricultural soil.
Compensation issues	None expected.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementing this recovery option would require an effective communication strategy to assure the affected population that the water was potable (suitable for drinking) and meets the required quality standards. Any restrictions on the use of drinking water need to be explained. Workers at the water treatment plants would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	Carried out under normal procedures by water companies to deal with numerous incidents.
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available [April 2012] at; http://www.environment-agency.gov.uk/business/topics/waste/32200.aspx Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste, Second edition: Version 2.3 (2011). Available [April 2012] at: http://publications.environment-agency.gov.uk/pdf/GEHO0411BTRD-e-e.pdf K. C. Thompson and J. Gray. Water contamination emergencies: Can we cope? 2004
Comments	
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(7) Modification of existing water treatment

Objective	To reduce exposure to consumers by modifying existing water treatment practises and processes to dilute chemical contamination in drinking water in the event of chemical concentrations in the supplied (treated) water exceeding UK Water Quality Standards.
Other benefits	Will remove other impurities.
Recovery option description	Any changes to existing water treatment processes to enhance removal of specific chemicals from water, for example; increased frequency of replenishing or cleaning filter material or application of sorbents (i.e. activated charcoal or natural clay minerals). The introduction of completely new processes will often require major extensions to treatment works and new buildings ranging from ion exchange units to new treatment works. This recovery option is more appropriate for longer term remediation strategies, to deal with chronic contamination.
Key information requirements	Seek specialist advice and guidance. Where are the water sources treated, and what water treatment methods are used? Is there information on the efficacy of water treatment processes in reducing the chemical contamination? What additional water treatment options/ solution could be provided?
Linked recovery options	This is a **remediation option** and may need to be linked to **protective options.** This recovery option should also be considered in conjunction with; (5) Controlled blending of drinking water supplies (8) Water treatment at point of use [tap] and (13) Natural attenuation (with monitoring) If contaminated water has already been treated, wastes arising from water treatment may be contaminated, see; (9) Drain to temporary storage; (10) Discharge to off-site using tankers (tankering); (11) In-situ treatment and discharge (foul, land, surface water) and (14) Treatment of sludge
Target	This recovery option is suitable for public drinking water supplies. The introduction of a new treatment could also be applicable to some (usually larger) private water supplies if the current treatment was ineffective at reducing/removing contamination or no chemical treatment is currently undertaken.
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Any** **Large scale:** Building of new water treatment works. **Medium scale:** Introduction of chemicals (sorbents etc) to raw water at treatment works or to raw water sources, or adding new treatment to existing treatment regimes for example: • Chlorination • Ozonation • Filtration • Aeration • Chemical coagulation • Activated carbon adsorption • Wood fibre filters • Aerogels from chalcogenide clusters • Activated alumina

(7) Modification of existing water treatment

	• Bioremediation (biological nitrification, de-nitrification) • Reverse osmosis (under high pressure) • Ion exchange mechanisms • Nanotechnology • Plus De Montfort Fe catalyst H2O2 Oxidation – (untried on large scale but being piloted by Severn Trent). • Portable UV light **Small Scale:** Introduction of new treatments for private water supplies. • Ion exchange • Reverse osmosis • Aeration/ holding tanks
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing, etc.)
Time of application	This recovery option can be implemented in the **early/ late phase (hours – months/ years)** of a chemical incident. Potential changes or modifications to existing water treatment processes should be identified as soon as contamination is confirmed (and the chemical/s identified). However, there may be a delay in implementing changes to existing water treatment process (from several days – weeks). If new processes (i.e. 'new build') are initiated, equipment and infrastructure are required and installation could take some time, with the recovery option operating over months – years. This recovery option should only be considered for a chronic situation.

Considerations

Public health considerations	Changes to water treatment processes used may give rise to increased exposure to water treatment operatives. This could be as a direct result of exposure to contaminated water or to the accumulation and storage of contaminated waste from treatment (see Appendix A)
Legal implications and obligations	Drinking water produced following any changes to water treatment will have to comply with the UK Drinking Water Standards. Refer to Appendix A for more information.
Social implications	There may be a loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There may be issues regarding the acceptability of residual levels of contamination by the public; this is likely to be related to the availability of alternative supplies (e.g. bottled water). Potential Increased demand for bottled water. Social disruption if modification of existing water treatment requires a new construction or facility (i.e. 'new build').
Environmental considerations	If normal disposal routes for waste water and other solid wastes are used, there may be a risk of spreading low levels of contamination in the environment, e.g. in natural water courses.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Consideration should be given to possible exposure to operatives, and any risks associated with additional tasks undertaken by operatives at the water treatment plants would need to be assessed. There may be inequality between beneficiaries (water consumers) and those living close to waste facilities.

Effectiveness

(7) Modification of existing water treatment

Recovery option effectiveness	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agencies and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. Generally, treatments used to remove a high content of solids (which lead to colour or turbidity in treated water) from surface water sources may be effective at removing some chemical contamination because many chemicals will adsorb to particulate matter in the water. Physical filtration is also very effective at removing this particulate material. 'Clean' ground water sources (i.e. some boreholes and aquifers) may only undergo minimal treatment and this would be less effective at removing contamination, due to reduced ability to introduce chemical manipulation and low levels of particulate material in the water. Membrane filtration is a physical process used for 'clean' water sources with a very low content of solids and there are no chemical processes involved.
Technical factors influencing effectiveness of recovery option	The effectiveness of this recovery option is dependent on the types and number of treatment processes used and also the chemicals(s) involved and their physicochemical properties. 'Normal' water treatment may vary between different water companies. Infrastructure needs to be in place to support the expansion of or changes to water treatment works if additional treatments are to be brought 'on-line' (increased frequency of operations, etc, 'new build'). Modification to private water supplies may necessitate the installation of additional water treatment equipment under the sink which could concentrate chemical contaminants in filter media.

Feasibility and intervention costs

Specific equipment	Specific equipment is likely to be required for the modification of existing water treatment options techniques.
Utilities and infrastructure	Infrastructure needs to be in place to support the expansion of, or changes to water treatment works if additional treatments are to be brought 'on line' (increased frequency of operations, etc, 'new build'). For private water supplies there may be a requirement to build additional outbuildings to house treatment unit.
Consumables	Additional natural sorbents and materials such as activated charcoal or natural clay minerals.
Skills, personnel and operator time	Training of operatives may be required if new treatment processes are implemented. There could be additional operator time if operations were performed more frequently. Transport of raw materials and waste to and from treatment works may also require additional operator time (loading and driving). 'New build' may require additional staff.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring in the treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the new treatment is having the desired effect. Changes to other working and safety practices may be required to minimise exposure to operatives.
Other limitations/factors influencing costs	Additional natural sorbents and materials such as activated charcoal or natural clay minerals giving rise to additional costs. Increased frequency of replenishing treatment materials will also give rise to additional costs.

(7) Modification of existing water treatment

Waste

Amount and type	Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from modified water treatment processes may come under the classification of 'hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Large quantities of waste material could be generated (e.g. contaminated sand and activated charcoal from filter beds and sludge) that is above levels permitted for normal use, which may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to disposal. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from normal treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Disposal of contaminated material generated from modified water treatment may be expensive as large quantities of contaminated waste could potentially be generated (e.g. sand from filter beds and sludge). Cost may also be influenced by: the availability of a suitable disposal route; the cost of contaminated waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.

Exposure

Averted exposure	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing). Averted exposure is influenced by the effectiveness of the recovery option and efficacy of modified water treatment practises to remove the chemical contamination.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). If working practices change due to the modification of a treatment works (e.g. sand filters are replenished more frequently than normal or new processes are added), this may give rise to a potential increased worker exposure. Due to specific nature of these tasks and the wide variation in treatment works, it is not possible to estimate likely increased exposure. They would, however, need to be assessed on a site specific basis in the event of any incident involving contaminated water prior to treatment. Therefore, monitoring at the water treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded.

(7) Modification of existing water treatment

	Changes to other working and safety practices may be required to minimise exposure to operatives.

Other considerations

Agricultural impact	Sludge may not be acceptable for amendment of agricultural soil.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementing this recovery option would require an effective communication strategy to assure the affected population that the water was potable (suitable for drinking) and meets the required quality standards. Any restrictions on the use of drinking water need to be explained. There would be a need to be a clear communication strategy to assure consumers that the water produced was potable and met the required drinking water quality standards. Any restrictions on the use of drinking water need to be explained. Workers at the water treatment plants would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident (2008). Available [April 2012]; http://www.environment-agency.gov.uk/business/topics/waste/32200.aspx Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste, second edition: version 2.3 (2011). Available [April 2012] at: http://publications.environment-agency.gov.uk/pdf/GEHO0411BTRD-e-e.pdf Fletcher T. Neighbourhood change at Love Canal: Contamination, evacuation and resettlement. Land Use Policy. 2002; 19: 311–323. Whitehead PG, Hall G, Neal C and Prior H. Chemical behaviour of the Wheal Jane bioremediation system. Science of the Total Environment. 2005; 338: 41-51.
Comments	
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(8) Water treatment at the point of use [tap]

Objective	To reduce ingestion exposure to consumers by adding additional treatment 'at the tap' to remove or partially remove chemical contamination from drinking water in the event of chemical contaminant concentrations in supplied water exceeding the UK Drinking Water Standards (data current for trace metals).
Other benefits	Other impurities will be removed. This is a 'self-help' option. May provide additional reassurance regarding the quality of drinking water and the levels of chemical contaminants in the water, even if the water is deemed potable.
Recovery option description	There are commercially available options that can be used in the home or private premises that will reduce elemental contamination of drinking water from mains or private water supplies. Seek expert advice and guidance as the scope and efficacy of commercially available options will need to be evaluated on an incident and chemical specific basis. This Recovery option sheet considers the use of: • Jug filter systems for softening water that use a carbon filter with some ion exchange material. • Small reverse osmosis units that can be installed under a sink and are suitable for both mains and private water supplies. • Ion exchange point of use
Key information requirements	Details on effectiveness of at tap water treatments for chemical of concern. Availability of equipment for treatment at tap.
Linked recovery options	This is a **remediation option** and may need to be linked to **protective options.** This recovery option should also be considered in conjunction with; (3) Restrict water use (Do Not Drink / Do Not Use notices); (6) Continuing normal water treatment (supported by a monitoring programme) and (13) Natural attenuation (with monitoring) The provision of alternative water supply (bottled or tankered water) may be more effective and acceptable than reliance on individuals to employ this self-help option, therefore this option should be considered with (2) Alternative drinking water supply.
Target	Drinking water from private supplies. This is also an additional measure that could be used for public water supplies if it is suspected that contamination has occurred after water treatment.
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of water treatment at the point of use [tap] for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is suitable for use with some heavy metals (e.g. arsenic).
Scale of application	**Small/ medium scale** – Jug filters would be suitable for very small scale use by an individual household producing a few litres of drinking water/ day. Reverse osmosis units would be suitable for larger scale use such as for entire premises, although units would have to be fitted to designated and identified taps. This option is suitable for producing several tens of litres of purified water a day. The scale of application will depend on the availability of equipment and resources and the numbers of properties. In most cases sanitary water needs no purification.
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing, etc.)
Time of application	This recovery option is suitable for implementation during the **early/medium phase (hours – weeks)** of a chemical incident. Jug filters could be used soon after contamination has been identified, the only delay would be the time taken to purchase them. Reverse osmosis units are more specialised pieces of equipment and may not be available 'off the shelf'. They also need

	fitting by a specialist engineer. The delay in purchasing and fitting one of these units could be several weeks.

Considerations

Public health considerations	None
Legal implications and obligations	Private water supplies have to comply with the UK Drinking Water Standards. Refer to Appendix A for more information.
Social implications	This option relies upon individuals purchasing the units, and in the case of reverse osmosis units, arranging installation either individually or with the person responsible for the supply. Appropriate use of designated drinking water in the premises depends on the individual. In addition, this recovery option will result in some disruption and access to people's homes. There could be a change in personal habits with regard to which tap is used for drinking water if a designated tap has to be used for drinking water. Also water from a tap has to be placed in the jug if that option is being used. Potential loss of confidence in water for other uses like sanitation if the water has not gone through water treatment. There may be an increased demand for bottled water. The provision of alternative water supply (bottled or tankered water) may be more effective and acceptable than reliance on individuals to employ a self-help option.
Environmental considerations	None
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Whether the cost of equipment should be paid for by the householder or the individual responsible for premises. Also there is a reliance on this option being implemented by individuals.

Effectiveness

Recovery option effectiveness	Water treatment at the point of use [tap] techniques are effective at reducing the amount of trace metal chemical contamination in the water as supplied at 'the tap'. For the jug filter it would be reasonable to expect a reduction of contamination of at least 50% for a new filter cartridge. For reverse osmosis units, the reduction could be in excess of 90%. These figures are based on the understanding of the chemistry involved and manufacturers advertising literature for stable elements and are only intended as a rough guide to efficiency. Seek expert advice and guidance, as the scope and removal efficacy for other chemicals (i.e. organic chemicals) will need to be researched. Dermal affects, following showering, bathing or garden watering would continue unabated.
Technical factors influencing effectiveness of recovery option	Effectiveness will be dependent on the chemicals(s) involved and their physical and chemical properties. Jug filtration, for example, would be very effective at removing contamination associated with particulate material, but requires the correct use of jug filters. Reverse osmosis are specialised pieces of equipment and need to be fitted by a specialist engineer. Flow rate through some filters can be slow. Filters could also be difficult to maintain.

(8) Water treatment at the point of use [tap]

Feasibility and intervention costs

Specific equipment	Jug filter. Reverse osmosis unit. Ion exchange unit A pump may be needed to ensure that there is adequate water pressure for the reverse osmosis units to work effectively. A minimum water pressure is a requirement. The installer would be able to advise whether a pump is needed. Jug filters are relatively inexpensive (<£40). Reverse osmosis units are comparatively expensive (>£300), with additional costs for pumps (if required). Replacement filter cartridges and filters are inexpensive compared with the rest of the equipment (<£10).
Utilities and infrastructure	For the reverse osmosis units a trained engineer (plumber) would be required for the initial installation.
Consumables	Filter cartridges for the jugs. Membranes for reverse osmosis units.
Skills, personnel and operator time	This is a 'self-help' option, and filter jugs are commercially available. Skilled personnel would be required for installation of reverse osmosis units.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Gloves and protective clothing may be needed for the removal of contaminated filter media (e.g. carbon cartridges, ion exchange resins and membranes) due to accumulation of chemical contamination.
Other limitations/factors influencing costs	Availability of jug filters and reverse osmosis units and qualified fitters. Availability of equipment, and the number of households or premises affected. There are also costs associated with fitting/ installation of reverse osmosis units and for the collection, transport and disposal of spent filters.

Waste

Amount and type	Waste is produced following water treatment (i.e. spent filter cartridges, membranes from reverse osmosis filter units), depending on the chemical contamination; waste may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Spent filter cartridges from the jugs will be produced every 2-4 weeks. Membranes for the reverse osmosis unit may need changing after 6 months. Specific monitoring or research would be required to establish when the efficiency of the filter systems declines and the cartridge needs changing. Changing of filter cartridges and cleaning of membranes is likely to be more frequent over the period when chemical concentrations in the water are higher.
Possible transport, treatment, disposal and storage routes	It is possible that spent filters may be considered 'hazardous waste' and so require special consideration for collection, transport and recovery/disposal/storage. Seek specialist advice and guidance. Contaminated material such as spent filters may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see http://www.dft.gov.uk/topics/freight/dangerous-goods/
Factors influencing waste issues (i.e. cost)	The number and rate of spent filters produced. Chemical concentrations within the spent filters will have to be assessed and monitored. There are also costs associated with the collection, transport and disposal of waste.

(8) Water treatment at the point of use [tap]

Exposure

Averted exposure	Reduced exposure to contaminated drinking water. Averted exposure is influenced by the effectiveness of the recovery option and efficacy of water treatment at the point of use [tap] techniques (jug, reverse osmosis units or ion exchange filters) to remove the chemical contamination will influence averted exposure.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Fitting and removal of filters may give rise to incremental exposure. However, the task that is likely to give rise to the highest incremental exposure is the removal of filters installed in the home and premises.

Other considerations

Agricultural impact	N/A
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Implementing this recovery option would require an effective communication strategy to assure the affected population that the water was potable (suitable for drinking) and meets the required quality standards. Any restrictions on the use of drinking water need to be explained. To implement this recovery option will require a clear communication strategy with householders and individuals on whether existing water treatment is adequate for private water supply users; what type of equipment should be purchased; the length of time that these options should be in place; correct usage of filters, particularly with respect to the disposal of filter cartridges.

Additional information

Practical experience	Reverse osmosis units and jug filters are used routinely in domestic and commercial properties to reduce other contaminants in drinking water. Tap filters are used in parts of Bangladesh to reduce arsenic contamination in water supplies. Jug filter units are advertised (and sold) to improve taste (i.e. removing trace inorganic and organic impurities).
Key references	Ahmed F, Minnatullah K, Talbi A. Arsenic mitigation technologies in south and east Asia. Bangladesh university of engineering and technology, World Bank. Available [April 2012] at: http://siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/ArsenicVolII_PaperIII.pdf DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
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(9) Drain to temporary storage

Objective	To reduce ingestion exposure to consumers by modifying existing water treatment to enhance removal (or partial removal) of chemical contamination in supplied (treated) drinking water in which chemical concentrations exceed UK Drinking Water Standards. May also allow natural degradation (attenuation) of short lived chemicals that produce benign breakdown products. To allow treatment at alternative treatment or new treatment works.
Other benefits	Will remove other impurities.
Recovery option description	The basic principles of containment, identification, treatment and disposal apply to water supply sites and distribution networks. If contamination is confirmed or suspected in the supply or distribution system network, the water undertaker (i.e. water utility company) may isolate part of the system to prevent further spread of contamination. Contaminated water could be contained in temporary storage where the contaminant can be determined and an appropriate treatment method identified. Once the water has been treated and the contaminant made safe, further treatment may be necessary to make the water fit for disposal to the environment (Water UK, 2003).
Key information requirements	Are appropriate storage containers available? What are the potential waste-water disposal routes?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (14) Treatment of sludge
Target	Drinking water supplies
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is suitable for use with persistent chemicals.
Scale of application	**Small/ Medium**
Exposure pathway prevention	Dermal contact with contaminated drinking water.
Time of application	This recovery option should be implemented in the **early/medium phase (hours – weeks)** of a chemical incident. However, it could take days – weeks to drain the affected area. Changes to water treatment processes should be identified as soon as contamination is confirmed and the chemical(s) of concern have been identified. However, there may be a delay in implementing changes to existing water treatment process that could be several days to weeks.

Considerations

Public health considerations	Modifications to water treatment processes may result in increased exposure of water treatment operatives. This could be as a direct result of exposure to contaminated water or to the accumulation and storage of contaminated waste from treatment (see Appendix A).
Legal implications and obligations	Drinking water produced after changes to water treatment will have to comply with UK Drinking Water Standards. Refer to Appendix A for more information.

(9) Drain to temporary storage

Social implications	Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There may be issues regarding the acceptability of residual levels of contamination by the public; which may also be linked to the availability of alternative supplies (e.g. increased demand for bottled water). There may be loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	The volume /capacity that the water treatment/water supply company can store and where. Disposal routes for waste water and other solid wastes from treatment could lead to the spread of low levels of contamination in the environment (e.g. in natural water courses).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with additional tasks undertaken by operatives at the water treatment plants would need to be assessed. There may be inequity between beneficiaries ('water drinkers') and those living by waste facilities

Effectiveness

Recovery option effectiveness	Generally, treatments used to remove a high content of solids (which lead to colour or turbidity in treated water) from surface water sources would be particularly effective at removing particulate material in the water. Physical filtration is very effective at removing this particulate material. 'Clean' ground water sources (some boreholes and aquifers) only undergo minimal treatment and this would be less effective at removing contamination due to less chemical manipulation and low levels of particulate material in the water. Membrane filtration is a physical process used for 'clean' water sources with a very low content of solids and there are no chemical processes involved.
Technical factors influencing effectiveness of recovery option	The effectiveness of this recovery option will be dependent on the type(s) and number of treatment processes used, but also the physicochemical properties of the chemicals(s) contaminants. This recovery option will require skilled personnel to undertake the option. The availability of raw materials and the time needed to deliver them may influence the effectiveness of this option, and the capacity to store any additional waste.

Feasibility and intervention costs

Specific equipment	Seek expert advice and guidance (i.e. Water utility providers) as specific technical equipment is likely to be required. The installation of new equipment and infrastructure may be required to enable additional treatment processes, which may be expensive or take a long time to install.
Utilities and infrastructure	Infrastructure needs to be in place to support the expansion of, or changes to treatment works if additional treatments are to be brought 'on line' (increased frequency of operations, etc, 'new build').
Consumables	Sorbent materials such as activated charcoal or natural clay minerals.
Skills, personnel and operator time	Training of operatives may be required if new treatment processes are implemented. There could be additional operator time if operations were performed more frequently. The transport of raw materials (including waste to and from treatment works) will require additional operator time (loading and driving). Infrastructure needs to be in place, and if a 'new build' is required, this will result in additional staff (and increase costs).

(9) Drain to temporary storage

Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring in the treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the new treatment is having the desired effect. Changes to other working and safety practices may be required to minimise exposure to operatives. Appropriate safety equipment (hat, lifelines, waterproof safety clothing, boots) may be required.
Other limitations/factors influencing costs	The cost will also depend on whether the equipment is available and whether it can be easily installed as part of an existing plant. If new technologies are required, their development will also be very costly and will take a long time. The cost of consumables (i.e. sorbents), increased frequency of replenishing treatment materials will need to be considered. Availability of suitable disposal routes for contaminated waste.

Waste

Amount and type	Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from modified water treatment processes may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Large quantities of waste material could be generated (e.g. contaminated sand and activated charcoal from filter beds and sludge) that is above levels permitted for normal use, which may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to disposal. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from water treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.

(9) Drain to temporary storage

Factors influencing waste issues (i.e. cost)	Disposal of contaminated material generated from water treatment may be expensive as large quantities of contaminated waste could potentially be generated (e.g. sand from filter beds and sludge). Cost may also be influenced by: the availability of a suitable disposal route; the cost of contaminated waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.

Exposure

Averted exposure	Dermal contact with contaminated drinking water.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). If working practices change due to the modification of a treatment works (e.g. sand filters are replenished more frequently than normal or new processes are added), this may give rise to a potential increased worker exposure. Due to specific nature of these tasks and the wide variation in treatment works, it is not possible to estimate likely increased exposure. They would, however, need to be assessed on a site specific basis in the event of any incident involving contaminated water prior to treatment. Therefore, monitoring at the water treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded. Changes to other working and safety practices may be required to minimise exposure to operatives.

Other considerations

Agricultural impact	None
Compensation issues	N/A
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case there would be a need to assure consumers that the water produced was potable and met the required drinking water quality standards. Any restrictions on the use of drinking water need to be explained. Workers would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Water UK. Protocol for the disposal of contaminated water. Version 2.1 2003. https://www.water.org.uk/guidance/disposal-of-contaminated-water-may-2018/
Comments	
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(10)	Discharge off site using tankers (tankering)
Objective	To reduce ingestion exposure to consumers by removal or partial removal of chemical contamination in supplied (treated) drinking water in which chemical concentrations exceed UK Drinking Water Standards.
Other benefits	Will remove other impurities.
Recovery option description	Disposal of contaminated water and potentially, contaminated water from water supply sites, water distribution networks and service reservoirs. Disposal of contaminated water from the distribution system using tankers where the water treatment system is unable to treat or contain the contaminated water.
Key information requirements	Are appropriate storage containers available? What are the potential waste-water disposal routes?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (11) In-situ treatment and discharge (foul, land, surface water) and (13) Natural attenuation (with monitoring).
Target	Mainly for public drinking water supplies, although the introduction of new treatment practises or processes could apply to a private supply system if the current treatment(s) are ineffective at reducing/removing contamination or no chemical treatment is currently undertaken.
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is suitable for use with persistent chemicals.
Scale of application	**Small/ Medium**
Exposure pathway prevention	Dermal contact with contaminated drinking water.
Time of application	This recovery option should be implemented in the **early/medium phase (hours – weeks)** of a chemical incident. Changes to water treatment processes should be identified as soon as contamination is confirmed and the chemical(s) of concern have been identified. However, there may be a delay in implementing changes to existing water treatment process that could be several days to weeks. This recovery option is unlikely to be sustainable for the long-term phase of a chemical incident.
Considerations	
Public health considerations	Changes to water treatment processes used may give rise to increased exposure to water treatment operatives. This could be as a direct result of exposure to contaminated water or to the accumulation and storage of contaminated waste from treatment (see Appendix A).
Legal implications and obligations	Any transportation of contaminated water will be required to be undertaken under appropriate authorisation. Refer to Appendix A for more information.

(10) Discharge off site using tankers (tankering)

Social implications	Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There may be issues regarding the acceptability of residual levels of contamination by the public; which may also be linked to the availability of alternative supplies (e.g. increased demand for bottled water). There may be loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	Disposal routes for waste water and other solid wastes from treatment could lead to the spread of low levels of contamination in the environment (e.g. in natural water courses). Utilisation or disposal of contaminated water or sludge needs to be considered as the chemical concentrations may be above the levels permitted for normal use (land spreading or landfill).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with additional tasks undertaken by operatives at the water treatment plants would need to be assessed. There may be inequity between beneficiaries ('water drinkers') and those living by waste facilities
Effectiveness	
Recovery option effectiveness	If the contaminated water can be isolated and removed from the system then the effectiveness will be up to100% in reducing contamination to the drinking water system.
Technical factors influencing effectiveness of recovery option	This recovery option will require skilled personnel to undertake the option. The effectiveness of this recovery option will be dependent on the physicochemical properties of the chemicals(s) contaminants, and availability of suitable storage and disposal routes.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Water utility providers) as specific technical equipment is likely to be required, including specialist tanker contractors with trained drivers and pumping equipment may be required.
Utilities and infrastructure	Power (electricity) supply, water and suitable storage containers and roads.
Consumables	None
Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel are likely to be required to undertake this recovery option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that any limits on operative exposure are not exceeded. Appropriate safety equipment (hat, lifelines, waterproof safety clothing, boots) may be required.
Other limitations/factors influencing costs	The cost will be influenced by the availability of; Appropriate equipment. Suitable disposal routes for contaminated waste. Staff and personnel requirements (if operations were performed outside normal working patterns/shifts this may increase costs).

(10) Discharge off site using tankers (tankering)

Waste

Amount and type	This recovery option does not generate waste directly.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from water treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Disposal of contaminated material generated from water treatment may be expensive as large quantities of contaminated waste could potentially be generated (e.g. sand from filter beds and sludge). Cost may also be influenced by: the availability of a suitable disposal route; the cost of contaminated waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.

Exposure

Averted exposure	Dermal contact with contaminated drinking water.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Changes in worker activities would need to be assessed on a case-by-case basis in the event of any incident involving contaminated water being removed from the site by tankers.

Other considerations

Agricultural impact	Sludge may not be acceptable for amendment of agricultural soil.
Compensation issues	N/A
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case, effective communication is required to convey to members of public the measures being implemented are likely to benefit public health and reduce contamination in the environment. Workers would need to be informed that they could be exposed to chemical contamination.

(10)	Discharge off site using tankers (tankering)

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
Comments	
Document History	

(11)	In-situ treatment discharge (foul, land, surface water)
Objective	To treat and dispose of chemical contamination within the water distribution system without major disruptions.
Other benefits	
Recovery option description	The basic principles of containment, identification, treatment and disposal apply to water supply sites and distribution networks. If contamination is confirmed or suspected in the supply or distribution system network, the water undertaker (i.e. water utility company) may isolate part of the system to prevent further spread of contamination. Contaminated water could be contained in temporary storage the contaminant can be determined and an appropriate treatment method identified. Once the water has been treated and the contaminant made safe, further treatment may be necessary to make the water fit for disposal to the environment (Water UK, 2003).
Key information requirements	List of where each source of water goes to be treated and what water treatment is used. Data on effectiveness of water treatment in reducing chemical concentrations in water. It is important to note that groundwater contamination can be increased by periods of heavy rain, and should therefore me monitored.
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should also be considered in conjunction with; (9) Drain to temporary storage; (10) Discharge to off-site using tankers (tankering) and (13) Natural attenuation (with monitoring).
Target	Foul, land and surface waters
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable to all chemicals that can contaminate water supply systems.
Scale of application	Depends on the magnitude of the incident
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option should be implemented in the **early/medium phase (hours – weeks)** of a chemical incident. The recovery option will need to be in place for the duration of any drinking water restrictions.
Considerations	
Public health considerations	In situ treatment of contaminated water will give rise to increased exposure to water treatment operatives. This could be as a direct result of exposure to contaminated water or to the accumulation and storage of contaminated waste from treatment (see Section 3).
Legal implications and obligations	Drinking water undergoes treatment normally to comply with UK Drinking Water Quality standards. Any waste arising from water treatment may need a new authorisation. Refer to Appendix A for more information.

(11) In-situ treatment discharge (foul, land, surface water)

Social implications	Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There may be issues regarding the acceptability of residual levels of contamination by the public; which may also be linked to the availability of alternative supplies (e.g. increased demand for bottled water). There may be loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	Could lead to spread of low levels of contamination in the environment, e.g. natural water courses. Utilisation or disposal of contaminated water needs to be considered as the chemical concentrations in the water may be above the levels permitted for normal use (land spreading or landfill for solids).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with additional tasks undertaken by operatives at the water treatment plants would need to be assessed.
Effectiveness	
Recovery option effectiveness	If the contaminated water can be isolated and removed from the system then the effectiveness will be up to 100% in reducing contamination to the drinking water system. However, the effectiveness of this option will depend on the remediation action taken for specific chemical(s).
Technical factors influencing effectiveness of recovery option	This recovery option will require skilled personnel to undertake the option. The effectiveness of this recovery option will be dependent on the physicochemical properties of the chemical(s) contaminant(s), and availability of suitable storage, disposal routes, time of application and weather conditions.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Water utility providers) as specific technical equipment is likely to be required, including specialist tanker contractors with trained drivers and pumping equipment may be required.
Utilities and infrastructure	Adequate access to the site
Consumables	Equipment specific to the remediation process chosen
Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel are likely to be required to undertake this recovery option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring in the treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the new treatment is having the desired effect. Appropriate safety equipment (PPE) will need to be worn when handling the effluent.

(11)	In-situ treatment discharge (foul, land, surface water)
Other limitations/factors influencing costs	The cost will be influenced by the availability of; Appropriate equipment. Suitable disposal routes for contaminated waste. Staff and personnel requirements (if operations were performed outside normal working patterns/shifts this may increase costs).
Waste	
Amount and type	Seek specialist advice and guidance. Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from modified water treatment processes may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Large quantities of waste material could be generated (e.g. contaminated sand and activated charcoal from filter beds and sludge) that is above levels permitted for normal use, which may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to disposal. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from water treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Disposal of contaminated material generated from water treatment may be expensive as large quantities of contaminated waste could potentially be generated (e.g. sand from filter beds and sludge). Cost may also be influenced by: the availability of a suitable disposal route; the cost of contaminated waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.
Exposure	
Averted exposure	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and

(11) In-situ treatment discharge (foul, land, surface water)

	Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). None if appropriate precautions are taken

Other considerations

Agricultural impact	Water may not be acceptable for discharge to land. The use of drinking water supplies may not be acceptable for irrigating or watering crops. There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case communication regarding the overall management of the treatment and waste arising would need to be addressed. There would be a need to assure consumers that the water produced was potable and met the required quality standards. Any restrictions on the use of drinking water need to be explained. Workers would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	
Key references	Bowen G.G, Dussek C and Hamilton R.M. Pollution resulting from the abandonment and subsequent flooding of wheal Jane Mine in Cornwall UK. *The Geological society*. 1998 128:93-99 DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Heidrich S, Schirmer M, Weiss H, Wycisk P, Grossmann J, Kaschl A,. Regionally contaminated aquifers, toxicological relevance and remediation options (Bitterfield case study). *Toxicology.* 2004 (3):143-55 (2004) Water UK. Protocol for the disposal of contaminated water. Version 2.1 2003. Available [April 2012] at; https://www.water.org.uk/guidance/disposal-of-contaminated-water-may-2018/
Comments	
Document History	

(12)	Flush distribution system
Objective	To reduce exposure to chemicals of concern in available drinking water by flushing through the water distribution system.
Other benefits	None
Recovery option description	If water contamination cannot be isolated, then a water treatment company may consider procedures such as flushing. Although flushing is a routine operation that water companies are familiar with, flushing following a chemical incident should be implemented with care as the type and concentration of the potential contaminant may be unknown at this time. Thus, worker safety/protection measures should be taken and possible impacts to the environment (due to discharged water) should be considered. This recovery option should be supported by a suitable monitoring strategy wherever possible. The Environment Agency should be consulted for any planned discharges to a wastewater collection systems or surface waters. If contamination is confirmed or suspected in the supply or distribution system, the water undertaker should isolate that part of the system to prevent further spread of contamination. The contaminated water should be contained until such time as the contaminant can be determined and the appropriate treatment identified. Once the water has been treated and the contaminant made safe, further treatment may be necessary to make the water fit for disposal to the environment
Key information requirements	Important considerations should be taken into account before flushing water distribution system, including; • Has the water utility provider obtained appropriate regulatory clearances? • Is isolation feasible (e.g., contaminant source/spread unknown or contamination has dispersed to system areas lacking the technical capacity or configuration to support isolation); • Customer notification is anticipated to have limited effectiveness (e.g., contamination spread involves the notification of many, widespread users); and • The weight of evidence suggests contamination is compatible with a flush response (e.g., the contaminant type and concentration are sufficiently well known and deemed low risk in a release context or, in the absence of this specificity, there are strong indications that a release from the system will have no tolerable environmental, general public health, and sewer system impacts).
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (2) Alternative drinking water supply; and (3) Restrict water use (Do Not Drink/ Do Not Use notices). Storage/ treatment of contaminated water (post treatment) would also need to be considered, recovery options include; (9) Drain to temporary storage; (10) Discharge off site using tankers (tankering); and (11) In situ treatment and discharge.
Target	Public drinking water supplies (may also be viable for certain larger private water supplies depending on their distribution network)
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency and Water Utility providers) should be sought on the efficacy of flushing the water distribution system for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	Will depend on the size of the water network/ distribution system contaminated
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option should be implemented in the **early phase (hours - days)** of a chemical incident.

(12) Flush distribution system

Considerations

Public health considerations	Flushing of the distribution system should continue until the contamination has been completely removed from the distribution system or diluted to a level, which is below water quality standards, or an agreed level (such as SNARL) which does not pose a long term risk to health.
Legal implications and obligations	There is a legal duty on water suppliers to provide alternative water supplies such as bottled water (see (2) Alternative drinking water supply) Refer to Appendix A for more information.
Social implications	Public acceptability and trust in the flushing processes to remove or reduce chemical contamination. There may be issues regarding the acceptability of residual levels of contamination by the public; which may also be linked to the availability of alternative supplies (e.g. increased demand for bottled water). There may be loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Possible increase in public confidence that the problem of contamination is being effectively managed. Social impacts depend on whether the flushing process is protracted requiring water companies to provide alternative water supplies, such as bottled water. Otherwise there is only likely to be a short-term social impact.
Environmental considerations	If normal disposal routes for waste water and other solid wastes from treatment continues, this could lead to the spread of low levels of contamination in the environment, e.g. in natural water courses. In most cases the contaminated water will pass through a sewage treatment process or be diverted in its diluted state to storm tanks. However, despite best endeavours, it may not be possible to divert contaminated water into the foul sewer and that the flow will be direct to a watercourse. If this happens, the EA in England and Wales, SEPA in Scotland or NIEA will take the appropriate action to mitigate the effect on the environment.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). The risk of ingestion exposure would need to be measured against the need to provide drinking water.

Effectiveness

Recovery option effectiveness	Can be effective in preventing exposure although it is possible that some members of the community will not adhere to the notice or understand the instructions if access to water is restricted while the flushing process takes place. The efficacy of the recovery option depends on efficacy of the communication medium and compliance of the community to adhere to warning notices.
Technical factors influencing effectiveness of recovery option	Some people may ignore restrictions and continue to drink the contaminated water. Some people may not be aware that restrictions are in place and that an alternative supply is available. Shortages of alternative supplies could lead to people drinking the contaminated water. If the area affected involved large numbers of people, the supplies might not meet demand. Mainly compliance of individuals and length of time this notice is in force.

Feasibility and intervention costs

Specific equipment	None in the short-term however if protracted then alternative water supply will need to be considered (see (2) Alternative drinking water supply).
Utilities and infrastructure	See above
Consumables	See above

(12) Flush distribution system

Skills, personnel and operator time	No specific skills are required other than those already employed by the worker company/ supplier.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Staff and personnel costs should not be significantly in excess of normal working practices. There may be costs associated with provision of alternative drinking water supplies if implementation of this recovery option is expected to be protracted.
Waste	
Amount and type	Seek specialist advice and guidance. Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from modified water treatment processes may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Large quantities of waste material could be generated (e.g. contaminated sand and activated charcoal from filter beds and sludge) that is above levels permitted for normal use, which may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water) and (14) Treatment of sludge. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to disposal. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from water treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. In the majority of options available for the disposal of contaminated water the ultimate use of the sewerage system and the sewage treatment works is the most practical. The diversion of the contaminated water by the sewerage undertaker to storm tanks buys time for the method of final disposal to be properly planned. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	In the managed disposal of the water from the distribution system, water undertakers should consider the following options in consultation with the EA in England and Wales, SEPA in Scotland and NIEA, the Drinking Water Inspectorate, the local Environmental Health Officer and the sewerage undertaker based on the hierarchy shown below: (9) Drain to temporary storage facility; (10) Discharge off-site using tankers [tankering] and (11) In situ treatment and discharge (foul, land and surface water)

(12) Flush distribution system

Exposure

Averted exposure	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing). Exposure to the public will be influenced by their knowledge, understanding and compliance of associated advisory notices, warning about the incident.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Exposure could be received by individuals in connection with implementing the recovery option and will be determined by risk assessments, safety plans and procedures adopted by the water companies to protect their operators.

Other considerations

Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case, communication regarding the following aspects will need to be addressed: Planned work on the water supply: advance notices are delivered to each building in the affected streets. The notice will give details of the work, particularly the timing of any shut down of the supply. For example, it may advise that water may be discoloured when the supply is restored and what to do if this does not clear on flushing the mains tap. Adequate and effective communication to ensure compliance. All responding agencies should ensure that only a common agreed form of public advice in the form of, for example, Frequently Asked Questions (FAQ) is provided to their staff in call centres or placed on websites.

Additional information

Practical experience	Water companies will have considerable experience in flushing water systems following pipe repairs or maintenance. Also see Case Study 1 (Section 10.3).
Key references	Paddock R, Anaraki S. Water contamination in North East London. Incident response. CHaP Report HPA. 2005 (3):16 The Drinking Water Inspectorate. Drinking Water Safety. Guidance to health and water professionals (2009). Available [April 2012] at; http://dwi.defra.gov.uk/stakeholders/information-letters/2009/09_2009Annex.pdf Water UK. Protocol for the disposal of contaminated water. Version 2.1 2003. Available [April 2012] at; https://www.water.org.uk/guidance/disposal-of-contaminated-water-may-2018/
Comments	
Document History	

(13)	Natural attenuation (with monitoring)
Objective	To allow the natural degradation of a chemical in all water environments with monitoring
Other benefits	None
Recovery option description	Natural attenuation processes include a variety of physical, chemical or biological processes that, under favourable conditions, act without human intervention to reduce the mass toxicity, mobility, volume or concentration of contaminants in groundwater. These processes include; • **Destructive mechanisms**; biodegradation, destruction, abiotic oxidation and hydrolysis • **Non-destructive mechanisms**; sorption, dispersion, dilution, and chemical or biological stabilisation or transformation, and volatilisation Monitoring of water environments to confirm whether natural attenuation processes are acting at a sufficient rate to ensure that the wider environment is unaffected and that remedial objectives will be achieved within a reasonable timescale
Key information requirements	To properly evaluate this recovery option, it is necessary to know the location, concentration of the contaminant, and how the contaminant behaves in the environment (i.e. physicochemical properties) • Are there sufficient site data to support monitored natural attenuation is a viable recovery option? • Do the site characterisation data and results of modelling demonstrate that natural attenuation is occurring and can achieve the risk management objectives? (i.e. what is the water temperature, depth) • Is the monitoring programme sufficiently robust? • Do the results of the monitoring demonstrate that remedial goals have been achieved and monitoring can cease?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option may form a component of an integrated treatment approach, incorporating active remedial measures. Therefore, this recovery option should be considered in conjunction with; (2) Alternative drinking water supply; (3) Restrict water use (Do Not Drink / Do Not Use notices); (9) Drain to temporary storage; (10) Discharge off site using tankers (tankering); (11) In-situ treatment and discharge (foul, land and surface water); (12) Flush distribution system and (14) Treatment of sludge.
Target	Contaminated groundwater drinking supplies
Targeted chemicals and important physicochemical properties	The physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance (i.e. Environment Agency) should be sought on the efficacy of natural attenuation (with monitoring). PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is less suitable for metals than it is for organics and some inorganic chemicals. This recovery option is suitable for chemicals that are; low toxicity; moderate solubility (thus reducing the risk of a high contaminant load developing, which will depend on dispersion and short half-life (to facilitate rapid degradation).
Scale of application	Any
Exposure pathway prevention	Ingestion, inhalation and dermal contact with contaminated water (i.e. drinking, food preparation and washing).
Time of application	This recovery option can be implemented from the **early/ late phase (hours – months/ years)** of a chemical incident. This recovery option may take several decades to arrive at a satisfactory outcome.

(13) Natural attenuation (with monitoring)

Considerations

Public health considerations	Volatilisation can present some health risks, e.g. by migration of vapour through the vadose zone into buildings from groundwater. Potential for users of recreational water to be affected by long term contamination.
Legal implications and obligations	Depending on the nature of the contamination, consultation with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland or the Northern Ireland Environment Agency (NIEA) will be required. There is legislation linked to the enforcement and control of natural attenuation as a remedial option. Some of the activities that are associated with monitored natural attenuation may themselves be subject to regulatory control. Refer to Appendix A for more information.
Social implications	Acceptance of monitored natural attenuation requires liaison and agreement with various stakeholders (landowners, insurers, financiers and prospective purchasers) and the relevant regulators. Regular consultation is recommended throughout the screening, demonstration, assessment and implementation stages of this recovery option. Public may perceive this option as 'doing nothing' which can have negative implications.
Environmental considerations	Degradation may lead to the generation of intermediate products with greater toxicity/ mobility than the parent compound. Potential for spread of contamination in environment
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). The option may be perceived as "doing nothing" and have negative implications.

Effectiveness

Recovery option effectiveness	The effectiveness of this recovery option will depend on the physicochemical properties of the chemical involved.
Technical factors influencing effectiveness of recovery option	This recovery option may take from hours several decades to arrive at a satisfactory outcome; therefore this potentially long-term time frame makes this recovery option susceptible to changes in various technical, economic and regulatory conditions, including water geochemistry, land-use and legislative changes. These factors need to be considered in the design and application if natural attenuation (with monitoring) is selected as a long-term remediation strategy. In addition, the level of perceived or actual risk will influence the appropriateness of implementing this recovery option, including; • Sensitivity of the site (strategic resource value of water and the presence and proximity of vulnerable receptors); • Hazardous properties of the chemical contamination (mobility, persistence and toxicity, and the potential to degrade to other substances with these properties); • Seriousness of the pollution (e.g. List I and II substances under the EC Directives); • The level of uncertainty in the definition of the conceptual model and in assessment/ monitoring data available.

Feasibility and intervention costs

Specific equipment	Screening and monitoring equipment
Utilities and infrastructure	Capacity to analysis samples (i.e. laboratory facilities).
Consumables	None
Skills, personnel and operator time	Skilled personnel to take samples and undertake analysis.

(13)	Natural attenuation (with monitoring)
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	There is the potential for the long-term monitoring for many years (decades), which will require significant financial provision; other recovery options may provide a more favourable cost-to-benefit ratio; there is also a risk that data may confirm that active remediation is required after all. Finally, the cost of developing contingency plans may be prohibitive.
Waste	
Amount and type	No waste is generated by this option.
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Exposure to the public will be influenced by their knowledge, understanding and compliance of associated advisory notices, warning about the incident.
Potential increased worker exposure	Recovery workers (i.e. sampling and monitoring team) may be at risk of exposure. The appropriateness of implementing this recovery option will be determined by risk assessments, safety plans and procedures adopted by the water companies to protect their operators.
Other considerations	
Agricultural impact	Due to the potential for spread on contamination in the environment, there is also a risk of agricultural impacts in the affected area.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. Acceptance of natural attenuation (with monitoring) requires liaison and agreement with various stakeholders (landowners, insurers, financiers and prospective purchasers) and the relevant regulators. Regular consultation is recommended throughout the screening, demonstration, assessment and implementation stages of this recovery option. Potential concerns could be raised due to the civil liabilities associated with migration of contamination between neighbouring properties; therefore communication of site monitoring is of key importance.
Additional information	
Practical experience	

(13) Natural attenuation (with monitoring)

Key references	Carey MA, Finnamore JR, Morrey MJ and Marsland PA. Guidance on the assessment and monitoring of natural attenuation of contaminants in groundwater. *Environment Agency* (2000). Health Protection Scotland weekly report. *Gannet oil spill, Scotland.* 2011. Huhne C. Gannet oil spill: written ministerial statement. Available [April 2012] at; http://www.decc.gov.uk/en/content/cms/news/gannet_wms/gannet_wms.aspx. (accessed 13 September 2011) Welch F, Murray VSG et al. Analysis of a petrol plume over England: 18-19 January 1997. *Occupational and Environmental Medicine.* 1997 56 (10) 649-56.
Comments	Natural attenuation is used when referring to the naturally occurring physical, chemical and biological processes that act within a water environment (i.e. aquifer) to reduce contaminant load, concentration, flux or toxicity.
Document History	

(14)	Treatment of sludge
Objective	Complex technique(s) to deal with the most hazardous sludge produced
Other benefits	None
Recovery option description	If the decision is made that the contaminated water can flow through the treatment processes, contaminated sludge may be produced. If the normal operation is to spread sludge on agricultural land, this may no longer be acceptable. Initially this will be retained in sludge lagoons (where available). Specialist techniques may be required to deal with complex chemically contaminated sludge. In the managed disposal of the sludge, the following options will be considered, depending on the nature of the contamination, in consultation with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland or the Northern Ireland Environment Agency (NIEA): • Incineration or advanced sludge treatment • Landfill [with or without pasteurisation • Onsite encapsulation [with or without pasteurisation]
Key information requirements	Effectiveness of treatment for chemical of concern Quantity of sludge requiring treatment
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with: (10) Discharge off site using tankers (tankering) and (11) In- situ treatment and discharge (foul, land, surface water)
Target	Chemicals that could be bound in sewage sludge.
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on the efficacy of treatment of sludge from standard water treatment practice and processes for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is suitable for all chemicals (including very persistent chemicals) in the environment
Scale of application	**Small/ Medium**
Exposure pathway prevention	Dermal contact/inhalation from vapours released from contamination.
Time of application	This recovery option can be implemented in the **medium/ late phase (weeks – months/ years)** of a chemical incident. The time taken to implement this option will depend on the volume of contaminated sludge requiring treatment.
Considerations	
Public health considerations	None
Legal implications and obligations	Waste disposal legislation. Any waste arising from treatment may need a new authorisation. Refer to Appendix A for more information.

(14) Treatment of sludge

Social implications	There may be issues regarding the acceptability of spreading sludge. There may be loss of confidence in the quality of water provided by water companies to the public (and other parties for private water supplies). Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	Might disrupt the landscape of the site Utilisation or disposal of contaminated sludge needs to be considered as the chemical concentrations in the sludge may be above the levels permitted for normal use (land spreading or landfill).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Consideration should be given to possible exposure to operatives.
Effectiveness	
Recovery option effectiveness	The effectiveness of this recovery option will depend on the amount of sludge present and the efficiency of the technique for the contamination being dealt with.
Technical factors influencing effectiveness of recovery option	Monitoring in the treatment works and of operatives may be required to ensure that nay limits on operatives are not exceeded and to confirm that the new treatment is having the desired effect.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Water utility providers) as specific technical equipment is likely to be required, including specialist tanker contractors with trained drivers and pumping equipment may be required.
Utilities and infrastructure	Existing landfill sites Incinerators (usually attached to water treatment works) Specialist incineration
Consumables	Variable
Skills, personnel and operator time	Seek specialist advice and guidance as skilled personnel are likely to be required to undertake this recovery option. Operator time and personnel requirements will vary depending on the size and scale of the chemical incident. Training of operatives may be required if new processes are implemented.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring in the treatment works and of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the new treatment is having the desired effect. Appropriate safety equipment (overalls, gloves and boots and respiratory protection may be required if the chemical contaminant is an inhalation hazard and health risk.
Other limitations/factors influencing costs	The complexity of sludge contamination will influence remediation costs. There could be additional operator time if operations were performed more frequently. Transport of raw materials and waste to and from treatment works will also require additional operator time (loading and driving).

(14) Treatment of sludge

Waste

Amount and type	Seek specialist advice and guidance. Waste is produced following water treatment (i.e. contaminated material from filter or resin beds, waste water or sludge); depending on the chemical contamination, waste from modified water treatment processes may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. Sludge is generated continuously as part of normal water treatment; the quantity depends on the content of solids in the raw water. Larger quantities of sludge are often stored on site prior to disposal. Sludge is also generated during cleaning of storage tanks. Cleaning of storage tanks and the replenishment of filters and resins may take place more frequently following chemical contamination to prevent high concentrations of chemical waste arising. Large quantities of contaminated sludge above levels permitted for normal disposal (i.e. land-spreading), may require additional treatment prior to disposal, see (11) In-situ treatment discharge (foul, land, surface water).
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste arising from water treatment of water may require disposal and/or storage under authorisation and a suitable disposal route. The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Will depend on the amount and type of waste generated. The nature of the chemical contamination. The availability of a suitable disposal route.

Exposure

Averted exposure	Exposure to the public will be influenced by their knowledge, understanding and compliance of associated advisory notices, warning about the incident.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Exposure could be received by individuals in connection with implementing the recovery option and will be determined by risk assessments, safety plans and procedures adopted by the water companies to protect their operators.

(14) Treatment of sludge

Other considerations

Agricultural impact	Sludge may not be acceptable for discharge to land. The use of drinking water supplies may not be acceptable for irrigating or watering crops. There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water supplies provided by water companies and suppliers (i.e. manufacturing, production or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case effective communication is required to convey to members of the effected public the measures being implemented are likely to benefit public health and reduce contamination in the environment. Workers would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
Comments	
Document History	

(15)	Restrict access to inland, recreational or coastal (controlled) water environments
Objective	To reduce possible exposure from chemically contaminated waters and to prevent members of the public from accessing a contaminated area.
Other benefits	Any necessary recovery options will be implemented more easily whilst the population are absent from the contaminated area.
Recovery option description	In most cases the public may only require access to inland, recreational or coastal water environments for recreational purposes (i.e. fishing, swimming, and surfing). Water environments to consider restricting access to include; coastal waters (sea), reservoirs, rivers and lakes. There may also be some exceptions to recreational use such as professional fishermen or divers. This recovery option could be implemented using communication through the media combined with using appropriate signs. If severe contamination has occurred a cordon with appropriate security may be required. Following a large scale incident, coastal waters may not be a high priority for clean-up unless there is the potential for the contamination to spread to drinking water so restricting access may be necessary prior to any clean-up or recovery strategy being implemented. This recovery option could be implemented more easily in the short term; members of the public may be less likely to adhere to notices over a period of months/years if they wish to use the water environments for recreational purposes. Realistically, only a total prohibition on access will be enforceable. Any partial restriction cannot be controlled and it will not be possible to control the exposures received by members of the public. Secretary of States Representative for Maritime Salvage and Intervention (SOSREP) may issue an exclusion zone which would encompass both shipping and aerial.
Key information requirements	What is the nature or use of recreational water by the public? (i.e. fishing, sailing, swimming) What is extent of the contamination?
Linked recovery options	This is a **protective option** and may need to be linked to **remediation options.** This option could also be considered in conjunction with; (16) Restrict transport through inland, recreational or coastal (controlled) water environments
Target	People who may use water environments for recreational purposes
Targeted chemicals and important physicochemical properties	Any toxic chemicals with potential to contaminate water environments. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Any**
Exposure pathway prevention	Exposure could be by multiple routes depending on the chemical and nature of the incident. However dermal and inhalation exposures are likely to be most associated with contaminated water environments.
Time of application	This recovery option can be implemented in the **early/late phase (hours – months/ years)**. Restricting access may be necessary prior to any clean-up being implemented. There would be maximum benefit if this recovery option was implemented soon after the initial contamination or incident. There are no time limits associated with this recovery option, it can be applied at any time and for any duration.
Considerations	
Public health considerations	None if implemented correctly

(15)	Restrict access to inland, recreational or coastal (controlled) water environments
Legal implications and obligations	May require legislation to restrict access to land, depending on ownership. Restricting use of private areas may not be allowed by law. Refer to Appendix A for more information.
Social implications	There may be issues with compliance and there might be pressure to re-open a site depending on what function it had previously (for example sailing clubs, recreational water areas, surfing etc). Members of public may be unhappy at being prevented from carrying out their normal activities This option may disrupt routine social activities and commercial activities relating to the water environment (sailing clubs, angling). There could be a change in public perception of the acceptability of recreational water areas.
Environmental considerations	None
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN).
Effectiveness	
Recovery option effectiveness	If complied with there should be no further exposure to members of the public
Technical factors influencing effectiveness of recovery option	Effectively isolating and area from public access may be difficult if the contaminant has not been fully contained (e.g. in river, open sea). Effective exclusion of people from an area may be difficult to demonstrate (i.e. success of barriers and fences (if used)). People may also ignore restrictions if they want to get access to other items (e.g. attractive/ valuable items washed up on beach). This option assumes that the contaminated water environment has been contained and that restrictive access intervention is a viable option.
Feasibility and intervention costs	
Specific equipment	Barriers and other equipment to block off access to the water environment. Machines may be required to erect effective barriers. Water buoys warning signs. May require machinery if large fencing/ barriers are required.
Utilities and infrastructure	Access routes such as roads to the contaminated water area
Consumables	Notices, signs, barriers.
Skills, personnel and operator time	Limited skills required to set up barriers/signs
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Duration for which this recovery option is required to be in place (security to restrict access to the affected area).
Waste	
Amount and type	None

(15)	Restrict access to inland, recreational or coastal (controlled) water environments
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	Averted exposure could be from multiple routes depending on the chemical and nature of the incident. However dermal and inhalation exposures are likely to be most associated with contaminated water incidents.
Potential increased worker exposure	Worker and public exposure will be reduced by 100% if access is effectively stopped.
Other considerations	
Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of normal water activities (i.e. sailing/ fishing or farming practices). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case communication with the affected communities about the rationale for choosing this option would be desirable and should form part of a wider communication and information strategy
Additional information	
Practical experience	This recovery option was implemented to restrict public access to the beach during the remediation of the MSC Napoli (2009).
Key references	Bennett S, Bolton P. Operation MSC Napoli. *Chemical Hazards and Poisons report, HPA*. 2009;14:15. Marine Coast guard Agency MCA. *Counter pollution response.* Available [April 2012] at; https://www.gov.uk/government/organisations/maritime-and-coastguard-agency
Comments	
Document History	

(16)	Restrict transport through inland, recreational or coastal (controlled) water environments
Objective	To reduce or prevent exposure to chemical contamination in water environments to members of the public and to prevent spread of contamination in the environment by water vessels.
Other benefits	Other recovery options necessary for the recovery of the incident could be carried out more easily in the absence of water vessels.
Recovery option description	Prohibit use of vessels (of any form, size and purpose) within a contaminated water environment. This recovery option also includes the potential closing of ports and harbours to prevent use of transport. This recovery option will not reduce contamination levels in the environment, but it will prevent vessels from spreading contamination This recovery option may also limit the import/export of goods if an incident occurred in major shipping area.
Key information requirements	Location and spread of contamination
Linked recovery options	This is a **protective option** and may need to be linked to **remediation options.** This recovery option will not reduce contamination levels in the environment, but it will prevent vessels from spreading contamination. Therefore, this recovery option should also be considered in conjunction with; (19) Removal/ containment of sediment within inland, recreational, coastal and underground water environments; (20) Containment: use of dams, booms and absorbent material and (21) Retrieval of chemical(s) and containers
Target	Aquatic vessels
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is likely to be suitable for chemicals with a density lower than water (i.e. float), such as oil (hydrocarbons).
Scale of application	**Any**
Exposure pathway prevention	All routes (ingestion, skin contact, inhalation) - depends on the physiochemical properties of the chemical under consideration
Time of application	Likely to be easier to implement in the short term

Considerations

Public health considerations	None
Legal implications and obligations	Refer to Appendix A for more information.
Social implications	There may be issues with compliance and there could be pressure to re-open access through the affected environment, especially those whose livelihoods would be affected (i.e. fishermen). Members of public may be unhappy at being prevented from carrying out their normal activities This option may disrupt routine social activities and commercial activities relating to the water environment (sailing clubs, angling).

(16)	Restrict transport through inland, recreational or coastal (controlled) water environments
Environmental considerations	Any environmental impact of using vehicles on water may be reduced
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). There may be a risk of exposure to those enforcing the restriction zone.
Effectiveness	
Recovery option effectiveness	This option is effective in preventing vessels from spreading contamination.
Technical factors influencing effectiveness of recovery option	Compliance :an effective public information strategy will be essential This option is likely to be implemented more easily in the short term; people may be less likely to adhere to notices over a period of months/years if they wish to use the water environments for recreational or work purposes.
Feasibility and intervention costs	
Specific equipment	Boats may be required to patrol areas to ensure enforcement in marine environments.
Utilities and infrastructure	None
Consumables	Signs
Skills, personnel and operator time	Boat handling skills for marine environments. Operator time will depend on the scale of the incident and the restrictions and enforcements required.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	There may be costs associated with enforcing the restrictions over protracted period.
Waste	
Amount and type	None
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	N/A
Exposure	
Averted exposure	All routes (ingestion, skin contact, inhalation), depending on the physicochemical properties of the chemical contamination.
Potential increased worker exposure	This will depend on the physicochemical properties of the chemical involved and there is a risk of exposure to those enforcing the restriction zone (i.e. inhalation hazard).

(16) Restrict transport through inland, recreational or coastal (controlled) water environments

Other considerations

Agricultural impact	None.
Compensation issues	There may be requests for compensation for costs associated with loss of trade (i.e. fishing or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case communication with the affected communities about the rationale for choosing this option would be desirable and should form part of a wider communication and information strategy

Additional information

Practical experience	The Marine Coastguard Agency (MCA) has a range of experience in restricting water vehicle access during maritime pollution incidents.
Key references	Bennett S, Bolton P. Operation MSC Napoli. *Chemical Hazards and Poisons report, HPA*. 2009 14:p15. Lunel. T. Oil fate governed by dispersion. IOSC 2005: Proceedings of the 2005 International Oil Spill Conference. pp. 790-793 Marine Accident Investigation Branch. *Report on the investigation of the structural failure of MSC Napoli English Channel*. Report No 9/2008. Marine Coast guard Agency MCA. *Counter pollution response.* Available [April 2012] at https://www.gov.uk/government/organisations/maritime-and-coastguard-agency Shetland KP. Recovery of the marine environment following the Braer spill. IOSC 2005: Proceedings of the 2005 International Oil Spill Conference. pp 6797-6815
Comments	
Document History	

(17)	In-situ treatment of inland, recreational, coastal and underground waters
Objective	To remediate the contamination within the affected water environment
Other benefits	Will not damage or disrupt other surrounding areas
Recovery option description	This recovery option considers the remediation or treatment of a chemical contaminant within the water environment. It should be noted that raw drinking water sources undergo treatment which has the capacity to remove some chemical contamination (see (6) Continuing normal water treatment (supported by a monitoring programme) to meet water quality standards. There are likely to be limited treatments available to contaminated controlled waters as it is more difficult to introduce water treatments when compared to water treatment works (complicated by the size and scale of the affected area). **Examples** • One of the most common in-situ treatments is the use of oil dispersants to break up an oil spill by breaking oil into smaller parts and aiding natural biodegradation • Biological nitrification has been used to remove ammonia from surface waters • Wood fibre filters: Aspen wood has been shown to remove polycyclic aromatic hydrocarbons from river waters. • Chemical coagulation has been used to treat surface waters e.g. to remove heavy metals and low solubility organic chemicals • Other examples include oil skimmer techniques, oil/water separation, activate charcoal techniques, For recovery it is likely that responders will have contained or isolated the chemical contaminant using booms, dams or in the case of open sea will have defined the area/ extent of contamination (see (20) Containment: use of dams, booms and absorbent materials)
Key information requirements	Type of water environment that has been contaminated (i.e. inland or coastal waters) Size of the affected area Effectiveness and efficacy of the proposed treatment for chemical of concern
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should also be considered in conjunction with; (18) Drainage of inland, recreational, coastal and underground (controlled) waters and (20) Containment: use of dams, booms and absorbent materials
Target	Water bodies in various environments (rivers, reservoirs, marine environments)
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on the efficacy of in-situ treatment of inland, coastal and underground waters for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is suitable for all chemicals which have known and effective treatments
Scale of application	This recovery option could potentially be implemented on any scale, but may not be applicable if dilution is excessive (e.g. release to sea).
Exposure pathway prevention	Prevent exposure to recreational users (e.g. swimmers) via skin contact / inhalation and accidental ingestion. Also prevent contamination depositing in new environments such as beaches or river banks.
Time of application	In most cases the earlier the option is implemented the more effective it will be at reducing contamination as natural processes may breakdown or disperse the chemical in the

	environment. However certain water treatments may take a number of days to implement in surface waters.
Considerations	
Public health considerations	None
Legal implications and obligations	Legal access may be required although authorised officers within the local authorities and Environment Agencies will have powers of entry to investigate pollution incidents. Refer to Appendix A for more information.
Social implications	Disruption to normal activities such as closing controlled water or restricting transport to recreational water activities. Public acceptability and trust in authorities to remove or reduce chemical contamination. Acceptability of residual levels of contamination in the environment. Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	The topography of the areas or access issues may limit or prevent in situ recovery options. Inclement weather could disrupt or prevent this recovery option. Unlikely that dispersants would be used within 5km from the shoreline. Dispersal or degradation of contamination may have adverse effects on aquatic life. Need to consider toxicity of any dispersants used on marine life or if it reached the shore.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with additional tasks undertaken by operatives at the incident would need to be assessed. There may be inequity between beneficiaries (recreational users, environment) and those undertaking the work.
Effectiveness	
Recovery option effectiveness	Will depend on the chemical and affected water environment.
Technical factors influencing effectiveness of recovery option	Effectiveness will be dependent on the types and number of remediation processes used and also the chemicals(s) involved and their physiochemical properties. There are different dilution factors involved between marine and inland waters along with tidal patterns (in marine environments) which will need to be considered when employing in situ treatments.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required.
Utilities and infrastructure	Tools and roads to access the affected area
Consumables	Will depend on the type of recovery technique employed
Skills, personnel and operator time	Seek expert advice and guidance (i.e. Marine Coastguard Agency) as specific technical equipment is likely to be required, including specialist contractors. Operator time will vary according to the complexity of the chemical(s) being treated.

(17) In-situ treatment of inland, recreational, coastal and underground waters

Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs).
Other limitations/factors influencing costs	Will depend on the size and scale of the chemical incident and affected water environment.
Waste	
Amount and type	Most in situ remediation techniques are designed to limit waste. However physical removal techniques such as oil skimmers will produce waste equivalent to their removal efficiency and the amount estimated within the environment. For sediments (sands) contaminated with hydrocarbon oils it may be possible to consider oil recovery for recycling, with the return of clean material back to the environment. The MCA has experience of possible techniques (see also (18) Drainage of inland, recreational, coastal or underground (controlled) waters.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Any waste arising from in-situ treatment of water will require disposal and/or storage under authorisation and a suitable disposal route. If appropriate, transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Contaminated material such as waste water or sludge may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods
Factors influencing waste issues (i.e. cost)	The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste. Other factors influencing waste issues include the availability of a suitable disposal route; the cost of chemical waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.
Exposure	
Averted exposure	Preventing exposure to recreational water users (e.g. swimmers) via skin contact / inhalation and accidental ingestion. Also prevents contamination depositing in new environments such as beaches or river banks.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Exposure could be received by individuals in connection with implementing the recovery option and will be determined by risk assessments, safety plans and procedures adopted by the water companies to protect their operators. Monitoring of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the remediation is having the desired effect. Changes to other working and safety practices may be required to minimise exposure to operatives.

(17) In-situ treatment of inland, recreational, coastal and underground waters

Other considerations

Agricultural impact	There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of trade (i.e. fishing or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case, adequate and effective communication to ensure compliance will be required. All responding agencies should ensure that only a common agreed form of public advice in the form of, for example, Frequently Asked Questions (FAQ) is provided to their staff in call centres or placed on websites. Communication with the affected communities about the rationale for choosing this option would be desirable and should form part of a wider communication and information strategy

Additional information

Practical experience	The MCA Counter Pollution and Response team maintain extensive response equipment stockpiles, positioned at strategic locations around the UK for in-situ treatment of inland, recreational and coastal waters.
Key references	Bennett S, Bolton P. Operation MSC Napoli. Chemical Hazards and Poisons report, HPA. 2009 14:p15. DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-wasteMarine Coast guard Agency MCA. Counter pollution response. https://www.gov.uk/government/organisations/maritime-and-coastguard-agency Water UK. Protocol for the disposal of contaminated water. Version 2.1 2003. https://www.water.org.uk/guidance/disposal-of-contaminated-water-may-2018/
Comments	While large spill incidents remain relatively rare, events such as the Deepwater Horizon in the Gulf of Mexico and, more recently, the grounded container ship Rena in New Zealand show the importance of effective response. Rapid response, improved preparedness and effective post-incident monitoring and assessment are all key parts of an effective response. A set of new guidelines to strengthen the response to oil and chemical spills at sea was published on 15 November 2011, including post-incident monitoring guidelines.
Document History	

(18)	Drainage of inland, recreational, coastal and underground (controlled) waters
Objective	To remove contaminated water from the environment so it can be treated or disposed of, or, to access contaminated sediment
Other benefits	None
Recovery option description	Contaminated controlled waters such as reservoirs, canals and small harbours may require draining to remove chemically contaminated water.
Key information requirements	Availability of appropriate storage facilities Identification of potential waste disposal routes
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (15) Restrict access to inland, recreational or coastal (controlled) water environments
Target	Water bodies in various environments (reservoirs, canals, and small harbours in marine environments)
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on the efficacy of drainage of inland, coastal or underground waters for the removal of the chemical contamination on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	Variable although less likely to be required if dilution is excessive (e.g. release to sea).
Exposure pathway prevention	Prevent exposure to recreational users (e.g. swimmers) via skin contact / inhalation and accidental ingestion. Also prevent contamination depositing in new environments such as beaches or river banks.
Time of application	In most cases the earlier the option is implemented the more effective it will be at reducing contamination as natural processes may breakdown or disperse the chemical in the environment. However certain water treatments may take a number of days to implement in surface waters.
Considerations	
Public health considerations	None
Legal implications and obligations	There may be some legal implications with regards to ownership and access to water. Legal access may be required although authorised officers within the local authorities and Environment Agencies will have powers of entry to investigate pollution incidents. There is also legislation pertaining to waste disposal. Refer to Appendix A for more information.
Social implications	Local communities may not find it acceptable for local waters to be drained.
Environmental considerations	Surrounding habitat may not allow for this
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with implementing this recovery option by operatives and recovery workers at the incident would need to be assessed. There may be inequity between beneficiaries (recreational users, environment) and those undertaking the work.

(18)	Drainage of inland, recreational, coastal and underground (controlled) waters
Effectiveness	
Recovery option effectiveness	If done under the appropriate circumstances, this recovery option may be effective
Technical factors influencing effectiveness of recovery option	Effectiveness will be dependent on the types and number of other remediation processes used and also the chemicals(s) involved and their physiochemical properties. There are different dilution factors involved between marine and inland waters along with tidal patterns (in marine environments) which may need to be considered.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required. High velocity pumps and necessary drains to set up a drainage system and route to water treatment decontamination.
Utilities and infrastructure	The installation of new equipment (e.g. high velocity pumping equipment) and accompanying infrastructure (i.e. power supply, roads and access to site) may be required.
Consumables	
Skills, personnel and operator time	Specialist and skilled workforce will be required to implement this recovery option. Infrastructure needs to be in place, and if a 'new build' is required, this will result in additional staff (and increase costs).
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Appropriate safety equipment (overalls, gloves and boots) are provided.
Other limitations/factors influencing costs	The installation of new equipment (e.g. high velocity pumping equipment) and infrastructure required to enable draining could be expensive and take time to install. Duration for which this recovery option needs to run will also influence costs.
Waste	
Amount and type	Waste sediment is likely to be produced following drainage of inland, recreational, coastal and underground (controlled) waters. Depending on the chemical contamination, waste sediment may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste sediment arising from drainage of inland, recreational, coastal and underground (controlled) waters may require disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sediment may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to

	prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	Disposal of contaminated waste sediment may be expensive as large quantities may potentially be generated (e.g. sand from filter beds and sludge). Cost may also be influenced by: the availability of a suitable disposal route; the cost of contaminated waste disposal; chemicals involved and levels of contamination; amounts of waste requiring disposal.
Exposure	
Averted exposure	Preventing exposure to recreational users (e.g. swimmers) via skin contact / inhalation and accidental ingestion. Also prevents contamination depositing in new environments such as beaches or river banks.
Potential increased worker exposure	Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of operatives may be required to ensure that any limits on operative exposure are not exceeded and to confirm that the remediation is having the desired effect. Changes to other working and safety practices may be required to minimise exposure to operatives.
Other considerations	
Agricultural impact	Sediment may not be acceptable for discharge to land. The use of dewatered effluent may not be acceptable for irrigating or watering crops. There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss of trade (i.e. fishing or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case communication with the affected communities about the rationale for choosing this option would be desirable and should form part of a wider communication and information strategy
Additional information	
Practical experience	
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste

(18) Drainage of inland, recreational, coastal and underground (controlled) waters

Comments

Document History

(19)	Removal/containment of sediment within inland, recreational coastal and underground water environments
Objective	To eliminate and remove contamination from sediment and surrounding areas, such as sediment from river beds, lakes, canals, harbours, estuary or coastal waters (i.e. sands on beaches).
Other benefits	None
Recovery option description	A process whereby the sediment is removed completely from the contaminated area and either contained for further treatment or removed to an appropriate waste facility (e.g. hazardous landfill). Dredging normally involves cutting into the sediment and raising the material out of the water with buckets or pipelines. The material is then transported ashore by boat or pipeline, or disposed of elsewhere. Sometimes water jets are used to dislodge sediment and transport the material away from the site under the influence of natural flow or tidal currents. For controlled waters there are typically 2 types of dredging; bucket dredging and suction dredging. **Bucket dredging** involves bulk digging out of silt from the lake, drained if necessary; either with long-reach excavators from the shoreline or with excavators floated on barges on the lake, with spoil and contaminated sediment put either into barges or directly into trucks for removal. **Suction dredging** involves removal of sediment by pumping out slurry or water and sediment and piping it directly out of the affected water environment (i.e. lake). Suction dredging has the advantage of being more 'sensitive' than bucket dredging, with less damage and impact caused to shoreline profiles. Suction dredging is also better targeted for the removal of specific layers of sediment. The dredging process may be complex if applied to a large-scale incident, therefore consideration needs to be given regarding the location, area, depth, volume, methodology, timing (i.e. tides) and disposal of contaminated sediment material.
Key information requirements	Seek specialist advice and guidance. Availability of skilled personnel, contractors and specialist equipment (i.e. dredgers). Are suitable sediment storage facilities available? What is size and scale of contamination?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should also be considered in conjunction with; (15) Restrict access to inland, recreational or coastal (controlled) water environments and (14) Treatment of sludge
Target	Contaminants which are persistent and adsorb onto dense sediment
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable to chemicals that are persistent, adequately dense, or adsorb onto sediment.
Scale of application	**Any.** This recovery option may be complex if applied to a large/ wide-scale incident
Exposure pathway prevention	Slow discharge into water body leading to ingestion or dermal exposure.
Time of application	This recovery option can be implemented in the **medium-late phase (months – years)** of a chemical incident.

(19) Removal/containment of sediment within inland, recreational coastal and underground water environments

Considerations

Public health considerations	None
Legal implications and obligations	There may be some legal implications with regards to ownership and access to water. Legal access may be required although authorised officers within the local authorities and Environment Agencies will have powers of entry to investigate pollution incidents and in the contaminated land regime. There is legislation pertaining to; waste recovery/disposal, disposal of contaminated water/ sediment and consents. Refer to Appendix A for more information.
Social implications	There may be issues with compliance, and pressure to re- open a site depending on what function it had previously (for example sailing clubs, recreational water areas, surfing etc). Public acceptability and trust in authorities to remove or reduce chemical contamination. Acceptability of residual levels of contamination in the environment. Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	Severe cold weather (snow or ice) may impact the effectiveness of this option. Utilisation or disposal of contaminated sediment needs to be considered as the chemical concentrations in the sediment may require specialist disposal. Dredging and dredged material placement involves the disturbance of existing sediments which can result in impacts on the environment. Sediments are often lost into the water during the process of dredging which can affect the clarity and quality of the water. Toxic chemicals contained in the sediment may also be released into the water and become available for uptake in water abstraction, to fish, plants and invertebrates. If a dredging or disposal activity would cause deterioration as a result of a physical modification, it may be possible to seek an exemption under the Water Framework Directive such that the activity can go ahead. Exemptions are provided where there are reasons of overriding public interest or the benefits inter alia to human health or safety or sustainable development outweigh the benefits of achieving the relevant WFD objective(s); In some estuaries, removing sediment may affect the overall budget of sediment in the ecological system. This could change the effectiveness of nearby mud or sand flats to provide habitat for wildlife. Dredging and disposal methods or timings can be designed to keep sediments within the system. For marine environments, consideration needs to be given to areas designated under the areas designated under the EC Bathing Waters Directive; EC Birds and/or Habitats Directives; areas designated under the EC Shellfish Directive and Freshwater Fish Directive; areas designated under the EC Nitrates Directive or Urban Wastewater Treatment Directive. To minimise the environmental impact the most beneficial time to undertake dredging is possibly late summer (UK National Trust, 2002).
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with implementing this recovery option by operatives and recovery workers at the incident would need to be assessed. There may be inequity between beneficiaries (recreational users, environment) and those undertaking the work.

Effectiveness

Recovery option effectiveness	If carried out appropriately, this recovery option could be up to 100% effective
Technical factors influencing effectiveness of recovery option	The type of sediment, site and abilities of the workforce implementing the procedure. This recovery option is also likely to require heavy specialist machinery, and be resource intensive for large areas (i.e. equipment and skilled personnel). This option assumes that the contaminated water environment has been contained and that restrictive access intervention is a viable option. This recovery option may be complex if applied to a large and wide-scale incident.

(19)	Removal/containment of sediment within inland, recreational coastal and underground water environments
	May involve machinery or manual work depending on the scale of the incident Severe cold weather (snow or ice) may impact the effectiveness of this option.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required. Dredgers/ excavator – barges, manmade lagoons, temporary storage facilities (i.e. oily waste/ water storage tanks, skips, drums, IBC's Waste Tankers and transport lorries). Containment material (see (20) Containment: use of dams, booms and absorbent materials)
Utilities and infrastructure	Seek expert advice and guidance as specialist decontamination contractors are likely to be required to undertake this recovery option.
Consumables	Variable depending on extent of remediation being undertaken. Notices, signs, barriers etc,
Skills, personnel and operator time	Seek expert advice and guidance as specialist decontamination contractors are likely to be required to undertake this recovery option.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). As well as hazards arising from the use of excavating machinery there will be issues concerning emergency procedures (e.g. if the excavator gets stuck), prevention of public access, and health hazards for staff or contractors involved. Monitoring of operatives may be required to ensure that exposure limits on operatives and recovery workers are not exceeded, and to confirm that the remediation is having the desired effect.
Other limitations/factors influencing costs	There may be issues regarding access to and from the site. The size and scale of the area requiring remediation will influence the costs associated with implementing this recovery option.
Waste	
Amount and type	Depending on the chemical contamination, waste sediment may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance. The amount of waste sediment generated by dredging depends on the size and scale of the contaminated water environment, but this recovery option is likely to produce significant amounts of waste. The Marine Coastguard Agency (MCA) has reported that 1 tonne spilled oil creates 10 tonne of waste.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Waste sediment may require recovery/disposal and/or storage under authorisation and a suitable disposal route. Contaminated material such as waste water or sediment may be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal

(19)	Removal/containment of sediment within inland, recreational coastal and underground water environments
	regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste. For oil waste from marine spills, oil refineries may have facilities to accept oil/water and oil/sand. They may also have sludge treatment facilities, storage lagoons and effluent treatment plants.
Factors influencing waste issues (i.e. cost)	The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated sediment/sludge although they are not responsible for removing the waste. A waste permit may not be required in an emergency under statutory defences. If it is decided that this 'statutory defence' no longer serves the public interest, deposits must be either permitted, registered exempt, removed or mitigated as appropriate within a specified timescale. If waste goes to landfill it is likely to require some pre-treatment which will add significant expense to this recovery option. Any associated liquid waste may require treatment prior to being returned or disposed of as waste. For sediments such as sands contaminated with hydrocarbon oils it may be possible to consider oil recovery for recycling, with the return of clean material back to the environment (see (14) Treatment of sludge). Costs are likely to be extremely high for this recovery option
Exposure	
Averted exposure	Ingestion or dermal exposure.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of operatives may be required to ensure that exposure limits on operatives and recovery workers are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving contaminated water.
Other considerations	
Agricultural impact	Sediment may not be acceptable for discharge to land. The use of dewatered effluent may not be acceptable for irrigating or watering crops. There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss or damage to property, or loss of trade and earnings (i.e. fishing, sailing or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk.
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

(19) Removal/containment of sediment within inland, recreational coastal and underground water environments

	In this case effective communication is required to convey to members of public the measures being implemented are likely to benefit public health and reduce contamination in the environment. Workers would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	The Environment Agency has wide experience of controlled water dredging. The MCA has wide experience of dredging, containing, washing sand sediments, for more information see; https://www.gov.uk/guidance/assessing-risk-and-responding-to-uk-coastal-and-marine-pollution
Key references	Bennett S, Bolton P. Operation MSC Napoli. *Chemical Hazards and Poisons report, HPA*. 2009 14:p15. DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste MCA pollution resource website. Available [April 2012] at; https://www.gov.uk/government/organisations/maritime-and-coastguard-agency Marine dredging guidance for compliance with the Water Framework Directive (EA,2010). https://www.gov.uk/government/publications/complying-with-the-water-framework-directive-marine-dredging Water UK. Protocol for the disposal of contaminated water. Version 2.1 2003. Available [April 2012] at; https://www.water.org.uk/guidance/disposal-of-contaminated-water-may-2018/
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(20) Containment: use of dams, booms absorbent materials

Objective	To reduce exposure to chemical contamination found in water bodies. Also to prevent the spread of contamination in the environment.
Other benefits	Prevent or limit harm to aquatic life. This recovery option may also prevent contamination of drinking water if abstraction points nearby.
Recovery option description	This recovery option considers the containment of spills on the surface of water such as rivers, reservoirs or marine environments. In extreme circumstances damming of water could be considered to prevent the spread of contamination. It involves the use of large booms to contain the chemical contamination combined with adsorbent material to aid the removal of contamination. Absorbent materials would vary according to the contaminant (e.g. polypropylene may be used for oil spills). In shallower water (e.g. streams) wooden planks may be used to raise water level and allow the use of river booms. In addition, use of booms can be combined with damning to raise water level in certain circumstances On a river, booms may be spread between 2 banks to improve recovery of contamination. Emergency booms can be used using a ladder wrapped in a salvage sheet if appropriate equipment is not available.
Key information requirements	Availability of specialist equipment
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (15) Restrict access to inland, recreational or coastal (controlled) waters environments and (16) Restrict transport through inland, recreational or coastal (controlled) water environments
Target	Surface of contaminated water
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to all chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. This recovery option is applicable to chemicals with a density less than water (i.e. float). Examples would include hydrocarbons, vegetable oil and certain solvents.
Scale of application	**Any**
Exposure pathway prevention	Skin contact/inhalation from vapours released from contamination. Also consumption of contaminated water if water abstraction point nearby.
Time of application	This recovery option is best implemented in the early phase of a chemical incident, before contamination has had the opportunity to spread.

Considerations

Public health considerations	None
Legal implications and obligations	There may be some legal implications with regards to ownership and access to water. Legal access may be required although authorised officers within the local authorities and Environment Agencies will have powers of entry to investigate pollution incidents. There is legislation pertaining to; waste recovery/disposal, disposal of contaminated water/ sediment and consents. Refer to Appendix A for more information.

(20)	Containment: use of dams, booms absorbent materials
Social implications	Containing contamination may not be seen as effective as physically removing it by public if contamination cannot be absorbed. There may be loss of public confidence in the contaminated water courses for recreational purposes. Possible increase in public confidence that the problem of contamination is being effectively managed.
Environmental considerations	Severe weather in certain environments (e.g. sea) could limit feasibility of implementing this recovery option. Severe weather may also enhance spread of contamination. Appropriate disposal of contaminated absorbent booms should be considered.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with implementing this recovery option by operatives and recovery workers at the incident would need to be assessed. There may be inequity between beneficiaries (recreational users, environment) and those undertaking the work.
Effectiveness	
Recovery option effectiveness	Could be up to 100% effective if employed in the early stages following an incident. The effectiveness of this recovery option will depend on the size and scale of the incident (i.e. Braer and Gulf oil spill)
Technical factors influencing effectiveness of recovery option	Will vary greatly depending on time of application, level of contamination and weather conditions. It is easier to use booms in slow running water.
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required. River/sea booms. May be solid (no air required) or inflatable. Can vary in size dependent on environment. Adsorbent material may vary according to chemicals under consideration. Air required to inflate booms. Wooden planks may be useful to raise water level in shallow environments (e.g. stream)
Utilities and infrastructure	Vehicles for transportation of equipment (e.g. trucks, boats)
Consumables	Adsorbent materials (e.g. polypropylene)
Skills, personnel and operator time	Seek expert advice and guidance as specialist decontamination contractors are likely to be required to undertake this recovery option.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). As well as hazards arising from the use of dams, booms and absorbent materials there will be issues concerning emergency procedures (e.g. if the recovery workers fall into the contaminated water), prevention of public access, and health hazards for staff or contractors involved. Monitoring of operatives may be required to ensure that exposure limits on operatives and recovery workers are not exceeded, and to confirm that the remediation is having the desired effect.

(20)	Containment: use of dams, booms absorbent materials
Other limitations/factors influencing costs	Availability of materials and time to implement them. The costs associated with this recovery option will depend on the size and scale of the contamination, for example 100m of booms cost circa £2500.
Waste	
Amount and type	Potentially large quantities of contaminated adsorbent material/booms, which may come under the classification of 'Hazardous waste'. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Contaminated adsorbent material/booms may require disposal and/or storage under authorisation and a suitable disposal route. These materials may also be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.
Factors influencing waste issues (i.e. cost)	The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste. Other factors influencing was include, how effective the absorbent material is at retaining contamination. For example some absorbent booms can hold 20 times their weight in oil.
Exposure	
Averted exposure	Skin contact/inhalation from vapours released from contamination. Also consumption of contaminated water if water abstraction point nearby.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving contaminated water.
Other considerations	
Agricultural impact	Need to ensure that there are no uses of contaminated water for farming purposes. There may be an agricultural impact if water was diverted from agricultural use, which could lead to a shortage of water for irrigation, particularly in conditions of limited water resources. Licenses to abstract water for agricultural use may be withdrawn.
Compensation issues	There may be requests for compensation for costs associated with loss or damage to property, or loss of trade and earnings (i.e. fishing, farming, manufacturing processes or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk

(20) Containment: use of dams, booms absorbent materials

Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case effective communication is required to convey to members of public the measures being implemented are likely to benefit public health and reduce contamination in the environment. Workers would need to be informed that they could be exposed to chemical contamination.

Additional information

Practical experience	There are number marine incidents where this recovery option has been implemented, including; Bennett S, Bolton P. Operation MSC Napoli. *Chemical Hazards and Poisons report, HPA*. 2009 14:p15. Shetland KP. Recovery of the marine environment following the Braer spill. IOSC 2005: Proceedings of the 2005 International Oil Spill Conference. pp 6797-6815 Cyanide spill at Baia Mare Romania (2000) UNEP/OCHA assessment.
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste Environmental Protection, Fire and Rescue Manual - Volume 2: Fire Service Operations. Marine Coast guard Agency MCA. *Counter pollution response.* Available [April 2012] at; https://www.gov.uk/government/organisations/maritime-and-coastguard-agency
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(21) Retrieval of chemical(s) and containers

Objective	To reduce or prevent exposure to chemical contamination in water environments to members of the public
Other benefits	Limit damage to marine life
Recovery option description	This recovery option considers the removal of chemical contamination (e.g. contained chemicals in barrels, or siphoning chemicals into temporary storage for removal) from a water environment. This could include damaged ships or containers that have sunk to significant depths. It is likely to involve the use of specialist equipment/ salvage operatives and specialist diving teams.
Key information requirements	What is the chemical involved? Is the chemical contained (i.e. in a barrel/ container) or leaking? What is the size of the potentially affected area? Are specialist equipment/ personnel available to undertake this option?
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option should be considered in conjunction with; (15) Restrict access to inland, recreational or coastal (controlled) water environments and (16) Restrict transport through inland, recreational or coastal (controlled) water environments
Target	Chemical contamination
Targeted chemicals and important physicochemical properties	Any chemical that may be in transit (either in a container/ barrel or leaking) Physiochemical properties of limited importance unless the container leaking. If the container is leaking, then toxicity, specific gravity, water solubility and physical form are important physicochemical properties to consider. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium.
Scale of application	**Small/Medium**
Exposure pathway prevention	Exposure of recreational water users to skin contact/ inhalation of chemical.
Time of application	Implementation required early (hours to days) if containers are leaking, but can be done later if chemical containers are still intact (weeks to months)

Considerations

Public health considerations	Potential for dispersion of chemical close to water surface that could increase exposure for recreational water users
Legal implications and obligations	The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste. Refer to Appendix A for more information.
Social implications	None
Environmental considerations	Weather conditions (i.e. marine currents) and depth of water. Potential for leaking container to contaminate wider environment during retrieval
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). Any risks associated with additional tasks undertaken by operatives at the incident would need to be assessed. There may be inequity between beneficiaries (recreational users, environment) and those undertaking the work

(21)	Retrieval of chemical(s) and containers
Effectiveness	
Recovery option effectiveness	The effectiveness will depend on the containment of the chemical (i.e. contained within barrels, or leaking). This option may be up-to 100% effective at removing contamination
Technical factors influencing effectiveness of recovery option	Weather conditions Marine currents, depth of water
Feasibility and intervention costs	
Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required (i.e. salvage equipment, scuba diving gear).
Utilities and infrastructure	None
Consumables	Salvage equipment Specialist diving equipment Specialist siphoning equipment
Skills, personnel and operator time	Seek expert advice and guidance as specialist decontamination contractors are likely to be required to undertake this recovery option.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of operatives may be required to ensure that exposure limits on operatives and recovery workers are not exceeded, and to confirm that the remediation is having the desired effect.
Other limitations/factors influencing costs	The size and scale of the area requiring remediation will influence the costs associated with implementing this recovery option.
Waste	
Amount and type	Potentially large quantities of chemical containers, which may come under the classification of ‘Hazardous waste’. To help determine is a waste is hazardous or not, seek expert opinion and consult available national guidance.
Possible transport, treatment, disposal and storage routes	Seek specialist advice and guidance. Chemical containers (i.e. barrels) may require disposal and/or storage under authorisation and a suitable disposal route. These materials may also be classified as dangerous in transport and will be subject to the transport of dangerous goods legislation whatever the mode of transport used. For more information see https://www.gov.uk/government/collections/transporting-dangerous-goods Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated waste material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles. Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required for sorting out large amounts of contaminated waste.

(21) Retrieval of chemical(s) and containers

Factors influencing waste issues (i.e. cost)	The Environment Agency has special powers to respond to waste issues during major incidents. The EA would determine a legal disposal route for contaminated waste although they are not responsible for removing the waste.

Exposure

Averted exposure	Dermal/ inhalational exposure
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the retrieval of chemical contamination from water environments.

Other considerations

Agricultural impact	None
Compensation issues	There may be requests for compensation for costs associated with loss or damage to property, or loss of trade and earnings (i.e. fishing, farming, manufacturing processes or transport of goods). Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that it may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments.

Additional information

Practical experience	This recovery option was implemented at the Tetraalkyl lead accident at sea: Cairns, J. Ecoaccidents. Plenum press: New York and London. 1985
Key references	DEFRA. Strategic national guidance: The safe management of wastes arising following a chemical, biological, radiological or nuclear incident.2008. Available; https://www.gov.uk/how-to-classify-different-types-of-waste Environment Agency. Technical Guidance (WM2): Hazardous waste: Interpretation of the definition and classification of hazardous waste (Second edition: Version 2.3, April 2011) https://www.gov.uk/how-to-classify-different-types-of-waste
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(22) Burning in-situ

Objective	To reduce or prevent exposure to members of the public of chemical contamination in water environments.
Other benefits	This recovery option facilitates the rapid conversion of oil into water and carbon dioxide, as a result, there is limited waste associated with this option (except for smoke and particulate matter). There is no need for collection, storage, transport and disposal of recovered material. It also actually puts many less people directly at risk compared to more manual clean-up methods.
Recovery option description	This recovery option is an oil spill response option that involves the controlled ignition and burning of spilled oil, at or near the spill site on the surface of the water or in a marsh. Response plans for this method call for the use of fire resistant booms to contain the oil and maintain the thickness of the oil slick during burning. This recovery option will result in a visible smoke plume, containing particulates (soot), combustion gases, unburned hydrocarbons and residue at the burn site. 5-15% of the oil is converted to smoke particles that are lofted into the air and dissipated over a large area. Smoke and particulate residue will float (and may also sink) as it cools which although it non-toxic, will require clean-up. (see linked recovery options).
Key information requirements	To properly evaluate burning in-situ as an appropriate recovery option, it is necessary to compare the risk expected from in situ burning to risks from using mechanical/chemical recovery methods. The main points to consider are: • The location of the spill, is it offshore or near shore? Where is the nearest settlement? • What are the burn characteristics of the oil? (not all spilled crude oil will burn) • What are the metrological conditions? i.e. wind speed and direction • What is the size of the spill and the spill rate? • What are the operational and logistic constraints/requirements? For example the distance of the spill off-shore, the availability of access roads and availability of support vessels. For remote areas, this recovery option is more feasible as it is logistically simple.
Linked recovery options	This is a **remediation option** and may need to be linked to **protection options.** This recovery option may form a component of an integrated treatment approach, incorporating other remedial measures. Therefore, this recovery option should be considered in conjunction with; (13) Natural attenuation (with monitoring); (15) Restrict access to inland, recreational or coastal (controlled) water environments; (16) Restrict transport through inland, recreational or coastal (controlled water environments); (17) In-situ treatment of inland, recreational, coastal or underground (controlled) waters; and (20) Containment: use of dams, booms and absorbent materials. Depending on the affected area, smoke and particulate residue will also require clean-up. Please check with other relevant sections of the Handbook, including **Food Production Systems**; (1) Closure of air intake systems to minimise the contamination of food processing plants and foodstuffs within them; and (3) Protection of harvested crops from contamination **Inhabited Areas;** (8) Physical decontamination techniques; (10) Pressure hosing; (12) Surface removal (buildings) and (15) Modify operation/ cleaning of ventilation systems.
Target	Flammable chemical contaminants
Targeted chemicals and important physicochemical properties	This recovery option is potentially applicable to flammable chemicals. However, the physicochemical properties of the chemical contaminant will influence whether or not this option is a suitable remediation technique. Expert guidance should be sought on an incident and site-specific basis. PHE has a compendium of chemical hazards, which includes information on chemical toxicity and is available to access; https://www.gov.uk/government/collections/chemical-hazards-compendium. Other physicochemical properties that are important to consider include; oil type, weathering (evaporation of oil), emulsification (water becoming incorporated into the oil) as these influence the burn characteristics of the oil.

(22) Burning in-situ

Scale of application	**Large scale** (in open waters)
Exposure pathway prevention	Skin contact/ inhalation from vapours released from contamination.
Time of application	This recovery option is only suitable to be implemented in the early phase of a chemical incident (hours – days). Prevailing metrological and oceanographic conditions are crucial as wind speed, wave conditions, water depth and current speed can cause physical changes in the spilled oil that can make it difficult or impossible to burn.

Considerations

Public health considerations	Immediate public health risks include the risk of flashback and secondary fires that could threaten human life in nearby settlements as well as recovery workers should be considered. Additional public health implications and risks are linked to the inhalation of combustion by-products and particulate matter (i.e. smoke) which may have serious public health implications for sensitive receptors.
Legal implications and obligations	There may be implications with regard to ownership and access to water. This recovery option and the ramifications associated with it are likely to be scrutinised by the press. There may be significant pressure to prevent this recovery option being implemented. Waste legislation would have to be complied with, as this option would potentially be subject to environmental permitting controls. Refer to Appendix A for more information.
Social implications	Public perception of risk associated with this option is a major concern (i.e. that the smoke is harmful to human health)
Environmental considerations	Concerns over atmospheric emissions and the human health effects associated with exposure to combustion by-products (i.e. smoke) will be a significant factor to consider in deciding whether or not to implement this recovery option. Therefore, the benefits of implementing this recovery option must be carefully evaluated against other available remediation techniques.
Ethical considerations	This recovery option should consider the Human Rights of the affected population to ensure that actions are proportionate, legal, accountable and necessary (PLAN). The exposure of recovery workers to combustion by-products and smoke, and nearby settlements would have to be considered prior to implementing this recovery option.

Effectiveness

Recovery option effectiveness	Removal efficiencies for thick oil slicks can easily exceed 95% given the right conditions.
Technical factors influencing effectiveness of recovery option	This recovery option has a limited window-of-opportunity to conduct successful burn operations. Factors that define this window are: • The type of oil spilled (not all crude oil spills burn) • Thickness of oil slick • Prevailing metrological and oceanographic conditions (wind speed, wave conditions, water depth, current speed) these can cause physical changes in the spilled oil that can make the oil difficult or impossible to burn. • The amount of water taken up by the oil (emulsification) Once the oil spills, it begins to form a stable emulsion, once the water content exceeds 25% most oil slicks are un-ignitable. • Evaporation Prevailing metrological and oceanographic conditions are crucial as wind speed, wave conditions, water depth and current speed can cause physical changes in the spilled oil that can make it difficult or impossible to burn.

(22) Burning in-situ

Feasibility and intervention costs

Specific equipment	Seek expert advice and guidance (i.e. Marine Coastguard Agency, Environment Agency) as specialist technical equipment is likely to be required (i.e. igniters and fire resistant booms). There are currently 3 types of booms available for in-situ burning, thermally resistant fabric, stainless steel and water-cooled booms. The cheapest of these types of booms are the thermally resistant fabric booms, and the most expensive being the stainless steel booms.
Utilities and infrastructure	None.
Consumables	Booms to contain the spill.
Skills, personnel and operator time	Seek expert advice and guidance as specialist decontamination contractors are likely to be required to undertake this recovery option.
Safety precautions	Will depend on the chemical involved and a risk assessment would need to be undertaken. Seek specialist advice and guidance. Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of operatives may be required to ensure that exposure limits on operatives and recovery workers are not exceeded, and to confirm that the remediation is having the desired effect.
Other limitations/factors influencing costs	Control of burning fires is the most essential aspect of this technique to ensure safety. Type of booming used, amount of booming required, availability of relevant materials (generally only fabric based booms are stockpiled in appreciable quantities)

Waste

Amount and type	Burn residue on water
Possible transport, treatment, disposal and storage routes	N/A
Factors influencing waste issues (i.e. cost)	If burn residues sink before being removed, it will be difficult to retrieve.

Exposure

Averted exposure	Skin contact/ inhalation from vapours released from contamination.
Potential increased worker exposure	Employers have a duty of care to protect employees from hazards and risks in the workplace. Employers have to comply with the Health and Safety at Work Act to ensure that water treatment operatives use appropriate PPE (if required) and follow Standard Operating Procedures (SOPs). Monitoring of recovery workers may be required to ensure that exposure limits are not exceeded, and to confirm that the remediation is having the desired effect. For example, recovery personnel working in close proximity to the burn site may be exposed to levels of gases and particulates that will require use of PPE, to minimise inhalation of and skin contact with combustion by-products. Due to the specific nature of tasks and the wide variation of possible chemicals involved, it is not possible to estimate likely recovery worker exposure. They would, however, need to be assessed on a case-by-case basis in the event of any incident involving the retrieval of chemical contamination from water environments.

(22) Burning in-situ

Other considerations

Agricultural impact	None
Compensation issues	There may be requests for compensation for loss or damage to property caused by secondary fires. Financial and legal advice relating to compensation after a major incident can be found at www.gov.uk
Public information	It is essential that prior to, during and after the response to a chemical incident or event, clear communication strategies are developed and implemented. The probability that the event may not only be the focus of local, regional, national and international media scrutiny, but that is may also attract government interest at local, regional, national and international level should be addressed. Any communication strategy must consider and define the information that is suitable to be given to the public at the scene and in the local (affected) area. This information must be developed in partnership with other experts, government agencies and departments. In this case effective communication is required to convey to members of the public the potential risks linked to in-situ burning. The rationale for implementing this recovery option would need to be justified and ratified, to ensure the public are confidence that this option as a remediation technique has been well planned and considered as the most effective way of removing oil and significantly reducing shoreline impacts. Responders will also need to be warned of potential exposure risks.

Additional information

Practical experience	This recovery option was first implemented in 1958 in northern Canada. It has since been implemented a number of times, with some successful outcomes (i.e. Exxon Valdez spill in 1989). This recovery option should only be considered on a site and incident specific basis, as the negative effects of this recovery option can have devastating impacts decades after the initial incident (i.e. Torrey Canyon, 1967).
Key references	Mullin JV, Champ MA. Introduction/overview to in-situ burning of oil spills. *Spill science and technology bulletin*. 2003 8:323-330 Fritt-Rasmussen J, Brandvik PJ. Measuring ignitability for in situ burning of oil spills weathered under Arctic conditions: From laboratory studies to large-scale field experiments. Marine Pollution Bulletin. 2011. 62:1780–1785.
Comments	In-situ burning is being viewed with renewed interest as a recovery option in high latitude waters where conventional mechanical and chemical technologies may not be possible or advisable due to the physical environment (extreme low temperatures, ice covered waters) or the remoteness of the affected area. In- situ burning of oil is strengthened under icy conditions. Additionally this recovery option requires minimal equipment, which can easily be transported to remote areas. The disadvantages of this method (namely the smoke plume, and potential of secondary fires) should be weighed up against the disadvantages of other available remediation techniques; for example (17) In-situ treatment of inland, recreational, coastal and underground waters, as oil dispersants have 2 major issues, effectiveness and toxicity. Mechanical recovery options (such as booms) are generally expensive, complex, labour intensive, and generate a mixture of oil, water and debris as well as seldom exceeding 20% efficiency.
Document History	

10 Worked examples

Generic scenarios and worked examples have been developed to help users become familiar with the content of the handbook and its structure. They also take the user, in a very general way, through the main decision steps and the types of problem that they would need to address in the development of a recovery strategy. The scenarios could also be used as a training tool for potential users.

The scenarios and worked examples provided are only illustrative and have been included solely to support training in the use of the handbook. The worked examples should not be used as proposed solutions to the contamination scenarios selected. These scenarios have been chosen for the sole purpose of illustrating the breadth of the information in the handbook.

10.1 Food production systems: Dioxin incident

This section should be read in conjunction with Section 4: Constructing a recovery strategy for Food Production Systems.

Scenario

- Contamination of oil used in animal feed with dioxins
- Food supplied to cows and sheep farms at 3 locations around the UK
- Contamination discovered 7 weeks following the initial incident
- Concentrations of 850.5pg/g in animal fat have been reported

Before going through the generic steps involved in selecting and combining options, users should appreciate that when using the handbook to develop a recovery strategy, they should also establish dialogue with national and local stakeholders; familiarisation with the structure and content of the handbook; develop knowledge of technical information underpinning a recovery strategy; and an understanding of the factors influencing implementation of options and selection of a recovery strategy.

10.1.1 Step 1: Obtain relevant information regarding the incident

Apart from the information given above in the scenario it would be important to determine the toxicity and physicochemical properties of Dioxins. The relevant physicochemical properties and toxicological properties for dioxins are produced below in Table 10.1 and Table 10.2. Following a chemical incident expert advice (e.g. PHE) would need to be consulted to determine the relevant data for the chemical of concern.

Table 10.1: Important physicochemical properties for dioxins.

Physical characteristic	Description	Interpretation	Dioxins	
			Value	Interpretation
Physical form (solid/liquid gas)	**Gases** and vapours spread out in the environment until they are equally distributed throughout the space available to them. **Liquids** will flow with gravity when released and must therefore must be safely contained to stabilise the incident and prevent further risk to persons, property and the environment. **Solids** need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion		Solid	Solid but may be dispersed via a plume
Partition coefficient between water and octanol (**K_{OW}**)	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = **K_{ow}**) > 1,000: Likely to bioaccumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bioaccumulating < 500: Unlikely to bioaccumulate (hydrophilic)- Low.	**High K_{OW}** Likely to be; Bio-accumulated: Sorbed in soil or sediments. Unlikely to be: Mobile	63095000	High value (hydrophobic). Likely to bioaccumulate. Unlikely to be mobile in the environment.
Biological half life	How long chemical will persist in animals (e.g. milk/sheep). Will give indication of how long recovery options relating to may be effective (e.g. manipulation of culling).		Years (animals)	Slow elimination from animals destined to be food products
Uptake by plants / crops	Potential for a chemical to transfer to grass /crops/plants and hence potentially contaminate food chain		Young oats and soybeans grown on a sandy loam (*cucurbitaceae* family) that was contaminated with 60 ppb TCDD accumulated 40 ppb TCDD (HSDB). However, uptake by most plants is thought to be negligible.	Potential to contaminate certain species of crops

Table 10.1: Important physicochemical properties for dioxins.

Physical characteristic	Description	Interpretation		Dioxins	
				Value	Interpretation
Potential for chelation / absorption from gut	Whether a chemical can have its removal enhanced from livestock by using chelating agents or absorbent materials (e.g. clay minerals)			No known agents to enhance removal	
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. Higher volatility would result in a higher vapour pressure. Interpretation (Units = Pascals) < 1.3 x 10^{-4}: Unlikely to volatilise Between 1.3 x 10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	**High VP** Likely to: Be an inhalational risk Evaporate quickly	**Low VP** Unlikely to be: An inhalational risk	Negligible	Low vapour pressure indicates dioxins would not be expected to volatilise
Persistence	The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.	**Short persistence**: Hours to days **Moderate Persistence:** Weeks to months **Long Persistence:** Months to Years		Long	May persist in the environment for years
Water solubility	The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread by flowing water. Water based decontamination of surfaces may be more effective if a chemical is water soluble; removal options or active decontamination may be more appropriate for non-water-soluble chemicals Interpretation: Units ppm (mg/l) <10: Negligible solubility Between 10 and 1000: Increasing likelihood of solubilising >1000: Likely to solubilise	**High Solubility,** Likely to be mobile: Unlikely to be; Volatilised or persistent	**Low solubility** Likely to be; Immobilised by adsorption and persistent Unlikely to be; Mobile	Virtually insoluble	Not likely to disperse significantly in water environments

Table 10.1: Important physicochemical properties for dioxins.

Physical characteristic	Description	Interpretation		Dioxins	
				Value	Interpretation
Soil sorption	Measures how readily a chemical is adsorbed to organic surfaces in the soil matrix. Some soils have very limited abilities to sorb chemicals e.g. sandy soils or ones with low clay or organic matter contents. Gives an indication of likely persistence in soil. Interpretation (Units = $\mathbf{K_{OC}}$) > 10,000: Likely to adsorb Between 1,000 and 10,000: Increasing likelihood of adsorbing < 1,000: Unlikely to adsorb	**High K_{OC}** Likely to be; adsorbed or accumulated Unlikely to be; Mobile	**Low K_{OC}** Likely to be; Mobile Unlikely to be; Adsorbed or accumulated	24540000	Expected to have very low mobility or be immobile in soil
Boiling point	Boiling point is the temperature at which a liquid's vapour pressure equals atmospheric pressure and the liquid starts to turn to vapour. Low boiling point substances tend to be either gases or very volatile liquids at ambient temperature			Approx 900 degrees centigrade	Does not turn into gas easily.
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.			Hydrogen chloride and chlorine but very small quantities	Toxic degradation products but unlikely to cause a public health risk.
Toxicity	Sum of adverse effects of the degree of danger posed by a substance to living organisms. It is expressed generally as a dose response relationship involving the quantity of substance to which the organisms are exposed and the route of exposure skin (absorption), mouth (ingestion), or respiratory tract (inhalation).			Dioxins are toxic by inhalation or ingestion • Ingestion of dioxins can lead to adverse effects on the skin, including chloracne, skin rashes or discolouration and excessive body hair • High levels may give rise to changes in the blood and urine, liver damage or changes in hormonal levels	Dioxins are toxic to health.

Table 10.1: Important physicochemical properties for dioxins.

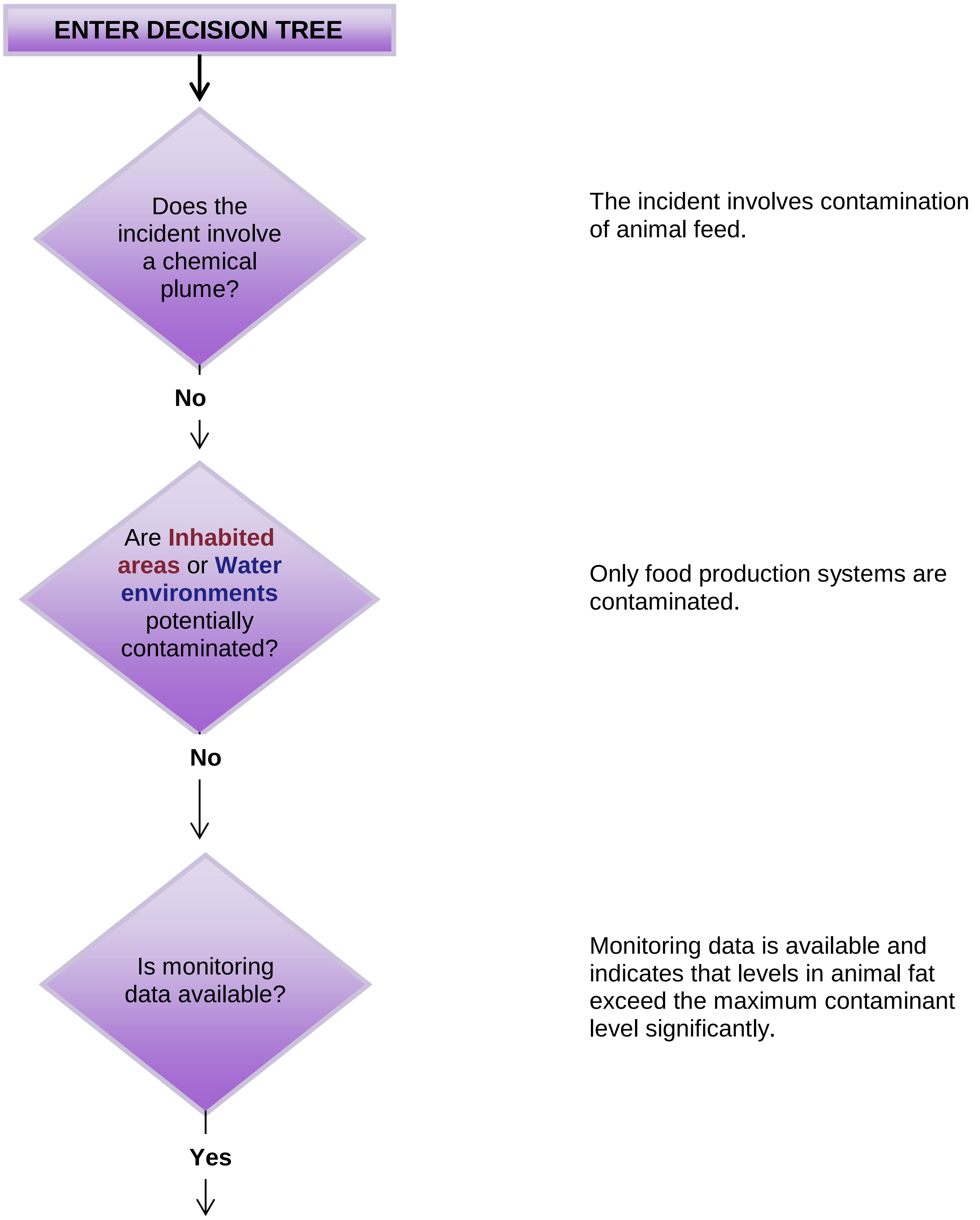
Physical characteristic	Description	Interpretation	Dioxins	
			Value	Interpretation
			• Other effects of exposure to very high levels of dioxins include vomiting, diarrhoea, lung infections and damage to the nervous and immune systems • TCDD is classified as a causing cancer in humans • TCDD produces a range of toxic effects on reproduction relating to both fertility and developmental toxicity	

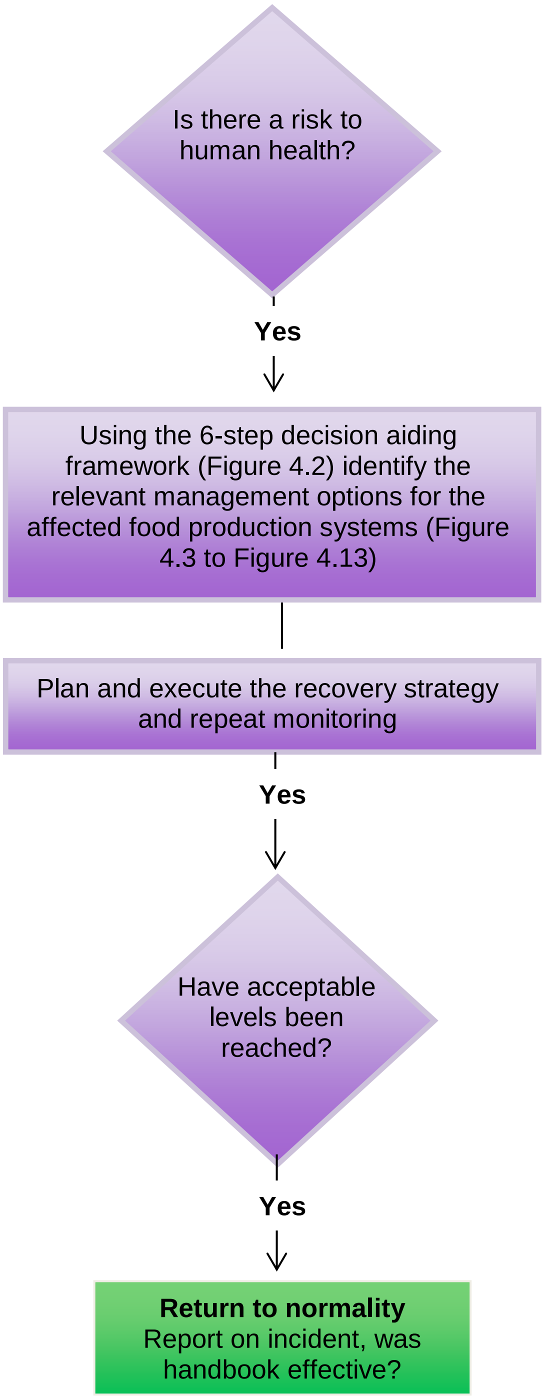
Table 10.2 Important human toxicity information for dioxins

	Main target organ(s)	Acute toxicity risk	*Latency of acute toxicity symptoms	Risk of sequelae	Carcinogen risk	Reproductive toxicity risk
Dioxins	CNS, Skin	Moderate	>24hr (years)	Yes	Yes	Probable
*Latency (onset of symptoms): Short: <1-hour Moderate: >1 hour Long: > 24 hours						

10.1.2 Step 2: Consult flow chart (Figure 4.1) and decision trees for food production systems

Refer to Figure 4.1 and Figures 4.3 to 4.13. Identify potentially applicable recovery options. Consult inhabited areas and water section of handbook (if applicable).





At this stage a risk assessment would be carried out with relevant stakeholders (e.g. FSA). The risk assessment would identify a risk of adverse health effects in humans who consumed contaminated animal produce.

The appropriate recovery options can be identified by using the 6-step decision process.

Plan and execute the recovery strategy and repeat monitoring.

Following the implementation of recovery options, further monitoring would be required to determine whether the remediation strategy has been successful.

If acceptable levels have not been reached, then the recovery strategy would have to be revised and an alternative remediation strategy developed using the 6-step decision process.

Consult relevant decision trees for food production systems (Figure 4.3 to Figure 4.13) to identify which recovery options are applicable for protection, restoration and fate of affected produce that should be considered for the affected food production systems – in this case both milk and meat production.

The relevant selection of recovery options is reproduced from Section 4 in Table 10.3, which lists options for milk (Figure 4.5) and meat (Figure 4.6) production. Subsequent steps will endeavour to eliminate options which are not applicable in this scenario. A number of recovery options apply for continuing both milk and meat production, but based on the characteristics of the incident, a number can be eliminated at this stage.

Table 10.3 Potentially applicable recovery options identified in Step 2

Protection options (actions taken to protect the food chain)	Retain	Rationale
(1) Closure of air intake systems at food processing plant	No	Only relevant if chemical plume involved
(4) Short-term sheltering of animals	No	Only relevant if chemical plume involved
(5) Restriction of entry of food into food chain/withdrawal from market	Yes	
(6) Product recall	Yes	
(7) Control of entry into food chain	Yes	
(8) Issue of a FEPA order	Yes	
(9) Precautionary (dietary) advice (non-commercial)	Yes	
(10) Processing or treatment of food products	Yes	
Restoration options (getting the production system back to normal)	**Retain**	**Rationale**
(14) Selection of alternative land use	No	Only relevant if agricultural land contaminated
(28) Administration of clay minerals to feed	Yes	
(29) Clean feeding/selective grazing regime	Yes	
(30) Suppression of lactation	Yes	
(31) Restrictions of animal breeding	Yes	
Fate of affected produce (waste disposal)	**Retain**	**Rationale**
(13) Temporary derogation	Yes	
(15) Selection of alternative product use	Yes	
(24) Biological degradation/decomposition	Yes	
(25) Bioremediation	Yes	
(32) Culling of livestock	Yes	
(33) Burial of carcasses	Yes	
(34) Disposal of contaminated milk to sea	Yes	
(35) Burning in-situ	Yes	
(36) Rendering	Yes	
(37) Incineration	Yes	

(38) Landfill	Yes
(39) Land-spreading of milk and/ or slurry	yes

*There are 27 potentially applicable recovery options (milk and meat production), of which 4 are eliminated at this stage (23 options remaining).

10.1.3 Step 3: Review effectiveness of recovery options

A: Elimination of recovery options based on physicochemical properties

The physicochemical properties of dioxins (from Step 1, see Table 10.1) are now used to eliminate options at this point in the decision process, the process is summarised in Table 10.4.

Table 10.4: Potentially applicable recovery options identified at Step 3

Protection options (actions taken to protect the food chain)	Retain	Rationale
(5) Restriction of entry of food into food chain/withdrawal from market	Yes	
(6) Product recall	Yes	
(7) Control of entry into food chain	No	Dioxins are likely to persist in animals for years, so manipulation of entry into the food chain (e.g. by varying time of culling) is unlikely to be of benefit
(8) Issue of a FEPA order	Yes	
(9) Precautionary (dietary) advice (non-commercial)	Yes	
Restoration options (getting the production system back to normal)	**Retain**	**Rationale**
(10) Processing or treatment of food products	No	There are no known treatments to remove dioxins from contaminated milk or meat
(28) Administration of clay minerals to feed	No	Dioxins are not absorbed by clay minerals
(29) Clean feeding	No	Dioxins are likely to persist in animals for years, so clean feeding is unlikely to be of benefit
(30) Suppression of lactation	No	Dioxins are likely to persist in animals for years, so suppression of lactation is unlikely to be of benefit
(31) Restrictions on animal breeding	Yes	
Fate of affected produce (waste disposal)	**Retain**	**Rationale**
(13) Temporary derogation	No	Dioxins have a very long half-life in humans (years) and is also a potential carcinogen. Raising intervention limits (temporary derogation) for milk and meat products is unlikely to be an acceptable option
(15) Selection of alternative product use	No	There are no known treatments to remove dioxins from contaminated milk or meat. Due to the persistency of dioxins it is unlikely to be an acceptable option
(24) Biological degradation/decomposition	No	Dioxins are very persistent (and a potential carcinogen) in the environment, there would be little justification for putting them back into the environment which this option entails

(25) Bioremediation	No	Dioxins are very persistent (and a potential carcinogen) in the environment, there would be little justification for putting them back into the environment which this option entails
(32) Culling of livestock	Yes	
(33) Burial of carcasses	No	Dioxin contaminated waste is Category 1, so burial of carcasses is not an appropriate option
(34) Disposal of contaminated milk to sea	Yes	
(35) Burial in-situ	Yes	
(36) Rendering	Yes	
(37) Incineration	Yes	
(38) Landfill	Yes	Dioxin contaminated waste is Category 1, so cannot go to landfill without prior treatment (i.e. rendering)
(39) Land-spreading of milk and/ or slurry	No	Dioxins are very persistent (and a potential carcinogen) in the environment, there would be little justification for putting them back into the environment which this option entails.

**There are 23 potential recovery options for milk and meat production, of which 12 are eliminated at this step in the decision-making process (11 options remaining)

B: Eliminate options based on effectiveness

Table 4.6 (Section 4) should now be consulted to determine the effectiveness of each remaining recovery option. This table is reproduced below (Table 10.5) for the remaining recovery options applicable for this example scenario. The retained or eliminated options are summarised in Table 10.6.

Table 10.5: recovery option effectiveness *Classification is based on evaluation of evidence base and stakeholder input

	Potential increased worker exposure	Effectiveness
Protection options (actions taken to protect the food chain)		
(5) Restriction on entry of food into the food chain/ withdrawal from market		
(6) Product recall		
(8) Issue a FEPA order		
(9) Precautionary (dietary) advice (non-commercial)		
Restoration options (Getting the production system back to normal)		
(31) Restrictions on animal breeding		
Fate of affected product (waste disposal)		
(32) Culling of livestock		
(34) Disposal of contaminated milk to sea		
(35) Burning in-situ		
(36) Rendering		
(37) Incineration		
(38) Landfill		

Effectiveness	**Up-to 100% effective**	**Moderately effective**	**Limited effectiveness**
Potential for increased worker exposure	**Unlikely**	**Moderate risk**	**High risk**

10.1.4 Step 4: review key considerations and constraints

It is inevitable that recovery options will have constraints associated with their implementation. Table 4.7 and Table 4.8 should now be consulted in Section 4 to identify the key constraints associated with the remaining recovery options. A detailed description of these constraints is provided in the recovery option sheets (Section 5). If an important (key) constraint is identified it does not indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis (Step 5).

These tables are reproduced below showing the recovery options remaining for this example, in Table 10.6 and Table 10.7.

Potentially applicable recovery options are outlined in Table 10.8.

Table 10.6: Key considerations for remaining recovery options (usually Table 4.7 – practical experience/ references have been removed for the purposes of this example)

	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
Protection options (actions taken to protect the food chain)		
(5) Restriction of entry into the food chain / withdrawal from market	Waste - There may be significant amounts of contaminated food products (i.e. milk, meat, eggs and crops) that will require a suitable disposal route, and may require disposal and/or storage under a waste transfer licence. Long term restrictions (e.g. FEPA order) may also lead to culling and disposal of livestock	
(6) Product recall	Waste - There may be significant amounts of contaminated recalled food products (i.e. milk, meat, eggs and crops) that will require a suitable disposal route, and may require disposal and/or storage under a waste transfer licence.	Social - Contacting members of the public
(8) Issue a FEPA order	Social: Economic loss occurring as a result of restrictions being imposed.	None
(9) Precautionary (dietary) advice (non-commercial)	Time – A decision needs to be made quickly as this option would need to be implemented as soon as a contamination problem is identified. There may be a delay between noting chemical contamination and toxicity in livestock (i.e. chickens following lead exposure) could result in contaminated produce being eaten by members of the public.	Public Health - There is a risk that some members of the public may already have been exposed prior to the advice being issued. Social - This is an advice option and is difficult to enforce. Food safety legislation does not apply to home grown produce.
Restoration options (getting the production system back to normal)		
(31) Restrictions on animal breeding	Technical - Depends on the nature of the chemical contaminant, persistence bioavailability, and the length of time animals would be subject to modified husbandry. Cost – May be high, considering; number of affected animals; consumables (i.e. feeding) and infrastructure (i.e. housing). For example, feeding and housing a dairy herd that are not used for milk production would be very expensive.	
Fate of affected produce (waste disposal)		
(32) Culling of livestock	Waste – There may be significant amounts of condemned livestock carcasses that will require further action (i.e. rendering, incineration and landfill). Social - Major disruptions to food business and farmers. Culling requires the consent of the owner, and there may be resistance of the public and impact on the farming community and cost.	Public Health – There is the potential for increased worker exposure (i.e. driver and operators at the abattoir, farm or knackers-yard. Time - A decision needs to be made quickly as this option would need to be implemented in the early – medium phase of an incident for this option to be effective.

	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(34) Disposal of contaminated milk to sea	Technical - Identification of long sea outfalls with capacity to discharge milk, authorisation to discharge milk to sea and transportation and offloading at discharge points. Cost - May be high, considering; the volume of milk requiring disposal; personnel; equipment and potential compensation issues.	Social - Acceptability with the public.
(35) Burning in-situ	Public Health - Negative impact on the public health of susceptible groups (children, elderly or pregnant women). Adults and children with respiratory or cardiovascular problems are also to be at higher risk of experiencing complications with existing chronic conditions. Waste - There may be significant amounts of contaminated pyre ash and there is a risk that this waste disposal method could lead to low levels of contamination in the environment. Social - Acceptability with the general public. Perception of risk, land subsequently being blighted. Technical - Suitability of land, associated land blight afterwards, transportation, and disposal of remaining pyre ash to land fill. This removes the contaminant from the food-chain, but doesn't remove the contamination.	Cost - May be high, considering; quantities of crops of number of animals/ livestock requiring disposal; personnel; equipment and potential compensation issues.
(36) Rendering	Waste- The products of rendering will need further disposal.	Public Health - Potential for the general public to develop concerns over health effects, with smell/ odour complaints. Technical - This option may be up-to 95% effective, but depends on the nature of the chemical contamination and volume of material involved. This option is also affected by the suitability of material (i.e. livestock or solid wastes) for rendering and the availability of commercial facilities and capacity in the area. Cost – May be high, considering; volume of affected food products (including livestock); personnel costs; equipment (hiring machinery).
(37) Incineration	None	Social - There could be local opposition near to an incineration plant due to public perception that chemical contamination will be released to the atmosphere. Acceptability with the general public and concerns over health effects should also be considered. Technical - This option may be up-to 95% effective, but depends on the nature of the chemical contamination and volume of material involved and the availability of commercial facilities and capacity in the area. Large municipal waste incinerators can process 300-500,000 tpa and could therefore take a large volume of waste. Cost – Incineration costs are high (but controlled)
(38) Landfill	Waste – For hazardous waste there is limited capacity and transport requirements may be significant.	Public Health - Acceptability with the general public and concerns over health effects. Cost – Incineration costs are high (but controlled)

Table 10.7: Summary of recovery option considerations

Recovery option	Public Health	Waste	Social	Technical	Cost	Time
Protection options (actions taken to protect the food chain)						
(5) Restriction on entry of food into the food chain/ withdrawal from market.						
(6) Product recall						
(8) Issue a FEPA order						
(9) Precautionary (dietary) advice (non-commercial)						
Restoration options (getting the production system back to normal)						
(31) Restrictions on animal breeding						
Fate of affected produce (waste disposal)						
(32) Culling of livestock						
(34) Disposal of contaminated milk to sea						
(36) Rendering						
(37) Incineration						
(38) Landfill						
Constraints	**None or minor**		**Moderate**		**Important (key)/ High**	
Time – when to implement recovery option	**No restrictions on time**		**Weeks to months/years**		**Hours – days**	

Table 10.8: Potentially applicable recovery options identified in Step 4

Protection options (actions taken to protect the food chain)	Retain?	Rationale
(5) Restriction of entry of food into food chain/withdrawal from market	Yes	
(6) Product recall	Yes	
(8) Issue a FEPA order	Yes	
(9) Precautionary (dietary) advice (non-commercial)	Yes	
Restoration options (getting the production system back to normal)	**Retain?**	**Rationale**
(31) Restrictions on animal breeding	No	There may be a risk of reproductive toxicity associated with exposure to dioxins. There are also the cost implications of keeping and housing animals if they are not being used from milk/meat production.
Fate of affected produce (waste disposal)	**Retain?**	**Rationale**
(32) Culling of livestock	Yes	
(34) Disposal of contaminated milk to sea	Yes	
(35) Burning in-situ	No	There are a range of major considerations including: public health, waste, social and technical aspects which would make this option unlikely.
(36) Rendering	Yes	
(37) Incineration	Yes	
(38) Landfill	No	Dioxin contaminated waste is category 1, so cannot go to landfill without prior treatment (i.e. rendering)

*There are 11 potential recovery options for milk and meat production, of which 2 are further eliminated at Step 4 of the decision making process (9 options remaining)

10.1.5 Step 5: Consult recovery option sheets

From the decision process, the following options remain (see Table 10.9 below).

Table 10.9: Remaining recovery options

Protection options (actions taken to protect the food chain)	Retain?	Rationale
(5) Restriction of entry of food into the food chain/withdrawal from the market	Yes	Key consideration is waste
(6) Product recall	Yes	Key consideration is waste
(8) Issue a FEPA order	Yes	Key considerations are social
(9) Precautionary (dietary) advice (non-commercial)	Yes	Key considerations are time (advice needs to be issued rapidly), and issues with compliance (social and public health) as precautionary dietary advice is not enforceable
Fate of affected produce (waste disposal)	**Retain?**	**Rationale**
(32) Culling of livestock	Yes	
(34) Disposal of contaminated milk to sea	Yes	
(36) Rendering	Yes	
(37) Incineration	Yes	

Recovery option sheets could now be consulted (see Section 5) to eliminate further options based on further constraints identified.

10.1.6 Step 6: Compare remaining recovery options

To aid with the selection of a recovery strategy, Table 4.9 in Section 4 could be used to compare remaining recovery options.

Implement monitor and evaluate

Once the recovery strategy has been selected it should be implemented, monitored for effectiveness and evaluated (see Section 4).

10.2 Inhabited areas: Sulphur mustard incident

This section should be read in conjunction with Section 6: Constructing a recovery strategy. For the purposes of this example only external building surfaces are considered in the decision process.

Scenario

- Small scale incident on 1st August
- Deliberate release of sulphur mustard into the commercial district of a town (shops and offices)
- It rained at the time of release

Current situation

- The population has been evacuated to a distance of 400m in all directions

10.2.1 Step 1: Obtain relevant information regarding the incident

Apart from the information given above in the scenario it would be important to determine the toxicity and physicochemical properties of Sulphur Mustard. The relevant physicochemical properties and toxicological properties for sulphur mustard are produced below (Table 10.10 and 10.11).

Table 10.10 (Recreated from Table 6.5) Important physicochemical properties Sulphur Mustard

Physical characteristic	Description	Interpretation		Sulphur Mustard: Description/ value	Sulphur Mustard: Interpretation
Physical form (solid/liquid gas)	Gases and vapours spread out in the environment until they are equally distributed throughout the space available to them. Liquids will flow with gravity when released and must therefore require containment safely to stabilise the incident and prevent further risk to persons, property and the environment. Solids need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion			Liquid/ vapour	Two forms need to be considered
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. For instance, where the vapours being given off by a liquid pose a hazard (e.g. Sulphur Mustard) fixative / strippable coating options may be considered. Higher volatility would result in a higher vapour pressure. Interpretation (Units = Pascals) < 1.3 x 10^{-4}: Unlikely to volatilise Between 1.3 x 10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	High VP Likely to: Be an inhalational risk Evaporate quickly	Low VP Unlikely to be: An inhalational risk	9.33	High VP Indicates that it poses a risk via inhalation as vapour is released from sulphur mustard. Need to consider recovery workers. Fixative/ strippable options could be considered.
Vapour Density (D vapour)	This refers to the relative weight of a gas or vapour compared to air (or sometimes it can be compared to hydrogen gas). Air is assigned an arbitrary value of 1 and if a gas has a vapour density of <1.29 it will generally rise in air. If the vapour density is >1.29 the gas will generally sink in air. All vapours tend to be heavier than air.	D > 1.29 Will: Stay close to the ground	D < 1.29 Will: Rise and mix in air more easily	5.4 at 20°C (air = 1)	It is heavier than air so will accumulate in low lying areas and be a hazard to recovery workers. Not likely to be dispersed over a wide area.
Density of liquid (D Liquid)	The density (specific gravity) of a liquid is determined by comparing the weight of an equal amount of water. (Water = 1.0). If the specific gravity is less than 1.0 then it will float, if greater than 1.0 it will sink. This is likely to be an important factor following release to water where the use of certain recovery options (e.g. use of adsorbent booms/mats) could be considered for chemicals that float on water.	D > 1 Will: Sink in water	D < 1 Will: Form a surface film on water	1.27	It has a specific gravity greater than 1 so would sink in water

<table>
<tr><th colspan="6">Table 10.10 (Recreated from Table 6.5) Important physicochemical properties Sulphur Mustard</th></tr>
<tr><th rowspan="2">Physical characteristic</th><th rowspan="2">Description</th><th rowspan="2" colspan="2">Interpretation</th><th colspan="2">Sulphur Mustard</th></tr>
<tr><th>Description/ value</th><th>Interpretation</th></tr>
<tr><td>Persistence</td><td>The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.</td><td colspan="2">Short persistence: Hours to days
Moderate Persistence: Weeks to months
Long Persistence: Months to Years</td><td>1-2 days half life in soil under normal temperature, months in cold temperatures.</td><td>Moderate persistence. May remain in environment for months (dependent on temperature)</td></tr>
<tr><td>Absorb to porous surfaces</td><td>The ability of a substance to absorb to porous surfaces (e.g. concrete) is an important consideration as this may influence the effectiveness of decontamination options. In some cases (e.g. Sulphur mustard) options such as surface removal may be more appropriate</td><td>Absorbs
Likely to be effectively removed via:
Surface removal
Disposal and dismantling</td><td>Does not absorb
Likely to be :
Easier to decontaminate</td><td>Absorbs</td><td>May be more difficult to decontaminate from porous surfaces. Need to consider surface removal or disposal and dismantling</td></tr>
<tr><td>Surface Tension</td><td>Chemicals with a low surface tension are more likely to seep into relatively inaccessible surfaces (e.g. between screws/ bolts) which has implications for the remediation of these surfaces. Those with a higher surface tension are more likely to accumulate on a surface without penetrating inaccessible areas.
Examples, units: dynes /cm
Ethanol: 22.3 (low)
Water: 75.6
Mercury: 465 (high)</td><td>High
Likely to:
Accumulate on surface</td><td>Low
Likely to:
Contaminate inaccessible surfaces</td><td>42.0 dynes /cm at 25 degrees C</td><td>Low surface tension indicates has potential to contaminate inaccessible surfaces.</td></tr>
<tr><td>Water solubility</td><td>The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread by flowing water. Water based decontamination of surfaces may be more effective if a chemical is water soluble; removal options or active decontamination may be more appropriate for non-water-soluble chemicals
Interpretation: Units ppm (mg/l)
<10: Negligible solubility
Between 10 and 1000: Increasing likelihood of solubilising
>1000: Likely to solubilise</td><td>High Solubility
Likely to be:
Mobile
Decontaminated by water-based solutions
Unlikely to be:
Volatilised
Persistent</td><td>Low solubility
Likely to be:
Immobilised by adsorption
Persistent
Unlikely to be:
Mobile</td><td>0.684 mg/l</td><td>Very low solubility. Would be difficult to decontaminate surfaces using water alone. Not likely to disperse significantly in water environments.</td></tr>
</table>

Table 10.10 (Recreated from Table 6.5) Important physicochemical properties Sulphur Mustard

Physical characteristic	Description	Interpretation		Sulphur Mustard	
				Description/ value	Interpretation
Soil sorption	Measures how readily a chemical is adsorbed to organic surfaces in the soil matrix. Some soils have very limited abilities to sorb chemicals e.g. sandy soils or ones with low clay or organic matter contents. Gives an indication of likely persistence in soil. Interpretation (Units = K_{OC}) > 10,000: Likely to adsorb Between 1,000 and 10,000: Increasing likelihood of adsorbing < 1,000: Unlikely to adsorb	High K_{OC} Likely to be: Adsorbed Accumulated Unlikely to be Mobile	Low K_{OC} Likely to be: Mobile Unlikely to be Adsorbed	120 (SRC)-Estimated	Expected to have high mobility in soil, unlikely to adsorb
Partition coefficient between water and octanol (K_{OW})	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = K_{OW}) > 1,000: Likely to bioaccumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bioaccumulating < 5,00: Unlikely to bioaccumulate (hydrophilic)- Low	High K_{OW} Likely to be Bio-accumulated: Sorbed in soil or sediments Unlikely to be: Mobile	Low K_{OW} Likely to be: Mobile Soluble Biodegraded Unlikely to be: Bio-accumulated	257	Low K_{OW} (hydrophillic) Unlikely to be bio-accumulated.
Viscosity	The viscosity of a chemical determines how easily it flows within an environment. It may influence how easy it is to decontaminate from an environment (e.g. it would be difficult to vacuum a highly viscous chemical). Viscous chemicals are also less likely to resuspend in the environment. Examples: Units = mPa. Water: 0.894 (low) Corn syrup: 81 (high)	High: Likely to be: Difficult to decontaminate Unlikely to be: Vaccumed Resuspended Mobile	Low: Likely to be: Mobile Easier to decontaminate	3.95 at 20 degrees centigrade	Highly Viscous, more difficult to remove from environment
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.			Can be degraded via hydrolysis to thiodiglycol (also toxic)	Need to consider monitoring and remediation of degradation products when water present

Table 10.10 (Recreated from Table 6.5) Important physicochemical properties Sulphur Mustard

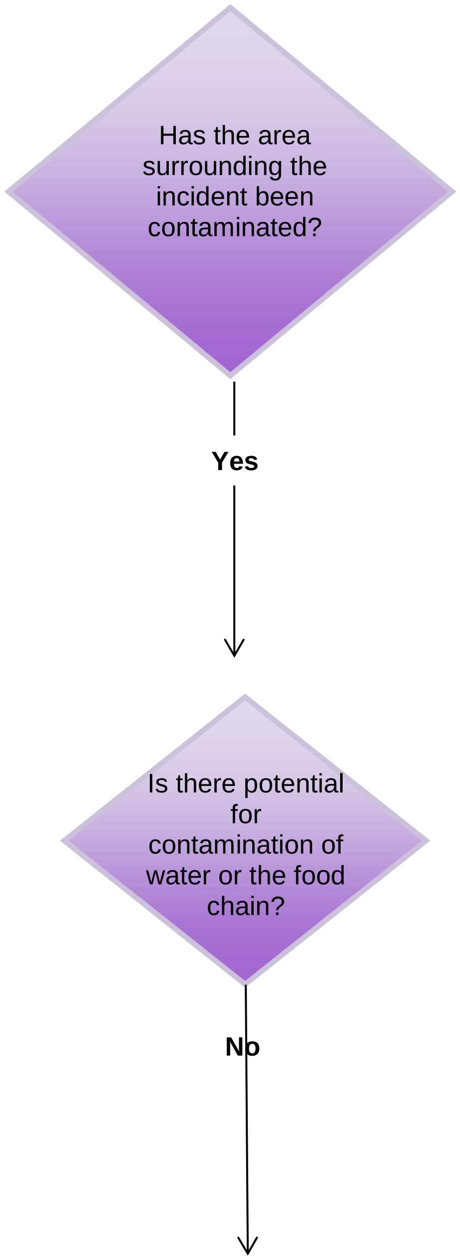
Physical characteristic	Description	Interpretation	Sulphur Mustard	
			Description/ value	Interpretation
Toxicity	Sum of adverse effects or the degree of danger posed by a substance to living organisms. It is expressed generally as a dose response relationship involving the quantity of substance to which the organism is exposed and the route of exposure skin (absorption), mouth (ingestion), or respiratory tract (inhalation).		Sulphur mustard is highly toxic. On skin contact it causes irritation and even burns. On inhalation it causes coughing, bronchitis and long term respiratory disease. Large amounts can cause death. It is a known mutagen and a carcinogen.	

Table 10.11: extract from Table 1.13 (Section 1) important human toxicity information for Sulphur Mustard

Chemical	Main target organ(s)	Acute toxicity risk	*Latency of acute toxicity symptoms	Risk of sequelae	Carcinogen risk	Reproductive toxicity risk
Sulphur mustard	Skin, eye, blood, respiratory	Moderate	<1hr - >24hr	Yes	Yes	Potential
*Latency (onset of symptoms): Short: <1 hour Moderate: >1 hour Long: > 24 hours						

10.2.2 Step 2: Consult flow chart and decision trees for Inhabited areas

Figure 10.12: Applicable sections of Inhabited areas decision tree



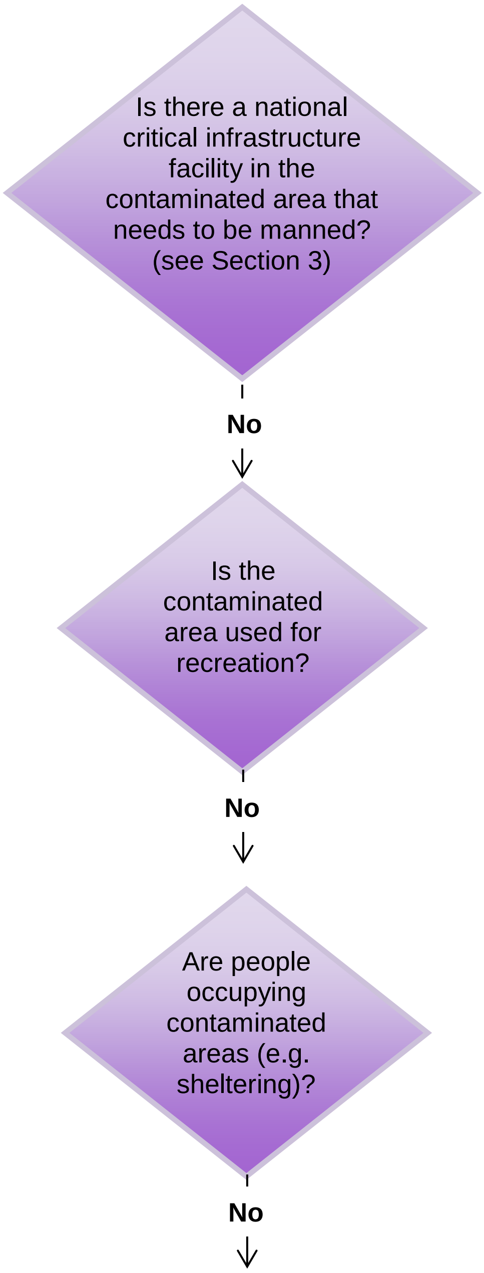
Scope the nature of contamination in the inhabited area. Refer to Section 1.11 for guidance.

Step 1 has identified that sulphur mustard is toxic and gives rise to inhalational and skin contact hazards.

Monitoring: Street dust, road gulley sediment soil and vegetation (leaves of shrubs) samples are taken to the laboratory for analysis via GCMS. Also, chemical detection equipment e.g. CAM (Chemical Agent Monitor), /detector paper /Raid M confirms contamination at the scene. Due to the toxicity of sulphur mustard detection of even low quantities in likely to be an issue.

This would be informed by the STAC who would undertake an assessment of the environmental behaviour of the chemical.

There is no immediate risk of water or food chain being contaminated as sulphur mustard is relatively water insoluble and does not bioaccumulate. Care would need to be taken that waste waters from any clean-up procedures are disposed of accordingly. If not the water part of the handbook would need to be consulted.



The affected area is a small section of a commercial district with shops and offices. (recovery option 2 prohibit public access) has already been initiated in the response phase, none are critical facilities.

With no critical facility in the area, there is no need to consider allowing some worker access (option 3 restrict workforce time access)

Similarly, the area is not used for recreational purposes

People are not occupying the immediate area as evacuation has taken place and it is not a residential area

Evacuation should be maintained ((2) Restrict public access) until monitoring and/or remediation has taken place

This needs to be balanced against the pressure to return people to the area as soon as possible. The area is not residential so the disadvantages of a prolonged evacuation won't be as pronounced but there may be commercial pressures e.g. (loss of business)

Does the chemical have a short persistency?

Sulphur mustard is persistent in the environment for several days but can be longer (e.g. months) in cold conditions

No

Is there evidence (e.g. visible) of hot spots of chemical contamination?

The important exposure pathways are through inhalation of vapour or skin contact with liquid. Option (13) Fixative / strippable coatings could be considered in the short-term. Temporary fixing materials can be applied to prevent further spread of contamination in the environment. They can also help to protect recovery workers present in the area.

Yes

Consider isolating contamination: e.g. building sealed temporary walls in indoor environment, covering with plastic sheeting
Consider recovery options that could reduce spread and potential exposure to contamination:
(7) Reactive liquids (bleaches/detergents, foams, gels)
(8) Physical decontamination techniques
(13) Fixable/strippable, coatings

Depending on the physicochemical properties of Sulphur mustard, reactive gases and physical decontamination techniques can be used to remediate.

Consider turning off HVAC systems (if indoors)
See: (15) Modify operation/ cleaning of ventilation systems
Carry out monitoring to fully characterise the contamination.
Perform a risk assessment to assess the potential exposure based on monitoring data and/or modelling (See Section 1.12)

Results of monitoring and/or modelling would now need to be considered

The important exposure pathways are through inhalation of vapour or skin contact with liquid.

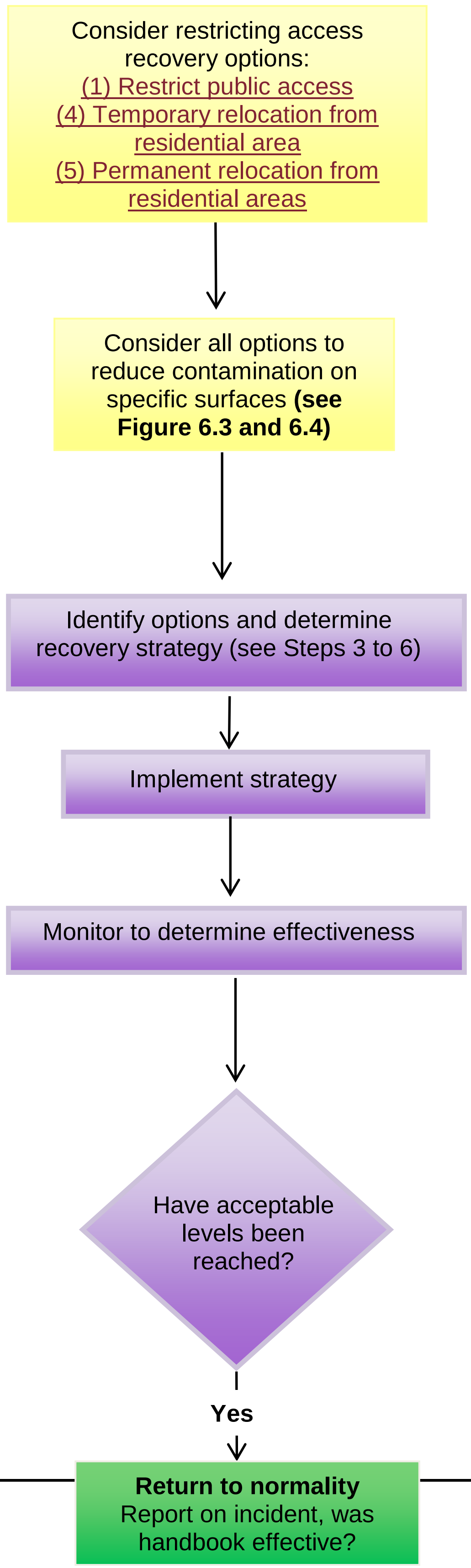
At this stage a risk assessment would need to take place (outside scope of handbook) to judge risk to people potentially inhabiting the area.

Is there a risk of adverse health effects to the population in the area?

As a residential area is not contaminated it is likely that only

Yes

maintaining the prohibition on public access) will be maintained



Given the nature of the affected area and the toxicity of sulphur mustard it is probable that potential exposure is the determining factor for reducing contamination levels. Therefore, all recovery options for appropriate surfaces should be considered.

Refer to Figure 6.3 the decision tree in Section 6 to identify applicable options. For the purposes of this example it is assumed that only external building surfaces are considered giving the remaining options listed in Table 10. 12

The recovery strategy can be further refined by eliminating potential options at steps 3 to 6 of the decision process (see sections below)

Once recovery options have been implemented, further monitoring would be required to determine the effectiveness of implemented options. Have cleanup targets been met?

If acceptable levels have been reached (as determined by a risk assessment) the area can return to normality

The relevant selection of recovery options is reproduced from Section 6 in Table 10.12. Subsequent steps will endeavour to eliminate options which are not applicable to this scenario.

Table 10.12: Potentially applicable recovery options identified at Step 2 (external building surfaces)

Protection options	Retain?	Rationale
(2) Controlled work force access	Yes	
(3) Impost restrictions on transport	Yes	
Remediation options	**Retain?**	**Rationale**
(7) Reactive liquids (bleaches, detergents, foams and gels)	Yes	
(8) Physical decontamination techniques	Yes	
(9) Other water-based cleaning methods	Yes	
(10) Pressure hosing	Yes	
(11) Vacuum cleaning	Yes	
(12) Surface removal (buildings)	Yes	
(13) Fixative/strippable coatings	Yes	
(14) Dismantle and disposal of contaminated material	Yes	
(19) Natural attenuation (with monitoring)	Yes	
(21) Snow/ice removal	No	No snow/ice with scenario

10.2.3 Step 3: Determine applicability of recovery options

A: Elimination of recovery options based on physicochemical properties

Table 10.13: Potentially applicable recovery options identified at Step 3 (physicochemical properties)

Protection options	**Retain?**	**Rationale**
(2) Controlled work force access	Yes	The sulphur mustard present within the environment poses a public health risk so this option should be retained
(3) Impose restrictions on transport	Yes	The sulphur mustard present within the environment poses a public health risk so this option should be retained
Remediation options	**Retain?**	**Rationale**
(6) Reactive gases and vapours	Yes	
(7) Reactive liquids (bleaches, detergents, foams and gels)	Yes	
(8) Physical decontamination techniques	Yes	
(9) Other water-based cleaning methods	No	Sulphur Mustard is water insoluble so unlikely to be effective
(10) Pressure hosing	No	Sulphur Mustard is water insoluble so unlikely to be effective
(11) Vacuum cleaning	No	Sulphur Mustard too viscous for removal by vacuuming
(12) Surface removal (buildings)	Yes	
(13) Fixative/strippable coatings	Yes	
(14) Dismantle and disposal of contaminated material	Yes	
(18) Natural attenuation (with monitoring)	No	Unlikely to be acceptable because sulphur mustard is too persistent and there will be pressure to clean-up area

This step has eliminated 4 options, with 9 remaining. Two are protection options and cannot be eliminated further at this step. The remaining options can be eliminated based on the surface material being considered.

B: Elimination of options based on surface material and physicochemical properties

Table 6.6 (Section 6) should now be consulted to determine the applicability/efficacy of the remaining recovery options dependent on the type of contamination (free vs. fixed) and the type of surface (inaccessible, robust or sensitive).

The implementation of “protection” recovery options is not influenced by the surface material, or type of contamination, so cannot be eliminated at this stage.

Table 6.6 is reproduced below as Table 10.14 for the remaining recovery options

Table 10.14: Recovery option efficacy for type of contamination and surface material/type

Recovery Option	Efficacy for type of contamination and surface material				
	Surface Type		Contamination type		
	Robust	Sensitive	Free	Absorbed	Inaccessible
(6) Reactive gases and vapours					
(7) Reactive liquids (bleaches, detergents, foams, gels) (new option)					
(8) Physical decontamination techniques					
(12) Surface removal (buildings)					
(13) Fixative/ strippable coatings					
(14) Dismantle and disposal of contaminated material					
Effectiveness	**Up to 100% effective**	**Potentially effective**	**Limited effectiveness**		

From Table 10.14 above it can be seen that specific recovery options could now be eliminated dependent on the surface involved or type of contamination.

If sulphur mustard had absorbed into a porous surface such as brick, option (8) Physical decontamination techniques could be eliminated.

If sulphur mustard had penetrated an inaccessible surface (e.g. underneath a bolt) options (8) Physical decontamination techniques and (12) Surface removal (buildings) could be eliminated.

If sulphur mustard was present on a sensitive surface such as glass, option (12) surface removal can be eliminated.

For the purposes of this example, all options are retained as there will be a mixture of surfaces contaminated. Remember that the 2 protection potions are still retained.

10.2.4 Step 4: Review key considerations and constraints

Table 6.7 and Table 6.8 should now be consulted in Section 6 to identify the key considerations of the remaining recovery options. These tables are reproduced below showing the recovery options remaining for this example scenario, in Table 10.15 and Table 10.16.

The key considerations identified **do not** indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis.

Table 10.15: Key considerations for remaining recovery options

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
Remediation options		
(6) Reactive gases and vapours	**Social -** There is a potential that the reactive chemicals used could damage the surface of buildings. Disruptions may also encourage residents to access their properties. **Cost -** Financial costs can potentially be high but depends on a number of factors such as; the gas/vapour used, the number of workers required, the size of the building and if scaffolding or repainting will be required.	**Technical -** Surfaces may need to be repeatedly treated to ensure the contaminant is effectively removed. Sampling and monitoring is required to confirm removal. **Time -** This recovery option needs to be implemented soon after a chemical incident as weathering processes may disperse the contaminant from the surface of the affected area into the environment.
(7) Reactive liquids (bleaches, detergents, foams, gels)	None	**Waste –** Depends on which decontamination liquid used; waste products in various forms can be generated which may require disposal and/ or storage under a waste transfer licence. **Social -** Disruptions may encourage residents to access their properties during the remediation process. **Technical -** Surfaces may need to be repeatedly treated to ensure the contaminant has effectively been removed. Sampling and monitoring is required to confirm this. **Cost -** Variable, depending on the type and amount of reactive liquid used, size of the building and amount of waste generated that will require appropriate disposal. **Time -** This recovery option needs to be implemented soon after a chemical incident as weathering processes may disperse the contaminant from the surface of the affected area into the environment.
(8) Physical decontamination techniques	**Waste -** Depending on which techniques are used; waste products in various forms will be generated. The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and Northern Ireland Environment Agency (NIEA) should be consulted on possible disposal routes (i.e. incineration and landfill).	**Technical -** The decontamination technique used depends on the nature of contaminated surface. For example, the type of surface, its evenness and the condition it is in. An effective monitoring programme needs to be implemented to determine when the contaminant has been removed. **Time -** Weathering will reduce contamination, rapid implementation of this option will improve the effectiveness.

Recovery Options	**Major (key) considerations** for selected recovery options	**Moderate considerations** for selected recovery options
(12) Surface removal (buildings)		**Waste -** This option is likely to produce significant quantities of contaminated surface material. The solid phase may be disposed of at a hazardous waste landfill, but this can be influenced by the chemicals involved. **Technical -** Effectiveness depends on the surface in question e.g. ease of removal, thickness of the surfaces and the scale. It also depends on the nature of the chemical involved e.g. persistence and how easily it could become dispersed. **Public health** – Certain destructive techniques such as sandblasting may produce chemically contaminated dust that could result in a public health risk if not contained appropriately.
(13) Fixative/ strippable coatings	**Waste -** Strippable coatings when removed are likely to be highly contaminated and will therefore require disposal and/or storage under a waste transfer licence. **Cost:** Likely to be high. Peel-able strippable coatings are highly labour intensive and likely to require significant resources which will vary depending on factors such as the level of contamination, type of coating used and size of the contaminated building. **Time -** The maximum benefit is achieved if this option is carried out soon after an incident when the maximum contamination is still on the surface, before it can be dispersed into the environment.	**Social -** Residents of the contaminated area may be sceptical of the contamination remaining in-situ, fears are likely to arise concerning potential future exposure. **Technical -** The effectiveness of this option depends on the nature of the chemical involved (i.e. its absorbent properties and if it is likely to migrate through the coating) Effectiveness also depends on the type, evenness and condition of the surface the coating is applied on. The size of the area in question can also influence effectiveness, fixative coatings can be applied over a large area, but strippable coating is more suitable for smaller areas.
(14) Dismantle and disposal of contaminated material	**Social -** Entering homes to remove contaminated objects can be disruptive to residents. Compliance issues can arise if personal items such as clothes or home appliances are being removed and are not covered by compensation packages. Dust emissions from building demolition could be a nuisance to the public. **Waste -** This option is likely to generate large amounts of contaminated material which will require disposal and/or storage under a waste transfer licence. **Cost-** Likely to be high. Dismantling is a highly labour-intensive process. Additionally, the large amount of waste generated will be costly to dispose of appropriately.	**Public health -** Building demolition results in dust and particulate matter emissions. This dust can be potentially toxic and pose a health risk to people in the surrounding area. Dust will therefore need to be monitored and controlled effectively. **Time:** The maximum benefit is achieved if this option is carried out soon after an incident when the maximum contamination is still on the contaminated material before it can be dispersed into the environment.

Table 10.16: Summary of recovery option considerations

Recovery Options Considerations	Public Health	Waste	Social	Technical	Cost	Time
Remediation options						
(6) Reactive gases and vapours						
(7) Reactive liquids						
(8) Physical decontamination techniques						
(12) Surface removal (buildings)						
(13) Fixative/ strippable coatings						
(14) Dismantle and disposal of contaminated material						
Considerations	**None or minor**		**Moderate**		**Important (key)**	
Time – when to implement recovery option	**No restrictions on time**		**Weeks to months/ years**		**Hours – days**	

10.2.5 Step 5: Consult recovery option sheets

From following the decision process, the following options remain (see Table 10.17).

Table 10.17: Remaining recovery options identified at Step 5

Protection options	Retain?	Rationale
(1) Restrict public access	Yes	Key considerations are time and social
(3) Impose restrictions on transport	Yes	Key considerations are social and technical
Remediation options	**Retain?**	**Rationale**
(6) Reactive gases and vapours	Yes	Key considerations are; time, moderate considerations are social and technical.
(7) Reactive liquids (bleaches, detergents, foams and gels)	Yes	Key considerations are; time, moderate considerations are waste and technical.
(8) Physical decontamination techniques	Yes	Not applicable to absorbed contamination or inaccessible surfaces. Key considerations are waste.
(12) Surface removal (buildings)	Yes	Not applicable for inaccessible surfaces or sensitive surfaces. Key considerations are waste and technical.
(13) Fixative/strippable coatings	Yes	Key constraints are; technical, moderate considerations are; waste, social and time.
(14) Dismantle and disposal of contaminated material	Yes	Key constraints are public health; moderate considerations are waste, social and cost.

Recovery option sheets could now be consulted (see Section 7) to eliminate further options based on further constraints identified.

To aid with the selection of a recovery strategy, Table 6.9 in Section 6 could be used to compare remaining recovery options.

Implement, monitor and evaluate

Once the recovery strategy has been selected it should be implemented, monitored for effectiveness and evaluated (see Section 6).

10.3 Water environments: Lead incident

This section should be read in conjunction with Section 8: Constructing a recovery strategy for water environments. For the purpose of this example only potentially affected drinking water supplies are considered in the decision process.

Scenario

- Small scale incident following a continual spell of heavy rainfall
- Resulted in flooding of mine shaft containing lead
- Detection of significant concentrations of lead within a private water source supplying a small village

Current situation

- The population has been advised to drink bottled water
- There is local pressure to investigate the lead contamination and remove it from the system

10.3.1 Step 1: Obtain relevant information regarding the incident

Apart from the information given above in the scenario it would be important to determine the toxicity and physicochemical properties of lead. The relevant physicochemical properties and toxicological properties for lead are produced below (Table 10.18). Following a chemical incident expert advice (e.g. PHE) would need to be consulted to determine the relevant data for the chemical of concern.

Table 10.18 (Recreated from Table 8.5, Section 8): Important physicochemical properties: Lead					
Physical characteristic	**Description**	**Interpretation**		**Lead**	
				Description/ value	**Interpretation**
Physical form (solid/liquid gas)	**Gases** and vapours spread out in the environment until they are equally distributed throughout the space available to them. **Liquids** will flow with gravity when released and must therefore require containment safely to stabilise the incident and prevent further risk to persons, property and the environment. **Solids** need further assistance to move greater distances and in general are easier to contain. However, solids in the form of fibres, dusts or smoke can be quickly carried by the air and present a risk to anyone situated in the path of dispersion			Solid	
Vapour pressure (VP)	A measure of how easily a liquid evaporates or gives off vapours. For instance, where the vapours being given off by a liquid pose a hazard (e.g. Sulphur Mustard) fixative / strippable coating options may be considered. Higher volatility would result in a higher vapour pressure. Interpretation (Units = Pascals) $< 1.3 \times 10^{-4}$: Unlikely to volatilise Between 1.3×10^{-4} and 1.33: Increasing likelihood of volatilising >1.3: likely to volatilise	**High VP** Likely to: Be an inhalational risk Evaporate quickly	**Low VP** Unlikely to be: An inhalational risk	N/A (at room temperature)	Volatilisation not important unless heated
Vapour Density (D vapour)	This refers to the relative weight of a gas or vapour compared to air (or sometimes it can be compared to hydrogen gas). Air is assigned an arbitrary value of 1 and if a gas has a vapour density of <1.29 it will generally rise in air. If the vapour density is >1.29 the gas will generally sink in air. All vapours tend to be heavier than air.	**D > 1.29** Will: Stay close to the ground	**D < 1.29** Will: Rise and mix in air more easily	N/A	
Density of liquid (D Liquid)	The density (specific gravity) of a liquid is determined by comparing the weight of an equal amount of water. (Water = 1.0). If the specific gravity is less than 1.0 then it will float, if greater than 1.0 it will sink. This is likely to be an important factor following release to water where the use of certain recovery options (e.g. use of adsorbent booms/mats) could be considered for chemicals that float on water.	**D > 1** Will: Sink in water	**D < 1** Will: Form a surface film on water	11.35	Specific gravity greater than 1 so would sink in water

Table 10.18 (Recreated from Table 8.5, Section 8): Important physicochemical properties: Lead

Physical characteristic	Description	Interpretation		Lead	
				Description/ value	Interpretation
Persistence	The time that the released chemical is physically present following release and is related to physicochemical properties and is affected by environmental conditions such as humidity and temperature. This is an important factor to consider when judging when recovery options can be implemented following an incident.	**Short persistence**: Hours to days **Moderate Persistence:** Weeks to months **Long Persistence:** Months to Years		Long persistence	Lead can persist in the environment for a long time as it is a stable solid metal.
Absorb to porous surfaces	The ability of a substance to absorb to porous surfaces (e.g. concrete) is an important consideration as this may influence the effectiveness of decontamination options. In some cases (e.g. Sulphur mustard) options such as surface removal may be more appropriate	**Absorbs** Likely to be effectively removed via: Surface removal Disposal and dismantling	**Does not absorb** Likely to be: Easier to decontaminate	N/A	
Surface Tension	Chemicals with a low surface tension are more likely to seep into relatively inaccessible surfaces (e.g. between screws/ bolts) which has implications for the remediation of these surfaces. Those with a higher surface tension are more likely to accumulate on a surface without penetrating inaccessible areas. Examples, units: dynes /cm Ethanol: 22.3 (low) Water: 75.6 Mercury: 465 (high)	**High** Likely to: Accumulate on surface	**Low** Likely to: Contaminate inaccessible surfaces	N/A	
Water solubility	The ability of a material (gas, liquid or solid) to dissolve in water. Materials can be insoluble, sparingly soluble or soluble. Water soluble materials (such as acids) may be more easily dispersed in water and have a greater potential to pollute water environments (e.g. groundwater). Many water insoluble materials (e.g. petrol) may be spread by flowing water. Water based decontamination of surfaces may be more effective if a chemical is water soluble; removal options or active decontamination may be more appropriate for non-water-soluble chemicals Interpretation: Units ppm (mg/l) <10: Negligible solubility Between 10 and 1000: Increasing likelihood of solubilising >1000: Likely to solubilise	**High Solubility** Likely to be: Mobile Decontaminated by water-based solutions Unlikely to be: Volatilised Persistent	**Low solubility** Likely to be: Immobilised by adsorption Persistent Unlikely to be: Mobile	**Low solubility** Insoluble in water	Does not disperse in water environments

Table 10.18 (Recreated from Table 8.5, Section 8): Important physicochemical properties: Lead

Physical characteristic	Description	Interpretation		Lead	
				Description/ value	Interpretation
Soil sorption	Measures how readily a chemical is adsorbed to organic surfaces in the soil matrix. Some soils have very limited abilities to sorb chemicals e.g. sandy soils or ones with low clay or organic matter contents. Gives an indication of likely persistence in soil. Interpretation (Units = K_{OC}) > 10,000: Likely to adsorb Between 1,000 and 10,000: Increasing likelihood of adsorbing < 1,000: Unlikely to adsorb	**High K_{OC}** Likely to be: Adsorbed Accumulated Unlikely to be Mobile	**Low K_{OC}** Likely to be: Mobile Unlikely to be Adsorbed		Lead adsorption to soil is heavily dependent on the pH of the soil in question
Partition coefficient between water and octanol (**K_{OW}**)	This gives an indication of relative solubility of a material (compound) in water and in octanol. Chemicals that preferentially dissolve in octanol are defined as hydrophobic and have a high partition coefficient. A high value also gives an indication of potential to sorb to soil and sediments. Interpretation (Units = K_{OW}) > 1,000: Likely to bioaccumulate (hydrophobic)- High Between 500 and 1,000: Increasing likelihood of bioaccumulating < 5,00: Unlikely to bioaccumulate (hydrophilic)- Low	**High K_{OW}** Likely to be Bio-accumulated: Sorbed in soil or sediments Unlikely to be: Mobile	**Low K_{OW}** Likely to be: Mobile Soluble Biodegraded Unlikely to be: Bio-accumulated	N/A	
Viscosity	The viscosity of a chemical determines how easily it flows within an environment. It may influence how easy it is to decontaminate from an environment (e.g. it would be difficult to vacuum a highly viscous chemical). Viscous chemicals are also less likely to resuspend in the environment. Examples: Units = mPa. Water: 0.894 (low) Corn syrup: 81 (high)	**High:** Likely to be: Difficult to decontaminate Unlikely to be: Vaccumed Resuspended Mobile	**Low:** Likely to be: Mobile Easier to decontaminate	N/A	
Henry's Law Constant	Describes the partitioning of a compound between a solution and the air above it. Tendency for chemicals to move from the aqueous phase to the gaseous phase.			N/A	

Table 10.18 (Recreated from Table 8.5, Section 8): Important physicochemical properties: Lead

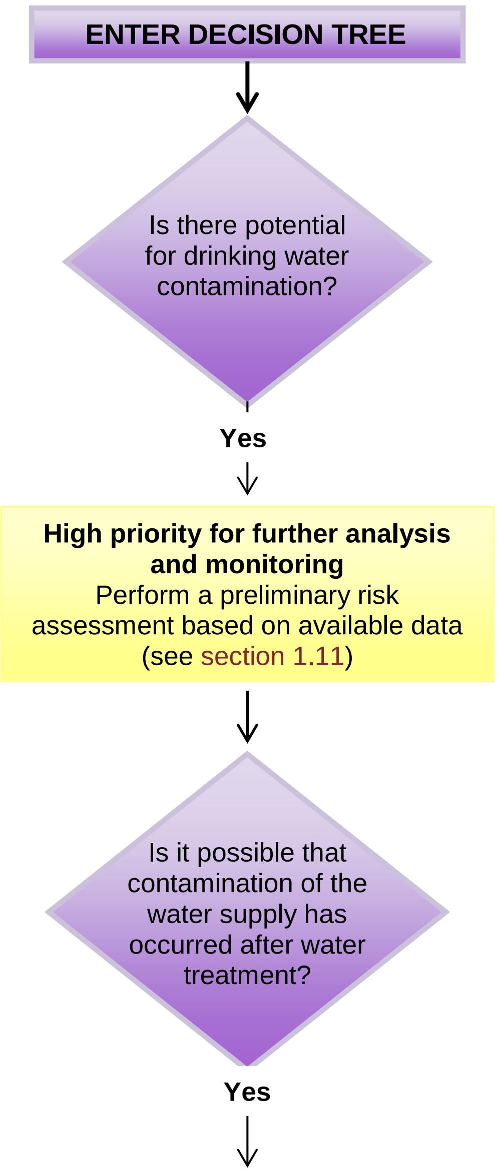
Physical characteristic	Description	Interpretation	Lead	
			Description/ value	Interpretation
Boiling point	Boiling point is the temperature at which a liquid's vapour pressure equals atmospheric pressure and the liquid starts to turn to vapour. Low boiling point substances tend to be either gases or very volatile liquids at ambient temperature		N/A	
Degradation and reaction by-products	Process by which chemicals decompose to their elemental parts or form by-products on reaction with other chemicals or water. Some chemicals can be converted to more toxic products during this process.			Lead does not decompose easily.

Table 10.19; Extract from Table 1.3 Section 1 Important human toxicity information for Lead

	Main target organ(s)	Acute toxicity risk	*Latency of acute toxicity symptoms	Risk of sequelae	Carcinogen risk	Reproductive toxicity risk
Lead	CNS, GI, Liver, Kidney	Moderate	>24yr (years)	Yes	Probable	Yes
*Latency (onset of symptoms): Short: <1 hour Moderate: >1 hour Long: > 24 hours						

10.3.2 Step 2: Consult decision tree/diagram for Water Environments

Figure 10.20: Applicable sections of Water environments decision tree 1 for potentially contaminated drinking water supplies.



The chemical has most likely contaminated the private water supply. Whilst only a small number of properties will have been sampled close to the source it is likely that all the properties will be affected over time.

These are private water supplies to residential properties. Therefore the water has not been through a water company treatment process; however some properties may have installed water treatment equipment to treat the water prior to consumption.

IMMEDIATE ACTION MAY BE REQUIRED
Consider:
(1) Isolate and contain water supply
(2) Alternative drinking water supply
(3) Restrict water use (DND/DNU notices)
(4) Changes to water abstraction point or location of water source
(5) Controlled blending of drinking water supplies
(12) Flush distribution system

As contamination is suspected in the distributed water supply post treatment or private supply, ingestion doses may already have been received by some people. Therefore immediate action prior to any further investigation is warranted, the highlighted options can be considered.

Go to **PART 2** of the decision diagram.

From Part 1

Is monitoring data available for drinking water supplied at 'at the tap')

Monitoring data. The estimates made can be used to identify whether levels of lead contamination in water used for drinking water supplies are likely to exceed private drinking water standards.

Assume that early estimates of concentrations in the drinking water from private supplies are very likely to have exceeded private drinking water supply standards.

Yes

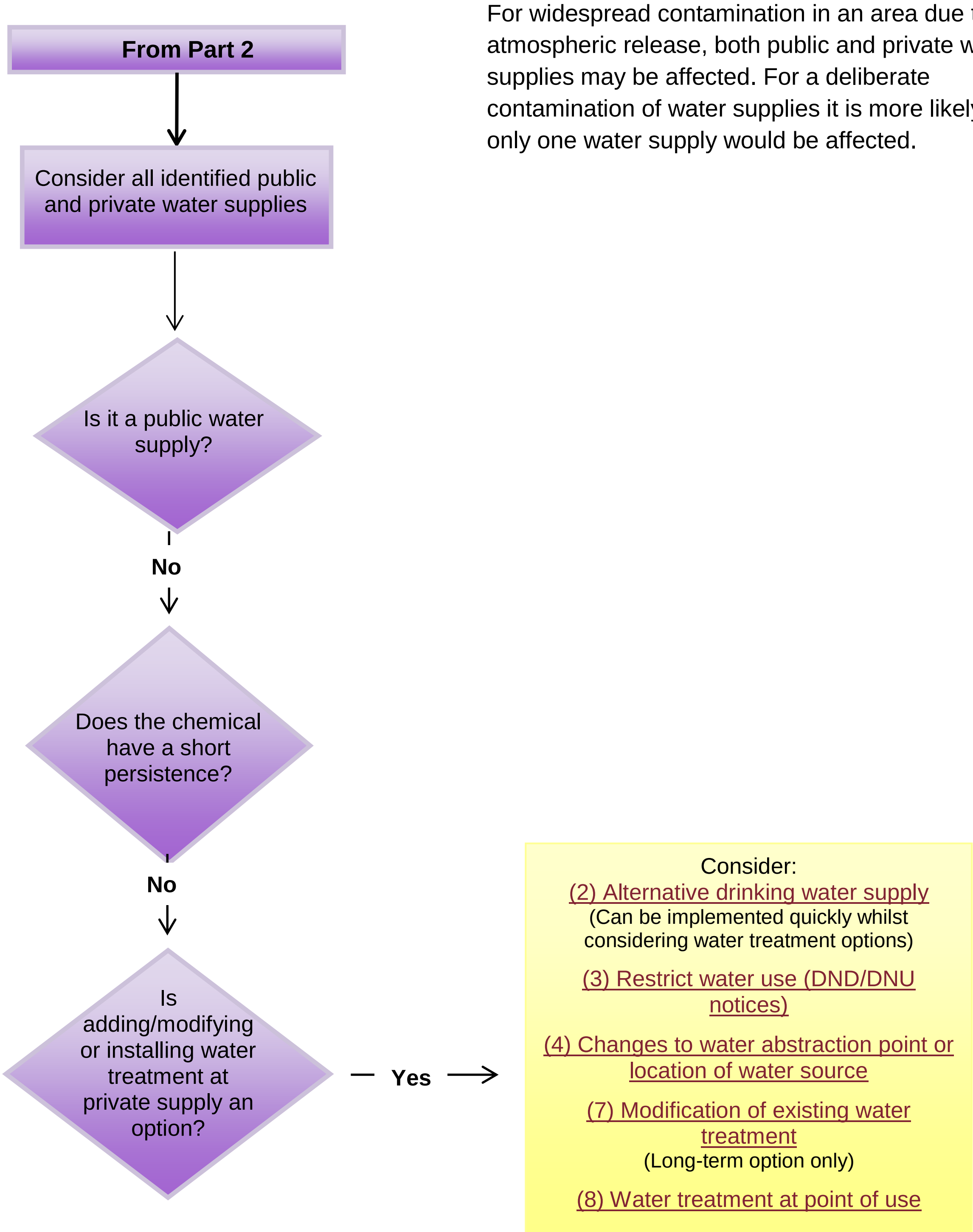
Do monitoring results in treated drinking water/water supplied 'at the tap' indicate there is a potential health risk to consumers?

At this stage, the chemical contamination is assumed to be a potential health risk, and therefore recovery options that prevent the intake of unsafe water must be implemented.

Yes

Go to **PART 3** of the decision diagram.

For widespread contamination in an area due to an atmospheric release, both public and private water supplies may be affected. For a deliberate contamination of water supplies it is more likely that only one water supply would be affected.



The relevant selection of recovery options is reproduced from Section 8 in Table 10.21, which lists options for different water environments. Subsequent steps will endeavour to eliminate options which are not applicable to this scenario.

Table 10.21: Potentially applicable recovery options identified at Step 2

Recovery options	Retain?	Rationale
(1) Isolate and contain water supply	Yes	
(2) Alternative drinking water supply	Yes	
(3) Restrict water use (DND/DNU)	Yes	
(4) Changes to water abstraction point or location of water source	Yes	
(5) Controlled blending of drinking water supplies	No	There is no alternative water source to blend water supplies
(6) Continue normal water treatment	Yes	
(7) Modification of existing water treatment (long-term option)	Yes	
(8) Water treatment at point of use (tap)	Yes	
(12) Flush out water distribution system	Yes	
(13) Natural attenuation (with monitoring)	Yes	

There are 10 potentially applicable recovery options.

10.3.3 Step 3: Review effectiveness of recovery options

A: Elimination of recovery options based on physicochemical properties

Table 10.22: Relevant recovery options (based on physicochemical properties)

Recovery options	Retain?	Rationale
(1) Isolate and contain water supply	Yes	There are health risks associated with drinking a lead contaminated water supply, therefore the water supply must be isolated and contained.
(2) Alternative drinking water supply	Yes	Alternative water must be supplied whilst investigations are being carried out.
(3) Restrict water use (DND/DNU notices)	Yes	There are health risks associated with drinking a lead contaminated water supply therefore water use must be restricted.
(4) Changes to water abstraction point or location of water source	Yes	
(6) Continue normal water treatment	Yes	
(7) Modification of existing water treatment (long-term option)	Yes	
(8) Water treatment at point of use (tap)	Yes	
(12) Flush out water distribution system	Yes	
(13) Natural attenuation (with monitoring)	No	Lead is persistent in the environment; therefore natural attenuation is unlikely to be an appropriate option

B: Eliminate recovery options based on effectiveness

Table 10.23: Eliminate recovery options based on effectiveness

Recovery Option	Effectiveness				
	Drinking water		Other Water Environments		
	Public	Private	Sewage Treatment	Inland and underground waters	Marine and coastal water
(1) Isolate and contain drinking water supply			NA	NA	NA
(2) Alternative drinking water supply			NA	NA	NA
(3) Restrict water use (DND/DNU notices)			NA	NA	NA
(4) Changes to water abstraction point or location of source			NA	NA	NA
(6) Continuing normal water treatment				NA	NA
(7) Modification of existing water treatment				NA	NA
(8) Water treatment at the point of use [tap]			NA	NA	NA
(12) Flush out water distribution system			NA	NA	NA

Effectiveness	**Up to 100% effective**	**Potentially effective**	**Limited effectiveness**	**Not applicable(NA)**

This step has not eliminated any options. All remaining 8 options are retained.

10.3.4 Step 4: Review key considerations and constraints of remaining recovery options

It is inevitable that recovery options will have considerations associated with their implementation. Table 8.7 (Section 8) should now be consulted to determine the key (major) and moderate considerations associated with implementing the remaining recovery options. This table is reproduced below (Table 10.24) for the remaining recovery options applicable for this example scenario. A detailed description of these constraints and considerations is provided in the recovery option sheets (Section 9). If an important (key) consideration is identified it does not indicate that the recovery option should necessarily be eliminated, although this may be done on a site and incident specific basis (Step 5).

These tables are reproduced below showing the recovery options remaining for this example, in Tables 10.24 and 10.25.

Table 10.24: Key considerations for remaining recovery options

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(1) Isolate & contain drinking water supply	**Public Health -** An alternative drinking water supply would have to be available. **Time -** This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard.	**Social -** Disruption is likely to be upsetting to members of the public. People will also need information on where restrictions are in place, where alternative water distribution points are and how long the situation will last. **Technical -** The considerations associated with this option will vary depending on what other options are implemented with it. If the water supply is isolated but the area which is served by the supply is rezoned, impacts will be fairly minimal, however, if alternative temporary supplies are required (i.e. tankers/ bowsers) then the technical, social and cost aspects will be increased. **Waste -** There may be significant amounts of contaminated water, which may require disposal and/ or storage under a waste transfer licence. Environment Agency should be consulted. **Cost -** The costs associated with other options which would need to be implemented alongside this.
(2) Alternative drinking water supply	**Social -** People will not want to travel too far to water distribution points. Older people and people with disabilities will require assistance in getting water to their homes. Bulk buying at shops is likely to lead to shortages of bottled water supplies. **Technical -** Separate individual supplies would need to be provided for hospitals, schools, office buildings and any other large premises containing large numbers of people. If bowsers are used, there is a requirement to sample the water in them every 48 hours and analyse for a full suite of contaminants. This would involve a number of personnel and significant resources in the laboratory depending on the number of bowsers/ tanks required. **Cost -** May be high, considering; vehicle hire (tankers and bowsers); consumables (fuel, bottles or containers for transporting water) and personnel (i.e. travelling time for drivers, possibly unsociable hours). **Time -** This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard.	**Public Health -** Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bath in, but not safe to drink or cook with may be difficult i.e. compliance. **Waste -** Providing bottled water would produce bottle plastics waste.

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
(3) Restrict water use (DND/ DNU notices)	**Public Health -** This recovery option should only be implemented if alternative water is available/ provided. Although existing water supplies may be suitable for sanitation purposes, convincing people that water is safe to bath in, but not safe to drink or cook with may be difficult i.e. compliance. A clear communication plan is required to ensure the water advice reaches the customers it needs to in a timely manner. **Social -** Reluctance of affected population to comply with and adhere to the restriction being imposed. Additionally the social implications of providing an alternative water supply would also need to be considered for this option (see above). **Cost -** May be high considering options that will need to be implemented alongside this. I.e. for alternative water supplies the following cost factors would need to be considered: vehicle hire (tankers and bowsers); consumables (fuel, bottles or containers for transporting water) and personnel (i.e. travelling time for drivers, possibly unsociable hours).	**Technical -** Ensuring the affected population are aware that restrictions are in place and that an alternative supply is available. Shortages of alternative supplies could lead to people drinking contaminated water, and if the area affected involves large numbers of people, the supplies might not meet demand. The technical implications of providing an alternative water supply during restriction of water use also need to be considered (see above). **Time -** This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard. It should be noted that when providing alternative water supplies following the implementation of this option, mobilisation of tankers/bowsers and bottled water can take time depending on the location of stores and the affected area, and whether locations for bowsers/tanks/bottled water have been pre-agreed, or not. **Waste -** Providing bottled water would produce bottle plastics waste.
(4) Changes to water abstraction point or location of water source	**Time -** This option should be implemented as soon as a contamination problem is identified and will need to be in place for the duration of any drinking water restrictions or until the contamination is within the UK Water Quality Standard.	**Social -** There may be problems regarding the acceptability of any remaining contamination in water supplies; there may also be concerns over the availability of alternative supplies. Where rezoning is used, or an alternative raw water source, acceptability may be an issue as customers may not like or be used to the alternative supply (e.g. upland water versus lowland; hard groundwater versus soft water). **Technical -** Priorities also need to be decided depending on the vulnerability of water supplies to the chemical emergency. Surface water supplies, such as rivers and reservoirs are likely to be of higher priority than boreholes in the short-term and this should be taken into account when formulating a monitoring strategy and identifying drinking water supplies of potential concern. In the longer term, monitoring and the implementation of this option may need to focus more on ground water sources, such as boreholes. The effectiveness of this measure depends on a programme of testing new abstraction points. Testing apparatus must be accurate. Rezoning carries a risk of discolouration of supplies if not carried out carefully – this is caused by the disturbance of iron and manganese deposits in water mains caused by a change in flow.
(6) Continuing normal water treatment	**Technical -** Continuing normal water treatment may require enhanced surveillance to evaluate the effectiveness of this option.	**Public Health –** Continuing normal water treatment may give rise to increased exposure to water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment. **Social -** There may be problems regarding the acceptability of any remaining contamination in water supplies; this is also likely to be related to the availability of alternative supplies such as bottled water.

Recovery Options	Major (key) considerations for selected recovery options	Moderate considerations for selected recovery options
		Waste – Although the works might remove the contamination, contamination may be concentrated in certain processes or in waste streams/ sludges. Disposal of these wastes would also carry costs and may require disposal and/ or storage under a waste transfer licence..
(7) Modification of existing water treatment	**Technical -** Infrastructure needs to be in place to support the expansion of or changes to water treatment works if additional treatments are required (increased frequency of operations, 'new build', space requirements for new kit, etc). **Cost -** May be high, considering; infrastructure (adaption of current treatment plant or installation of a 'new build'); equipment; technology and personnel (builders, specialist engineers); timescale (could take months – years to install or build); disposal of contaminated water (availability of suitable disposal route). **Time –** it may take a long time (months – years) to implement this option.	**Public Health -** Changes to water treatment processes may give rise to increased exposure to water treatment operatives, either from direct exposure to contaminated water or through the accumulation and storage of contaminated waste from treatment. **Waste -** There may be significant amounts of contaminated water, which may require disposal and/ or storage under a waste transfer licence. **Social -** Public acceptability and trust in water treatment processes to remove or reduce chemical contamination. There are also issues around the acceptability of residual levels of contamination by the public and the availability of alternative supplies (i.e. bottled water). There is also an aspect of disruption if modifications to existing water treatment require construction (i.e. 'new build').
(8) Water treatment at the point of use [tap]	**Technical -** This practicality of this option will be influenced by the availability of and installation of appropriate equipment	**Social -** This option relies upon individuals purchasing units, or arranging installation, as well as using them in an appropriate manner (e.g. not removing parts/ bypassing, etc). **Technical -** Reverse osmosis units require specialist engineers to install them and maintain/service them – if these activities are not carried out frequently, there are water quality risks **Cost –** Depends on the size of the area affected, and may be high, considering; equipment (jug filters are relatively inexpensive (<£40) whereas reverse osmosis units are more expensive (>£300); installation and maintenance (specialist engineers) and consumables (additional filters or pumps, if needed). **Time -** This option may take some time to implement considering the components required.
(12) Flush distribution system	**Public Health -** An alternative drinking water supply (and appropriate water notifications) would have to be available while the system is being flushed. **Waste -** There may be significant amounts of contaminated water to be flushed through the water distribution system, which could potentially lead to the spread of low levels of contamination in the environment.	**Time -** This option could take some time to implement depending on the size of the distribution system.

Table 10.25: Summary of recovery option considerations

Recovery Options Considerations	Public Health	Waste	Social	Technical	Cost	Time
(1) Isolate and contain water supply						
(2) Alternative drinking water supply						
(3) Restrict water use (DND/DNU notices)						
(4) Changes to water abstraction point						
(6) Continuing normal water treatment						
(7) Modification of existing water treatment						
(8) Water treatment at the point of use [tap]						
(12) Flush distribution system						

Considerations	None or minor (Low)	Moderate (Medium)	Important (key)
Time (when to implement recovery option)	No restrictions on time	Weeks to months/ years	Hours – days

10.3.5 Step 5: Consult recovery option sheets

From the decision process, the following options remain.

Recovery options	Retain	Rationale
(1) Isolate and contain water supply	Yes	
(2) Alternative drinking water supply	Yes	Alternative water must be supplied whilst investigations are being carried out. Providing bottled water for a water bowser should be easily achievable. However, for private water supplies, this is not a responsibility of water companies.
(3) Restrict water use (DND/DNU notices)	Yes	Easily carried out as long as the communication strategy is effective. Will rely on public adherence to restrictions. Will protect against exposure to the chemical from other water usages other than drinking.
(4) Changes to water abstraction point or location of water source	Yes	Will depend if there are other non-contaminated water sources available in the area or whether connection to a mains supply is possible.
(6) Continuing normal water treatment	Yes	This recovery option has been retained in case detailed monitoring indicates that lead concentrations are declining. If lead concentrations reduce to below the private drinking water standards there may be public pressure to demonstrate that the water is safe to drink.
(7) Modification of existing water treatment (long-term option)	Yes	This would depend on whether any water treatment is being undertaken by the individual properties. Option requires specialist equipment that may not be available
(8) Water treatment at point of use [tap]	Yes	Ion exchange and reverse osmosis processes could be considered, as these are likely to be very effective in removing lead, although they would be costly
(12) Flush distribution system	Yes	

Recovery option sheets should now also be consulted (Section 9) to eliminate further options based on evaluation of considerations and constraints.

To aid with the selection of a recovery strategy, Table 8.9 (Section 8) could be used to compare remaining recovery options.

Implement, monitor and evaluate

Once the recovery strategy has been selected, it should be implemented, monitored for effectiveness and evaluated (see Section 8.2).

11 Case studies

The following case studies are provided as illustrative examples identifying key recovery information and terminology presented within the handbook. They may not all reflect major chemical incidents but each is a real incident and presents recovery principles which underpin the recovery options included within the handbook. The case studies are drawn from previous incidents that involve Food Production Systems, Inhabited Areas and Water Environments.

11.1 Case Study 1: Irish Dioxins Incident (Food Production Systems)

11.1.1 Incident overview

Animal feed contamination with dioxins and PCB's was thought to have initially occurred in August 2008 but was not identified by authorities until November 2008. As well as product withdrawal, a number of farms that had received feed from the affected supplier were restricted from supplying meat to the market. The scale and severity of the incident would ultimately lead to the global withdrawal and destruction of thousands of tonnes of meat products, together with the cull and disposal of thousands of pigs and cattle, all at a cost of several hundred million Euros.

11.1.2 Timeline

- August 2008 (approximate): Contamination of animal feed occurred due to using contaminated transformer oil as fuel within feed drying process.
- Mid November 2008: Concern raised in the Republic of Ireland due to high levels of PCB's found in a pig fat sample. Dioxins also detected in Netherlands via pork products made in France.
- December 2008: Authorities in Republic of Ireland initiated a withdrawal of all pork products.
- January 2009: Milk from 2 dairy herds found to be non-compliant.

11.1.3 Food production systems affected

11.1.3.1 Meat and meat products (including livestock)

Contamination initially arose during August 2008 as the result of using a PCB-containing transformer oil as fuel for a direct drying system during the feed production process. The analytical profiles of the contaminants in the feed were identified as being consistent with the burning of PCBs.

Concern was first raised in the Republic of Ireland in mid-November when a high level of 'indicator' PCBs was reported in a pig fat sample during a routine screening test. In parallel to this work, a separate investigation was taking place in the Netherlands following a high dioxin result for a pork product made in France. Reported dioxin levels were up to around 300 times the regulatory limit of 1pg WHO-TEQ/g fat set out in European regulations.

Although only 6-7% of pig farms in the Republic of Ireland were thought to have received suspect feed, their animals went through the same processing plants as about 70% of all Irish pig production and there was no means of tracing products back to individual farms.

Subsequently, on Saturday 6 December 2008, authorities in the Republic of Ireland initiated a withdrawal of all Irish pork products. However, a pragmatic decision was taken in the first week following discovery of the incident by European Chief Veterinary Officers that any composite products containing less than 20% suspect meat could be release to the market. A number of farms that had received feed from the affected supplier were restricted from supplying meat to the market.

In Northern Ireland, about 8 beef herds were affected. Analysis of meat from animals in the affected herds already slaughtered had shown dioxin levels of up to 500 times the regulatory limit, although not all samples were so high. Manipulation of entry into the food chain was deemed to be unacceptable given the long half-life of dioxins in cows (estimated at several months), it was inconceivable that meat from animals contaminated at the highest levels would achieve compliance within a realistic timescale. In the event, rendering and incineration of culled livestock was necessary due to the nature of the contamination.

Further complexity was added because under animal by-product regulations, meat products rejected on the bases of exceedance of limits set out in EU legislation are deemed to be Category 1 material, for which the disposal routes are the most stringent (i.e. landfill is not acceptable).

All potentially affected meat products had to be place in quarantine by the affected food businesses, under the control of enforcement authorities, pending discussions on possible transfer back to suppliers and on disposal, raising additional issues such as who would cover the associated costs.

Food businesses who believed their products were unaffected also needed a means of positive release and advice was therefore required for the businesses and enforcement authorities about the analysis necessary to demonstrate compliance. Dioxin analysis is expensive and interpretation of the actual results can be complex.

Due to the delay in identifying the incident it was deemed likely that a considerable amount of contaminated products would already have entered the market and been consumed. A risk assessment by European Food Safety Authority (ESFA) concluded, however, that the risk to health would have been low.

11.1.3.2 Milk

Two dairy herds had potentially received contaminated feed although, in one instance, the farmer believed that the only exposure route was through use of the same shovel for contaminated feed going to other animals being used for clean feed for the dairy herd. Nevertheless, testing of milk in early January 2009 showed the milk from both herds to be non-compliant. Regular subsequent testing showed the dioxin levels in the milk to be falling, although at different rates. This raised a question of whether there might be a continuing low-level exposure. Unfortunately, there were insufficient resources to fully investigate this and both dairy farmers ultimately

11.1.3.3 Animal feed

When the incident was identified, contaminated feed remained on a number of the farms. The material remaining was placed under restriction although it was not removed. This was a concern due to the risk of inadvertent use or accidental exposure of animals, but it was several months before arrangements were finalised to transfer the feed back to the supplier in the Republic of Ireland. In addition, there were no validated methods available for the cleaning out of feed store, transporters or handling equipment and it proved very difficult to communicate to those involved how little of the most contaminated feed (low gram quantities) would need to remain to cause further non-compliances.

11.1.3.4 Slurry

There was a risk that slurry from exposed animals was contaminated particularly if it contained undigested feed, therefore farmers were advised not to spread it at least until it had been tested. While investigations were underway, slurry was, of course, still being generated. Some tanks were full and it was therefore necessary to find temporary storage facilities. In some cases empty slurry tanks were available on the farms but, more commonly, transfer by tanker was required to off-site storage. However, it was difficult to establish criteria for the release and spreading of slurry contaminated at a low level or to set a contamination level above which spreading should not occur. Ultimately, a method was needed for disposal of the contaminated slurry and several options were considered, including land spreading on non-agricultural land, passage through a waste-treatment facility, rendering or dewatering and incineration. Although the latter would be the lowest risk option, it was also the most expensive – and a cost that would tend to fall to the individual farm.

11.1.4 Analysis of the problem

This incident involved contamination of animal feed resulting in wide spread contamination of the food chain with dioxins. Due to delays in identifying the incident a wide variety of food production systems were contaminated including livestock, milk and food products. A wide variety of difficulties were encountered including cost and difficulty of monitoring for dioxins and that authorities were unable to seize contaminated animals or prevent the spreading of slurry onto agricultural land under current legislation.

11.1.5 Physicochemical properties

Dioxins are persistent in the environment and resistant to degradation and are likely to persist for years in soil. In addition, they can bioconcentrate in animals and have a relatively long biological half-life (months to years). In addition dioxins are hydrophobic and are more likely to accumulate in fatty tissues of animals or livestock. These properties influenced a number of decisions taken during the recovery phase of this incident (e.g. manipulation of entry into the food chain and culling of livestock).

11.1.5.1 Source – pathway – receptor

In this case study animal feed was contaminated with dioxins as a result of using oil contaminated with PCB's in the animal feed production process. Dioxins are a product of combustion from burning PCB's and were hence incorporated into the animal feed. Animal feed was then fed to livestock including pigs and cows resulting in bioaccumulation in the fatty tissues of livestock and milk. Following the cull of livestock contaminated dioxins were incorporated into meat products (pork and beef) resulting in contamination of the food chain and subsequent human exposure. Another potential pathway to consider following this incident was the contamination of farm land from the excretion of animals. Before the incident was discovered farmers are likely to have been land spreading contaminated slurry onto farmland. Although, not directly applicable to this incident if this land was also used for agricultural purpose there may have been the potential to contaminate crops and hence the food chain in these areas.

Table 11.1: Source – pathway – receptor criteria based on Irish Dioxins incident.

Dioxins	Meat Products	Milk	Slurry (potential)
Source	Contaminated animal feed	Contaminated animal feed	Contaminated animal feed
Pathway	Ingestion of animal feed by livestock	Ingestion of animal feed by dairy livestock	Ingestion of animal feed by livestock
	Culling and processing of meat into food products	Excretion of dioxins into milk	Excretion and/or land spreading of slurry onto farm land
			Uptake by crops growing on farmland
Receptor	Humans consuming meat products	Humans consuming milk	Humans consuming contaminated crops

11.1.6 Recovery options implemented

(5) Restriction on entry into the food chain/withdrawal from market

(6) Product recall

(13) Temporary derogation

(32) Culling of livestock

(36) Rendering

(37) Incineration

(39) Land-spreading of milk/slurry

The following food production systems recovery option was considered but not implemented:

(7) Control of entry into the food chain

11.1.7 Lessons learned

Although regulatory powers exist to seize and cull animals under certain circumstances (various diseases, detection of certain drug residues), no such powers exist for seizing live animals on the basis that their meat might exceed dioxin contaminant limits.

Therefore, culling had to be undertaken on a voluntary basis which, in turn, meant that a suitable compensation package had to be agreed with farmers. This took several months. The earliest opportunity to exclude potentially contaminated meat from entering the food chain arises at the slaughterhouse.

In a few cases, farmers were confident that cohorts of animals had not been exposed to contaminated feed and a means of positive clearance was required, preferably without the need to slaughter the animals first. As blood samples would not provide sufficient material for testing, a relatively novel technique based on testing of pooled samples of fat taken by live biopsy was used a number of animals were released on this basis.

Other than powers held by the Northern Ireland Environment Agency to protect water courses, there were no legal means of preventing land-spreading of slurry by farmers.

Full congener analysis for dioxins (which may cost £500-1,000 per sample) can take up to 3 weeks, although short turnarounds are possible in urgent situations, and there is limited capacity in terms of suitably accredited and experienced testing facilities.

11.1.8 Information for development of recovery handbook

All recovery options considered were generally effective and practical. However, their effectiveness in reducing exposure would have been reduced due to the delay in identifying the incident. The land-spreading of contaminated slurry would have resulted in contamination re-entering the environment so could not be considered a totally effective option. In addition, the fact that composite products with less than 20% of contaminated meat were allowed onto the market (effectively raising intervention limits), this could not be described as being totally effective at reducing potential exposure.

11.1.9 References

Adapted from HPA Chemical Hazards and Poisons Report - Issue 17, The Irish Dioxin Incident. David Mortimer, 2010. Available [April 2012] at; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/203572/HPA_Chemical_Hazards_17.pdf

11.2 Case Study 2: Nicotine contaminated ground beef (Food Production Systems)

11.2.1 Incident overview

This incident describes the contamination of meat products with nicotine in a single supermarket in Michigan, United States. It was an unusual case in that food contamination was deliberate and resulted in around 100 people falling ill, necessitating a product recall and appropriate waste disposal of the contaminated product.

11.2.2 Timeline

Ground beef sold to members of public on December 31st 2002 and 1st January 2003

18 people became ill soon after

3rd January product recall issued by Michigan Department of Agriculture (MDA)

36 further complaints of illness following product recall

120 people returned recalled product

- January 10th: Lab result indicate nicotine present in tested samples
- January 17th: Nicotine quantified as approximately 300 mg/kg in tested samples, supermarket issues initial press release and further product recall
- January 23rd: Hospital emergency departments notified
- January 24th: Confirmatory test results received, further press release stating nicotine was the contaminant involved
- February 12th: Supermarket employee arrested in respect of incident

11.2.3 Food production systems affected

11.2.3.1 Meat and meat products

Concern was first raised when a supermarket in Michigan, US informed the relevant authorities on the 3rd January that they planned to recall 1,700 pounds of ground beef following numerous complaints of adverse health effects following ingestion of the product. Adverse health effects reported included burning in the mouth, nausea, vomiting and dizziness. In the most severe case, one patient required treatment in hospital for atrial fibrillation. Following the initial product recall there were 36 further reports of ill effects linked to consumption of the product and 120 people returned the beef to the supermarket.

Supermarket officials initially submitted samples of the potentially contaminated ground beef to a private laboratory which indicated the samples were negative for any pathogens. However, further testing by a regional medical centre identified nicotine within the beef samples on the 10th January. Once high concentrations of nicotine concentrations were quantified (300 mg/kg) a week later (17th Jan) the intentional contamination with a nicotine based pesticide was suspected. The United States Department of Agriculture (USDA) and Federal Bureau of Investigation (FBI) were therefore notified as it was at first unclear at whether there was the potential for contamination across different US states. The beef product had been supplied by an out of state processor prior to being ground in the supermarket so there was initially a risk that other stores within the supermarket chain had also been supplied with the contaminated product. However, neither the food processor nor other potentially affected stores had received any complaints from customers who had bought and consumed the beef, lessening the public health implications. In addition, it was noted that no nicotine based pesticides were sold by the implicated supermarket suggesting the contamination was unlikely to be accidental.

Due to the potential for compromising a criminal case it was decided to limit the amount of information passed onto the public, therefore the second product withdrawal notice on the 17th of January stated that the implicated product contained an ‘unspecific, nonbacterial contaminant that could not be made safe by cooking’. Relevant local medical care facilities were notified on the 23rf of January prior to a second press release on the 24th January confirming that the contaminant was nicotine once this had been confirmed by repeated tests.

The local health department subsequently conducted an epidemiological investigation to identify individuals who developed symptoms consistent with nicotine poisoning following ingestion of the contaminated product. Although most individuals developed symptoms while the contamination beef was still on sale, some developed up to 49 days later indicating that they froze the product prior to consumption.

A supermarket employee was subsequently arrested in connection with the incident, accused of deliberately contaminating the ground beef was Black Lead 40 which contains high concentrations of nicotine (40%)

11.2.4 Analysis of the problem

This incident involved the contamination of ground beef with potentially lethal levels nicotine. Due to the relatively fast development of clinical symptoms following nicotine ingestion an issue was identified relatively early. The time taken to appropriately analyse and confirm the presence of nicotine in the food product led to delays in dietary advice being given to members of the public and health authorities.

11.2.4.1 Physicochemical / toxicological properties

Nicotine does not have the potential to bio-concentrate within the food chain but this incident indicates that if contamination occurs at a late stage in food processing it can still pose a public health risk. Nicotine is water soluble and has a boiling point of around 250 degrees, however it does volatilise within steam so can be removed by cooking. Further analysis of cooked beef samples supported this with concentrations about half that of the uncooked beef (180mg/kg). Small amounts of nicotine can be toxic; the fatal dose has been estimated to be as little as 40 mg of nicotine in adults. Nicotine has a short latent period; clinical effects develop rapidly following exposure. This resulted in poisoned individuals linking the contaminated beef ingestion to the symptoms they developed.

11.2.4.2 Source – pathway – receptor

In this case study ground beef was deliberately contaminated with a liquid nicotine-based pesticide. The nicotine based pesticide was in liquid form, ingestion would have been the primary route of exposure from contaminated food.

Table 11.2: Source, pathway, receptor criteria

Nicotine	Meat products
Source	Nicotine based pesticide
Pathway	Contamination of ground beef food product
Receptor	Humans ingesting food products

11.2.5 Recovery options implemented

(5) Restriction on entry into the food chain/withdrawal from market

(6) Product recall

11.2.6 Lessons learnt

Although contamination only affected one supermarket, the investigation into this incident involved the retailer and numerous government agencies, highlighting the issues brought about by deliberate food contamination.

If contamination of the food product had occurred at an earlier stage in food processing the incident could have affected a larger number of food supermarkets and increased the number of people affected.

The time taken to identify, quantify and confirm the concentration of nicotine in samples led to delays in issuing appropriate public health advice.

Individuals may freeze and then eat contaminated products increasing the time span for cases to be reported.

Clinicians should be advised to report clusters of poisonings via appropriate surveillance methods.

The overall public health response to chemical contamination of food needed to be strengthened in this region.

11.2.6.1 Information for development of recovery handbook

All recovery options considered were generally effective and practical. However, the delay in issuing a detailed press statement in conjunction with the product withdrawal could have contributed to the further exposure of individuals who had stored the beef prior to consumption.

11.2.7 References

1 Centers for Disease Control and Prevention. "Nicotine Poisoning After Ingestion of Contaminated Ground Beef—Michigan, 2003." Morbidity and Mortality Weekly Report 52 (May 9, 2003): 413-416.

2 Dasenbrock, O et al. Journal of Forensic Sciences. The determination of Nicotine and Sulfate in Supermarket Ground Beef Adulterated with Black Leaf 40.

11.3 Case Study 3: Asbestos release in residential flats (inhabited areas)

11.3.1 Incident overview

The incident location was a complex of 28 residential flats. The local authority (LA) managed this housing stock via a third-party arm's length management organisation (ALMO). The building had been surveyed for asbestos some weeks prior to the incident as part of an ongoing survey to comply with the Control of Asbestos at Work Regulations by the UK Parliament, 2006. Asbestos containing soffit boards were identified above the first the floor windows (Soffit boards are the boards which sit just beneath the facia board). The majority of asbestos found was mostly white (serpentine), the most commonly used in building materials, with smaller proportions of brown and blue asbestos.

When the building contractors arrived at the site to undertake the renovation of doors and windows to each flat the presence of asbestos soffit boards had not been communicated. Furthermore, the building contractors did not identify or query that the material was potentially asbestos during the renovation. Extraction of the windows took place whilst residents were still present and each unit was removed from inside their apartments and carried through the flat, via communal area (e.g. hallways, stairwells) and the building grounds for disposal in an outside skip, potentially depositing dust and debris along the way. Dust sheets were utilised in each flat to minimise the localised debris from the window removal.

On a Friday, 2 weeks following completion of the work, asbestos fragments were discovered by a separate company completing their asbestos survey on a separate part of the building complex. They observed fragments of asbestos facia board discarded around the external areas of the building and within a skip at the perimeters of the site. The asbestos boarding was identified as facia boards damaged during the removal of first floor windows.

On receipt of this information the LA immediately set up an Emergency Control Centre (ECC) contacted the Local Health Protection Unit and the Health and Safety Executive. The LA organised a specialist asbestos company to undertake air sampling and collect swab samples from 6 of the 28 flats. Advice from the specialist asbestos company confirmed that the air sampling was negative and that the risk to residents at this point was deemed to be low. Later that day a specialist licensed asbestos clean-up contractor was employed to remove asbestos from external areas of the grounds. It was proposed that once the clean-up had been undertaken the ECC could be stood down. Results from the swab samples were expected within a few days. When available they were described as 'gross' (i.e. spread throughout the flat).

Measures were put in place to evacuate the residents and undertake a more comprehensive survey of the asbestos contamination. However a decision had to be made whether to evacuate the residence that evening in the dark (circa 22:00) or the following morning. Considering that the residents had already been exposed to asbestos for over 2 weeks and that air sampling had recorded negative results it was considered more appropriate, due to the age of some of the residents to undertake the evacuation the following day.

Residents were evacuated and the flats were systematically sampled to determine whether they were contaminated and if so, the extent of contamination. The sampling methodology defined whether the flat was partially contaminated or grossly contaminated. The sampling results informed which content within the flats would need to be removed and disposed of.

Inventories of belongings were recorded in the contaminated flats and items which posed a risk were either professionally cleaned or disposed of as hazardous waste.

Once the flats had been professionally decontaminated the apartments were refurnished, re-sampled and residents reinstated.

Items disposed of:

- Microwaves, washing machines, items with fans
- Carpets and soft furnishings were removed and replaced and the flats were professionally cleaned by licensed asbestos contractors.

11.3.2 Analysis of the problem

A number of mismanagement and preventable events contributed to this incident and the case demonstrates that chemical incidents still occur as a consequence of human error even when preventative/protective legislation appears to be complied with.

The builders were not trained to recognise asbestos type material – this led to hazardous material not only being distributed around the complex of flats but illegally disposed of in the site skip.

The extent of the contamination was compounded by the building contractor’s method of removal and use of the same dust sheets for each flat.

Bottom floor flats were contaminated as a consequence of debris from window extraction from flats above which entered these properties through open windows. Residents had been advised to close windows to reduce dust ingress but the work was undertaken during a warm period when residents were less inclined to follow this advice.

11.3.2.1 Physicochemical properties

The migration of a chemical is governed by its physical and chemical properties, including its concentration. It is therefore important to consider certain physicochemical properties when responding to these types of incident (Section 1.8). In the case above the asbestos fibres were entrapped within the soffit board and where they were unlikely to pose an exposure risk to a residence. However, when this material was damaged during the removal of the window frames asbestos fibres were released into the property and could pose an inhalational risk to occupants.

11.3.2.2 Health based standards, monitoring and considerations for evacuation

Initial decision on evacuation of a property on the grounds of health should be based on the risk to health from acute exposure or the potential for an extended duration of exposure (days/weeks). In this case, internal air sampling suggested that asbestos levels were acceptable (acute exposure). However, swab samples suggested that asbestos fibres deposited in various locations within the properties posed a long-term health risk. As with all incidents other risk factors will need to be considered along with monitoring criteria.

11.3.2.3 Source – pathway – receptor models

Asbestos fibres are very small (<10 um) and would be transferred on air currents from the opening left by the windows. Some fibres would remain trapped within dust and dirt particles generated form the work whilst others would remain in the air until settling out (through gravity). Fibres will remain on surfaces until disturbed, for example by occupation, dusting or vacuuming potentially leading to long-term exposure unless removed.

As information becomes available, identifying source – pathway – receptor models is an important process in informing dynamic risk assessments and planning for recovery remediation.

Table 11.3: Source, pathway, receptor criteria

Residential flats	Soffit boards
Source	Asbestos fibres (within flats, communal areas, outside areas and skip)
Pathway	Air
	Dust sheets
	Other waste material
Receptor	Residents
	Building contractors (recovery workers)
	Adjacent property (school)

11.3.3 Recovery options implemented

Recovery options employed are prescribed in HSE Guidance:

(4) Temporary relocation from residential areas

(8) Physical decontamination techniques

(11) Vacuum cleaning

(13) Fixative/strippable coatings

(14) Dismantle and disposal of contaminated material

(17) Storage, covering, gentle cleaning of precious objects

11.3.4 Lessons learned

- Re-sampling is required to validate the cleaning process
- Asbestos contamination of residential or commercial premises can be extremely complex and recovery is disruptive and expensive
- Personal items and items of sentimental value need to be considered

- Further exposure to an asbestos release should be prevented. It is recommended that an area is sealed and staff and public are prohibited from entry until risk has been assessed
- Provision of public health information – to those potentially affected; to the media etc.
- Environmental sampling (air sampling and swab sampling) and analysis need to be undertaken to identify the presence, quantity and type of asbestos to inform the health risk assessments
- Where necessary, ensure that decontamination and clean-up of affected areas including surfaces, fixtures and fittings e.g. soft furnishings, electrical goods) etc are facilitated by specialist contractors
- Where necessary recommend that re-sampling and analysis are completed to validate clean-up
- Where exposure is significant, consider the need to recommend retrospective exposure assessments for individual groups at risk (e.g. staff, pupils, patients, homeowners, visitors etc)
- It is recommended that these assessments should be undertaken by specialist consultants

11.3.5 References

1 Dunne, A., Dobney A, and Hodgson G (2010). Asbestos: The hidden hazard in domestic, educational and health care settings. Chemical Hazards and Poisons Report (2010) 17: 10.

2 HSE (2006). Asbestos: The licensed contractors' guide.

3 UK Parliament (2006). The control of asbestos at work regulations 2006. SI2006 no 2739 http://www.opsi.gov.uk/si/si2002/20022676.htm

11.4 Cast Study 4: Sulphur mustard, Swansea (Inhabited Areas)

11.4.1 Incident overview

On 24th September 2009, a concerned member of the public reported to the police the discovery of a piece of military ordnance in sand dunes at a beach in North Gower, Swansea. The shell was disabled by Army Explosive Ordnance Disposal experts the same day. Three days later, Public Health Wales was notified that 2 members of the disposal team were receiving hospital case for severely blistered skin. The Ministry of Defence subsequently confirmed that the shell had contained sulphur mustard (commonly known as mustard gas) and considered it possible that a small amount of the thick and oily volatile liquid may have been released during the routine disposal of the device. The reported symptoms were consistent with exposure to the vesicant, sulphur mustard, a chemical warfare agent known to cause irritation and burns to skin, eyes and respiratory tract, potential reproductive effects, bone marrow depression and possibly respiratory tract cancer.

Following the release of sulphur mustard and other substances that could have been held within the device, there was potential for public exposure over a 4-day period before the authorities were alerted. Consequently, a multi-agency Incident Response Team was promptly convened. The membership of this group was comprised of representatives from key stakeholder agencies such as Public Health Wales, Public Health England, National Poisons Information Service, Ministry of Defence, Welsh Assembly Government, Police, Local Health Board and Local Authority. The multi-disciplinary team quickly agreed a framework to deliver a co-ordinated public health response, which included:

- Implementing immediate control measures by positioning a cordon around the potentially contaminated area and initially remediating it by removing materials that were either visually contaminated by sulphur mustard (or its degradation products 1,4-thioxane or 1,4-dithiane) or could be detected as being contaminated using field chemical agent detection equipment.
- Undertaking a health risk and exposure assessment
- Dealing with wider decontamination issues
- Formulating a risk communication strategy which involved informing local healthcare professionals, developing press statements and giving media interviews to raise awareness about the incident and request that other potentially affected or concerned individuals identify themselves; considering the need for longer-term follow-up of those exposed.
- Cleaning up the affected area and undertaking a comprehensive environmental sampling and analysis strategy (across 228 random sampling points) that demonstrated clean-up effectiveness with 99% confidence
- The extensive clean-up operation was completed, and environmental sampling strategy report finalised, by 16th November 2009.
- A follow-up press statement was released to the media soon after this to confirm that the risk of exposure to sulphur mustard in the affected area was extremely low and that there was no need to restrict any recreational activities

Whilst in this instance, no other individuals were affected, the potential public health implications could have been significant. The co-ordinated response delivered highlighted the wealth of specialist public health and toxicology expertise that exists in Wales, the commitment of partners to engage in acute incident response situations, and the added value of working collaboratively to protect public health.

11.4.2 Analysis of the problem:

- Sulphur mustard has been used as a chemical weapon, since as early as 1917 to much more recent conflicts such as the Iraq/Iran war (1980s)
- Shells originating from the Second World War containing sulphur mustard were sometimes buried or dumped at sea (e.g. Baltic), and these may constitute a risk to human health when they emerge
- The risk to public health from this incident was significant, any individuals utilising the area for recreational purposes would be at risk of exposure

11.4.2.1 Physicochemical properties

Sulphur mustard exists as a liquid at room temperature, and forms a vapour that is heavier than air and may accumulate at low-points in the environments. Under certain conditions 9e.g. cold temperature), sulphur mustard may persist in the environment for many years. This has been demonstrated by shells retrieved from the Baltic sea and off the coast of Northern France. Given the relatively cool temperatures present in Wales at this time of year, it is likely to volatise less than at higher temperatures, but this would result in it persisting longer in the environment.

11.4.2.2 Source- pathway – receptor models

The migration of a chemical is governed by its physical and chemical properties, including its concentration. It is therefore important to consider certain chemical physicochemical properties when responding to these types of incident (Section 1.8). In the case above it was possible that sulphur mustard or its degradation products may have disseminated around the immediate area during the process of disarming and removal of the military ordnance. Sulphur mustard poses a risk via both inhalation and skin contact, and transmission is likely due to its persistence. Given the relatively cool temperatures present in Wales at this time of year, inhalation is likely to present less of a risk than dermal contact as it will volatilise less.

As information becomes available identifying the source – pathway – receptor models is an important process in informing dynamic risk assessments and planning for recovery remediation.

Table 11.4: Source, pathway, receptor criteria

Sand dunes	Military ordnance
Source	Residual sulphur mustard
Pathway(s)	Dermal contact
	Inhalation
	Soil and vegetation
	Sand
Receptor	Members of the public
	Recovery workers
	Wildlife

11.4.3 Recovery options implemented

Inhabited areas:

(1) Restrict public access

(20) Soil and vegetation removal

Water environments:

(15) Restrict access to inland, recreational or coastal (controlled) water environments

11.4.4 Lessons learned

- Long term follow up of those exposed to sulphur mustard may be required
- An appropriate monitoring strategy is required to validate the cleaning process
- The sampling process can be extensive and expensive but is required to assure members of the public that there is limited risk following clean-up
- There is a risk of military ordnance reappearing many years after initial use containing a chemical which can still pose a significant public health risk
- An appropriate risk communication strategy is required to ensure further exposure is prevented and to reassure members of the public when clean-up is complete

11.4.5 References

1 Ashmore MH, Nathaniel CP (2008). A critical evaluation of the implications for risk based land management of the environmental chemistry of sulphur mustard. Environment International 34: 1192-1203.

2 Brunt H, Russell D, Brooke N. Sulphur Mustard Incident, Swansea. Chemical Hazards and Poisons Report (2010) 17: 4.

3 DSTL (2009). Confirmatory Sampling and Analysis Exercise, Whitford Burrows, Gower. Defence Science and Technology Laboratory UK (October 2009).

4 Maynard RL (2007) Chapter 19: Mustard Gas. Marrs TC, Maynard RL, Sidell DR. Chemical warfare agents: toxicology and treatment. John Wiley and Sons Ltd, Chichester.

11.5 Case Study 5: Long-term leakage of heating oil into soil leading to permeation of plastic water supply pipes (Water Environments)

(Adapted from Dr. Faith Goodfellow, Research Engineer – Water)

11.5.1 Incident overview

The incident location was a small estate of several houses, re-developed from a former stable block. The houses were situated in large grounds with adjacent lakes and gardens. All the houses were supplied with heating oil from a central oil tank. At the time of construction, separate plastic water supply pipes were laid to each house from the iron public water main which ran adjacent to the perimeter of the estate. The incident developed over several years demonstrating the protracted nature of some incidents.

Three main stages of the incident have been identified:

- Stage one – the first incident involved the contamination of the estate lake with oil. The source was traced back to surface drains from the housing development. It was found that the meters for the domestic heating oil supply to the houses had been designed for indoor siting, but had actually been located just outside each house. The meters had consequently corroded, and 2 meters were found to be leaking, with oil observed below ground level. The meters and the pipeline were replaced with those of more suitable material. The old meters were removed, but the old fuel oil pipes were left in situ, although it is believed that it were drained of any residual oil and then sealed
- Stage two – 2 years later, a complaint was made to the local water company regarding taste/odour problems with the drinking water. This was accompanied with an odour reported in 3 houses. In one house the odour from the water was described as 'horrific', however, no adverse health effects were reported. The most likely source of contamination was found to be oil contaminated soil, as a result of the previously leaking oil meters. This oil from the contaminated soil had permeated through the plastic water supply pipes and contaminated the drinking water. Initially the mains water supply was isolated and an alternative water supply was provided via bowsers and a standpipe for drinking water.

An overland water pipe directly from the main was installed by the water company. After connection to the overland supply the pipes were flushed through and no further oily smell in the water was observed. Additionally a quantity of contaminated soil was removed from outside some properties. The plastic pipes were replaced with plastic coated copper piping from the mains water supply.

- Stage three – a further year on, renewed concerns of taste and odour in the drinking water was reported. On investigation it was found that the connections from the water piping outside the house to the internal plumbing still composed of plastic and that oil still present in the soil had again permeated through the plastic connectors and into the drinking water. The plastic connectors were subsequently replaced along with extensive removal of contaminated soil from beneath several houses.

Adverse health effects were reported at this point, with some residents enquiring whether health problems experienced over the previous year might be related to the water contamination.

11.5.2 Lessons learned

Early investigation into the source of contamination is important. In this case, consumers may have been exposed for a number of months prior to the problem being identified

Early investigation is required to identify the substances involved in an incident and their concentrations, so that a health risk assessment can be carried out

The affected population should be kept informed during an incident, particularly about risks to health and action being taken to minimise adverse health effects

The main issue raised by this incident is soil contamination with organic chemicals leading to drinking water contamination through permeation of plastic water supply pipes. This pathway was not adequately considered, leading to recurrence of the contamination after initial remediation had been carried out.

This incident also highlights the need to replace all water pipe work with metal alternatives where organic chemical contamination is suspected. This incident has also raised questions of health effects arising from these types of events.

11.5.3 Analysis of the problem

A water body (in this case the drinking water supply) may be impacted even if the chemical spill/leak/incident occurred some distance from the source with no obvious connection.

11.5.3.1 Physicochemical properties

Oil is a liquid with a specific gravity close to one. It does not mix with mater. However, it will percolate through soil and migrate considerable distances. One property of heating oil is its ability to permeate through plastics. In this case, fuel oil saturating the ground soil was able to migrate through the plastic drinking water supply pipe. Oil is also volatile and therefore can lead to fumes which can enter buildings.

11.5.3.2 Health based standards, monitoring and considerations for evacuation

Initial decisions on evacuation of a property on the grounds of health should be based on the risk to health from acute exposure (<8 hours) to kerosene vapours >290 mg/m3. An air concentration of =/< 290 mg/m3 with the potential for an extended duration of exposure (days/weeks) may indicate the need to evacuate based on a potential risk to health. However with all incidents other risk factors will need to be considered along with monitoring criteria.

Domestic heating oil consists of a mixture of hydrocarbons, many of which are volatile organic chemical compounds. Hence, analysing for Total Petroleum Hydrocarbons (TPHs) or Volatile Organic Compounds (VOCs) provides a useful surrogate for determining kerosene vapour concentrations when the source is known.

Monitoring drinking water for Total Petroleum Hydrocarbons (TPHs) may provide additional evidence for the presence of contamination. However due to the lack of health-based drinking water standards this information has only limited value, but may be useful to determine when contaminants concentrations in the water supply are decreasing. Tainting is a more restrictive criterion.

Note: For more detailed information in responding to a kerosene incident Public Health England has published an action card for public health practitioners.

11.5.3.3 Source – pathway – receptor

In this case study both a local lake and drinking water supply were polluted by oil that leaked form meters and subsequently migrated up to a distance of several metres through the environment, see Table 11.5.

When heating oil has been released into the environment near a building, there is potential for fumes to accumulate in ground floor rooms, particularly if unventilated, giving an oil like odour.

The fuel oil (such as petrol or kerosene) or contaminated water leaking into soil will initially migrate downwards under the action of gravity. It may also begin to spread horizontally. Not all of the liquid will continue to flow through the soil – some of it will be adsorbed onto the particles of the soil through which it has moved. This leads to contaminated soil. Some of the contaminant, if volatile, may evaporate into the soil gases and be transported through the soil air. Pollutants may also follow or enter underground structures such as drainage systems through broken pipe/joints.

Oil may migrate through plastic pipes or plastic connectors located in the contaminated soil. This pathway was not considered in the initial assessments for this case, leading to the prolonged nature of the case. The permeation of oil through the plastic pipe resulted in contamination of the water supply and this led to tastes and odours of oil in the water supply from taps, and/or shower units.

Table 11.5: Source, pathway, receptor criteria

Heating oil (Kerosene)	Drinking water	Lake	Inside of property
Source	Leaking oil meters resulting in soil contaminated with heating oil (kerosene)	Leaking oil meters resulting in soil contaminated with heating oil (kerosene)	Leaking oil meters resulting in soil contaminated with heating oil (kerosene)
Pathway	Permeation of oil through the plastic drinking water pipe	Migration to lake (possibly flowing with ground water)	Migration through soil
		Migration of oil via underground services along redundant pipes/broken drain pipes	Soil / air
Receptor	Drinking water supply, exposure to residents primarily via ingestion but also skin contact/inhalation (e.g. during bathing/showering)	Lake and recreational users (e.g. anglers/swimmers). Potential for exposure primarily via skin contact and also accidental ingestion/inhalation	Residents exposed from fumes within property primarily via inhalation and to a lesser extent skin via contaminated air

11.5.4 Recovery options implemented

Water environments:

(2) Alternative drinking water supply

(3) Restrict water use (DND/DNU notices)

(12) Flush out distribution system

Inhabited areas:

(14) Dismantle and disposal of contaminated material

(19) Outdoor surface removal and replacement

(20) Soil and vegetation removal

11.5.4.1 Information for development of recovery handbook

All recovery options considered were effective and practical. The effectiveness of the inhabited areas options was reduced by the failure to address all the pathways of exposure. Once this had been done, then the options were effective.

11.5.5 References

1 Heating oil incidents: action card for public health practitioners v1.0 Available [April 2012] at; http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1284475799316 accessed May 2012

11.6 Case Study 6: MSC Napoli (Water environments)

(Adapted from Dr. Sue Bennett and Paul Bolton)

11.6.1 Incident overview

MSC Napoli suffered flooding to the engine room during force 8 gales in the Channel on Thursday 18 January 2007. The 26 crew abandoned ship and were safely rescued from their lifeboat by helicopter. The ship began to break up through the onslaught from the heavy seas. This created a massive risk of pollution and could have affected some of the UK's most beautiful coastline. There were over 3,500 tonnes of heavy fuel oil on board and 1,500 tonnes of diesel together with a very mixed cargo, some of which was highly toxic.

Very early on in the incident, an attempt was made to obtain the full ships manifest from Rotterdam. Information started to become available on the afternoon of Saturday, 20 January. Early actions advised by the Environment Group and the Salvage Control Unit were particularly aimed at protecting the environment and the food chain.

- Two tugs tried to put a boom around the Napoli to contain oil and diesel. This was difficult, due to the heavy seas;
- Booms were placed across local rivers at risk e.g. the Axe and the Sid;
- An exclusion zone was established to keep fishermen out of the area

In addition, access to the beaches near the Napoli was to be blocked by Devon Police to protect the public. Salvers took measures to strengthen the lashing holding the cargo to the ship so that they could cope with a 30 degree roll and 80 mph winds.

The MCA started modelling dispersion of escaped pollutants, based on tidal flows and predicted weather patterns. The modelling covered sudden and slow release of pollutants, and the release of containers – both floating and sinking/rolling on the seabed. The highest priority was to remove as much oil as possible from the Napoli and this was a very hazardous operation for the salvers, working in appalling weather conditions.

By Sunday, 20 January, the heavy seas overnight resulted in 150 containers being lost from the Napoli. These were not thought to contain hazardous materials. The ship's manifest confirmed that hazardous materials were stored in the centre of the hold with non-hazardous cargo on the outside. Six teams of coastguards walked the beaches to identify oil and containers. By 10.15am, a Gold Command had been established in Devon. The Royal Society for the Prevention of Cruelty to Animals and the Food Standards Agency had been notified and the salvers had been advised of the nature of hazardous chemicals on board.

At this time, key messages to Gold Command included:

- Close the beaches
- Reconnaissance staff to avoid contact with broken containers;
- Salvage Control Unit to be notified if hazardous material identified.

By Sunday afternoon, drums of nitric acid, potassium hydroxide and isopropanol drums had been lost overboard. Isopropanol is a highly flammable chemical and the advice to the shoreline responders was to avoid contact with sparks, try to prevent entry into waterways and cover spillages with sand/soil; the isopropanol would naturally decompose to water and carbon dioxide. However, early on in the incident the valuable nature of some of the cargo attracted the public and the press then appeared in droves. Sky News reported that there were beer kegs, motorbikes and Toyota cars on the beach, and that looting had already begun. Despite the public being attracted by ‘loot’ to an area where several hazardous materials were washed up, there was only one casualty overcome by fumes from a burning container.

The Environment Group continued to meet almost daily until 2 February 2007. Close contact continued to be made with chemical hazards specialists with the Health Protection Agency. Health protection queries continued to focus on the likely health effects if members of the public and those involved in the environmental clean-up operation were exposed to open containers of chemicals washed up onto the beaches. A decision was made not to use volunteers in the early stages of the clean-up due to the hazardous nature of some of the cargo.

Advice continued to be required from the Environment Group on dealing with the wreck of the container ship. There was a debate as to whether it would be better to use the ship as a diving wreck or to recycle her.

Risks involving recycling the Napoli by cutting up in situ included:

- Risks to salvers from what would be a dangerous operation
- Noise pollution
- Damage to life on seabed from ‘steel swarf’ small fragments from the cutting operation
- Large metal chinks and other items being lost and washed up on beaches; impact of debris on scallop beds to the east of the wreck

Eventually, it was decided to break the wreck into sections using controlled explosions. Part of the Napoli was then towed to Belfast for recycling and the remaining sections of the ship were cut up in situ, just off the east Devon coast. Before the recycling could proceed, the 2,000 or so containers remaining on the Napoli were taken to Portland Port using an enormous crane barge.

Weymouth Port Health Authority were responsible for:

- Inspection of all containers
- Examination of cargo and refrigerated unit records
- Determination of fitness to enter the food chain
- Issuing paperwork
- Disposal of unfit/contaminated foodstuffs

The examination of the cargo involved the following procedure:

- The container number was checked off against the manifest if available;
- Interested parties were asked to make themselves known;
- The seal was opened with bolt croppers;
- Examination of the content was undertaken and photographs taken; the container was re-sealed; along with a Port Health seal if the cargo was relevant;

- Paper work was completed indicating the status and determination of fitness of the contents

Surprisingly, some food transported in refrigerated containers remained fit for human consumption even after several days with no power. Other foods had exceeded temperature regulations, had become contaminated with sea water and chemicals, or were physically damaged; these had to be destroyed as they were unfit for human consumption.

Managing the disposal of the containers from the Napoli created a major challenge for the Weymouth and Portland Port Health Authority, which was exacerbated by a number of factors which are outlined here.

The identification of unlabelled chemicals not on the ship's manifest made their disposal complicated. Mixed use containers caused difficulties and highlighted a huge trade in undeclared goods worldwide.

A number of owners failed to claim their undamaged consignments resulting in food perishing whilst on the dock side. This subsequently had to be destroyed by incineration or sent to landfill. Liquid cargoes created unique disposal issues as they had to be deliquefied before reaching landfill.

The destruction of large quantities of spirits occurred due to importation complications which prevented possible reuse by conversion to industrial alcohol.

Producers and manufacturers would not allow the re sale of their branded goods for fear of damaging their commercial reputation. The Napoli salvage operation was the largest ever worldwide.

However, modern containers ships can now load x 22 wide x 7 high containers - 5 times the number on board the Napoli

11.6.2 Lessons learned

In this case there were multiple routes of exposure possible. It was therefore important to implement overarching recovery options such as restricting access and transport in the vicinity to protect members of the public and the immediate environment.

Be aware that command and control arrangements for maritime incidents operate in parallel to the land based Gold and Silver commands.

Establish links between sea and land based command structures at an early stage.

Hazardous cargo will be stored centrally and containers lost at an early stage in an incident will usually be from the outer layers and so less hazardous.

Try to obtain the ship's manifest at the outset of the incident – the MCA's Hazardous Cargoes Adviser will facilitate this.

Consider mutual aid arrangements – big salvage operations will take many months to complete and recovery advice may be needed over a long period of time.

Restricting access was difficult to enforce.

11.6.3 Analysis of the problem

This case involved a combination of the spread of oil and contamination in seawater with the wash up of barrels containing toxic chemicals onto the shore line. Bad weather limited the time available for some recovery options. The presence of attractive items washed up on the beach also limited the effectiveness of keeping people away from barrels/containers containing hazardous material also washed up. Maritime disasters of this kind are bound to happen again in the future, and even bigger container ships are being built which can carry 5 times the number of containers that could be carried by the Napoli.

11.6.3.1 Physicochemical properties

The migration of a chemical is governed by its physical and chemical properties, including its concentration. It is therefore important to consider certain chemical physicochemical properties when responding to these types of incident (Section 1.8.2 Water Environment section). With any large maritime incident it is possible that fuel or crude oil will have been discharged from the vessel. Oil leaking from a vessel will float and spread out to form an 'oil slick'. 1 tonne of spilled oil will rapidly spread out to a slick with an area of approximately 10,000 m^2. The rate of spreading will depend upon metrological conditions and chemical properties such as viscosity (e.g. waxy oils with high viscosity are more liable to break up rather than foam an oil slick).

11.6.3.2 Source – pathway – receptor

In the case above there were multiple chemical sources, pathways and receptors based on whether chemicals being transported had discharged into the sea (isopropanol), remained on the vessel or had washed up on the shoreline (barrels of nitric acid and potassium hydroxide), see Table 11.6. To identify chemicals being transported the ship's manifest should be determined at the outset of the incident. The MCA's Hazardous Cargoes Adviser will facilitate this.

As information becomes available, identifying the source-pathway-receptor model is an important process in informing dynamic risk assessments and planning for recovery remediation.

Table 11.6 Source, pathway, receptor criteria

Napoli	For fuel lost from the vessel	Washed up barrels, containers
Source	Leaking vessel (fuel oil)	e.g. barrel nitric acid
Pathway	Sea water	Localised sea water if present
	Sea food	Contaminated sand
	Sediment	Air/fumes
Receptor	Public (skin contact, inhalation and ingestion)	Public (skin contact, inhalation and ingestion)
	Shore line sand, sea weed etc.	Shore line sand, sea weed etc.
	Wildlife (e.g. birds)	Wildlife (e.g. birds)
	Marine life	Marine life
	Food chain	Food chain

11.6.4 Recovery options implemented

Water environments:

(15) Restrict access to inland, recreational, coastal (controlled) water environments

(16) Restrict transport within inland, recreational and coastal (controlled) water environments

(17) In-situ treatment of inland, recreational, coastal or underground (controlled) waters

(19) Removal/containment of sediment

(20) Containment: Use of booms, dams and absorbent material

Inhabited areas:

(8) Physical decontamination techniques

(14) Dismantle and disposal of contaminated material

Food production systems:

(5) Restriction of entry of food into the food chain/withdrawal from market

(37) Incineration

(38) Landfill

11.6.4.1 Other options used/considered

Sore and monitor recovered items prior to release for normal sale (though manufacturers unwilling to release for sale for fear of reputation issues)

De-liquification of liquids prior to landfill disposal

11.6.4.2 Information for development of recovery handbooks

It is clear that if there are multiple exposure routes then it is necessary to employ overarching options. It was necessary to consider product withdrawal for items which had been/potentially been exposed to sea water. The resale of branded goods was not supported by producers for fear of less of reputation. This led to proposed waste disposal options such as converting spirit based cargo to industrial alcohol; however this proved too legally complicated.

Restricting access on the shoreline was not 100% effective as people disregarded it due to the presence of attractive items. The dismantle and disposal options were not 100% effective due to weather conditions and insufficient time to implement them fully.

11.6.5 References

1 Adapted from HPA Chemical Hazards and Poisons Report - Issue 14, MSC Napoli S Bennett P Bolton, 2009. Available [April 2012] at; http://www.npis.org/PHE/14_HPA_CHaPR_Apr_2009.pdf

2 MCA Guidance website – Pollution Response Guidance/ Case studies. Available [April 2012] at; https://www.gov.uk/government/organisations/maritime-and-coastguard-agency

11.7 Case study 7: Volcanic eruptions (volcanic ash)

11.7.1 Incident overview

There have been a number of major volcanic eruptions over the years that have resulted in substantial amounts of ash fallout. Examples include:

11.7.1.1 Mount St. Helens, Yakima, Washington, USA 1980

Mount St. Helens is in the centre of the Cascade Mountain Range between the States of Oregon and Washington. Prior to its eruption in 1980, Mount St. Helens was dormant. The volcano reawakened on March 20, 1980, by the end of April, the north side of the mountain had started to bulge. On May 18th with little warning, an earthquake of magnitude 5.1, triggered a massive collapse of the north face of the mountain. It was the largest known debris avalanche in recorded history. The magma inside of St. Helens burst forth into a large-scale pyroclastic flow that flattened vegetation and buildings over 230 square miles. More than 1.5 million metric tons of sulphur dioxide were released into the atmosphere. For more than 9 hours, a vigorous plume of ash erupted, eventually reaching 12 to 16 miles above sea level. The plume moved eastward at an average speed of 60 miles per hour. Ash from the eruption was found collecting on top of cars and roofs the next morning, as far as the city of Edmonton in Alberta, Canada.

11.7.1.2 Eyjafjallajökull Volcano, Iceland, 2010

The Eyjafjallajökull Volcano, one of Iceland's largest, had been dormant for nearly 2 centuries, but began to erupt on the evening of March 20th, 2010. On 14th April 2010, an explosion sent clouds of ash soaring as high as 11,000 meters into the atmosphere. Due to unusually stable jet streams present at the time of the eruption, the ash cloud reached mainland Europe, forcing the closure of airspaces in around 20 countries including large parts of the UK, Scandinavia and Northern Europe.

11.7.2 Analysis of the problem

Fall out of volcanic ash from eruptions not only causes significant travel disruption, failure of mechanical equipment, potentially severe damage to infrastructure but also raises concerns about the effects of deposited ash on natural resources, in particular vegetation, soils and water surfaces. Additionally there are public health concerns over the exposure of volcanic ash and risk of acute respiratory problems in populations, especially in those with pre-existing respiratory disease (e.g. asthma)

11.7.2.1 Physicochemical properties of volcanic ash

Ash is made up of volcanic glass and mineral phases (crystals). The composition of the glass and the different types of minerals that it contains and in what abundance will vary from volcano to volcano. Volcanic ash particles are <2mm in diameter and can be as fine as 1µm. Typically ash is insoluble in water; however it will contain soluble substances such as acids and salts, including chlorine, sulphate sodium, calcium, potassium, magnesium and fluoride which can leach out.

The analysis of ash samples as soon as possible after an eruption is the first step in the characterisation of the potential health and environmental hazard. Data on the chemical composition and ash grain size distribution from the Eyjafjallajökull volcanic eruption are available from samples taken between the 15th and 28th of April 2010.

11.7.2.2 Inhabited areas

Volcanic ash differs from common household dust in both composition and shape. It has a crystalline structure which is usually sharp, jagged and angular. Due to these physical characteristics, ash deposited in inhabited areas can cause surface abrasion when removed by wiping or brushing. This abrasive and mildly corrosive nature of ash can damage mechanical and electrical equipment, this also includes air handling systems. In buildings where air quality is critical e.g. hospitals this effect could be sever.

Ash has a static nature allowing it to cling to fabrics, hair and shoes, meaning the contamination can spread very easily. Ash deposits will absorb a considerable amount of water before being eroded and washed away, these deposits can therefore lead to pavements and roads becoming very slippery. In cases where ash is deposited in gutters and drains designed to collect water from roofs, the mass of ash can lead to the collapse of these gutters and even roofs, also ash absorbing water can become very heavy increasing the likelihood.

11.7.2.3 Food production systems

It is likely that pastures under areas covered by volcanic ash clouds, would receive some atmospheric deposits. If so, grazing livestock (predominantly sheep and cattle) are likely to ingest the material or inhale fine ash particles.

Certain volcanoes can release ash which consists of potentially toxic levels of fluoride, which poses most concern for livestock health, with the risk of causing fluorosis. Adverse effects on grazing livestock have been reported in the past following volcanic eruptions. For example, as a result of a less than 5 mm ash fall on the Rangitikei Plain (Taupo) during the 1995 Ruapehu eruption, approximately 2,000 ewes and lambs (2.5% of the area's sheep population) were killed by eating ash-affected pastures. Autopsies of the dead animals suggest fluorine poisoning or pregnancy toxaemia as the cause of death. Three Ayrshire dairy cows died at Atiamuri in June 1996. It was reported that they had stopped eating and showed signs of lethargy after swallowing quantities of ash; toxic levels of fluorine were found in the dead animals' blood.

11.7.2.4 Water environments

Ash that falls directly into natural watercourses can potentially harm and irritate gills of fish and increase particle concentration (turbidity) which can be harmful to functioning within aquatic ecosystems. However this would need a relatively high concentration of particles for potentially detrimental effects to happen. Fluoride can leach from ash which falls directly onto water surfaces again altering the water environment.

Another risk to water environments comes from gaseous emissions and acidic precipitation. One of the main gases produced during volcanic eruptions is sulphur dioxide. Increasing levels of atmospheric sulphur dioxide following an eruption have been shown to enhance the natural acidity of precipitation (both rain and snow). Also as emissions come into contact with the soil and vegetation - it can eventually pass through the soil (as soil capacity to bind sulphate is exceeded) reaching surface waters thus reducing the pH and affecting the aquatic chemistry of water courses. Finally snowmelt containing sulphuric acid rapidly by passes the majority of soil- running overland from patches of snow directly into lakes and water courses. In the past increased anthropogenic acid precipitation has resulted in acidic lakes, streams and freshwater. Even short term acidification episodes have been shown to result in episodic fish kills.

Ash fall out can also affect drinking water supplies. For examples the 1980 eruption of Mount St. Helens produced significant hydrologic and water quality effects in areas affected by ash fall. The day after the eruption, raw sludge lines were becoming plugged; and pumping difficulties were being experienced. As grit and ash passed through the system, the inability to pump raw sludge threatened secondary treatment processes. The ash was becoming toxic to the biological media in the plant; pre-treatment systems were failing and lagoon basins were becoming inundated with ash.

Table 11.7 Source, pathway, receptor criteria

Volcanic ash	Inhabited areas	Water environments	Food production systems
Source	Contaminated buildings, cars, roads	Contaminated surface waters	Contaminated pastures
Pathway	Inhalation of volcanic dust residues on surface	Decreased water pH levels	Ingestion of pasture by livestock Uptake by crops growing on farmland
Receptor	Humans inhaling dust	Aquatic life not adapting to acidic water levels Consumption of water by humans	Humans ingesting contaminated meat and crops

11.7.3 Recovery options with potential to be applied

Recovery options from the handbook that could potentially have been applied include;

Inhabited areas (Section 7):

(1) Restrict public access: To prevent the spread of contamination from areas with heavy ash fall out.

(3) Impose restrictions on transport: In extreme scenarios- the public could be advised against driving as this could re-suspend ash into the environment. Additionally, ash deposited on roads may cause a loss of friction, making the roads more slippery and a hazard to road users. During the Seveso Incident (Italy, 1976) stricter speed limits were imposed to prevent re-suspension of dioxins within the environment, the same principle could be applied for volcanic ash.

(15) Modify operation/cleaning of ventilation systems: It will be important to disable ventilation systems to limit contamination entering buildings and spreading between different areas of buildings.

(16) Cleaning Vehicle ventilation systems: Important to replace filters and clean thoroughly- may be an option to consider placing pre-filters.

(11) Vacuum cleaning: To remove dust particulates using High Efficiency Particulate Air vacuums (HEPA)

(8) Physical decontamination techniques: This includes wet wiping/ blotting, process of dampening surfaces first, followed by blotting to remove chemically contaminated dust.

(9) Other water based cleaning methods (scrubbing, shampoo, steam-cleaning): Using detergent and water to clean can be used following initial physical decontamination and vacuuming (e.g. carpets).

(17) Storage, covering, gentle cleaning of precious objects / personal items: Electronic equipment may be particularly sensitive to ash, such objects should be covered until the environment is completely ash free.

(20) Soil and vegetation removal: Dust on the surface of soil may be dampened down and then removed using a spade.

Food Production Systems (Section 5)

(4) Short term sheltering of animals: Keeping animals in shelters could provide short term protection from volcanic ash fallout.

(16) Ploughing methods: Ploughing could be used to disperse/mix ash into soil.

(19) Removal/ relocation of topsoil: This option will remove ash deposits on the surface of pastures.

(29) Clean feeding/ selective grazing regime: using stored clean feed to prevent grazing from contaminated pastures

(32) Culling of livestock: In extreme cases stock may not recover in the long term, and so may have to be humanely slaughtered as they would no longer be fit for purpose.

Water environments (Section 9)

(13) Natural attenuation (with monitoring): It is unlikely that ash deposits would cause significant damage to water environments. However monitoring pH levels after eruptions can be beneficial. Any temporary decreases in pH are likely to be buffered naturally.

(7) Modification of existing water treatment: water treatment systems can be used which could filter out ash particles.

11.7.4 Lessons learned

11.7.4.1 Inhabited areas

The Mt St. Helens eruption left over 850 miles of paved arterials and residential streets in surrounding areas requiring ash removal. The ash that fell was so fine it could not be removed by conventional equipment. Much of it became airborne when it came into contact with conventional graders and street sweepers. Also just placing water on the ash did not help the situation.

The city experimented with different material to find an ideal binder that could be placed on the streets and would bind the ash, making it easier and more efficient to pick-up. Eventually they found that damp saw dust was the best binder. Crews applied damp saw dust on the city streets with sanders, the damp saw dust and ash were then swept up with conventional street sweepers. However, Mount St. Helens erupted in a big logging area where saw dust was in large supply. The scale of saw dust required after ash falls could be potentially enormous, and might be impossible to consider in countries like the UK where saw dust may need to be imported by shipload. Additionally some types of sawdust are potent allergens- which if put onto streets could trigger community asthma outbreaks. Therefore the application of saw dust may not be practical in the UK.

Previous volcanic eruptions like Mount St. Helens have highlighted some of the lessons that need to be kept in mind when dealing with volcanic ash in inhabited areas:

- Cleaned by blowing with compressed air or dry sweeping should be minimized
- A dustless method of cleaning such as one with water and an effective detergent/wetting agent are recommended. Damp rag techniques should be used whenever possible to remove the substance from small surface areas or flooring. On those areas where damp rag techniques cannot be implemented (for example, carpets) vacuum cleaning methods should be applied.
- After vacuuming carpets and upholstery may be cleaned with a detergent shampoo. Avoid excess rubbing action because the sharp ash particles may cut textile fibres.
- Glass, porcelain enamel and acrylic surfaces may be scratched if wiped too vigorously. Use a detergent soaked cloth or sponge and dab rather than wipe.
- High-shine wood finishes will be dulled by the fine grit. Vacuum surfaces and then blot with a cloth treated to pick up ash. A tack cloth used by furniture refinishers should work well.
- Floor sweepers with side brushes should not be used to clear aisles and floors because they may re-entrain dust particles into the air.
- Ash-coated fabrics should be rinsed under running water and then washed carefully.
- For several months after an ash fall, filters may need replacing often.
- During and after ash fall, keeping ash out of buildings and homes will significantly reduce clean-up costs and prevent damage to surfaces, electronics, appliances, floors, and other equipment.
- Restrict access to a building or home to the most protected entrance to reduce the potential for ash to get inside.
- Establish an entry room or cleaning and decontamination rooms for people entering the building. Provide vacuum cleaners and brushes for people to remove as much ash as possible from clothing; provide shoe covers and disposable caps as appropriate. Remove outdoor clothing before entering a building as appropriate.

- Seal entrances and openings (doors, windows, dampers, air intakes). Place damp towels at door thresholds and other draft sources; tape drafty windows.
- Establish any necessary, extra cleaning procedures to protect the interior environment.
- Stockpile cleaning supplies, duct tape, disposal containers, vacuum cleaner bags and filters.
- Use extra (and heavier) filters for external air intakes.

11.7.4.2 Food production systems

- When pastures are subjected to ash falls, evacuation of livestock to areas with good quality feed and water may be prudent. Even after evacuation, long-term inhalation of ash and exposure to fluoride may result in reduced productivity. In some cases, stock may not recover in the long-term, with humane slaughtering being the best option.
- Where ash falls affect a large area, evacuation of stock would be extremely difficult due to the logistics of moving large numbers of stock and sourcing feed in areas unaffected by the ash. This may result in large losses of livestock through dehydration and starvation.
- Keeping the animals in sheds and using stored feed would be an option in the shirt-term

11.7.4.3 Water environments

- Water supply intakes should be closed before turbidity and acidity levels become excessive; regular monitoring will determine when such levels are reached and indicate when the intakes can be opened again.
- High turbidity levels are usually manageable if water-treatment filters are cleaned or replaced frequently. Filters can become blocked, however, if turbidity levels become excessive.
- When turbidity is high, precautionary warnings to "boil water" might be issued to residents because the suspended ash may have decreased the effectiveness of any disinfection or flocculation process.
- As the fine ash can remain in suspension for long periods (days to weeks) a coagulation-flocculating agent may need to be added. Alum is found to be the best agent.
- To reduce the physical damage to water supply systems, equipment and pumps should be covered when there is an impending ash fall, and the ash should be removed before normal operations resume.
- Farm water troughs are highly vulnerable to contamination and would most probably need to be emptied and refilled after ash falls.

11.7.5 References

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2 FEMA 1984:Federal Emergency Management Agency (FEMA), REGION x, 1984. The mitigation of ash fall damage to public facilities: Lessons learned from the 1980 eruption of Mount St.Helens, Washington

3 Guidelines on preparedness, before, during and after an ashfall. International Volcanic Health HAZARD Network (IVHHN). Available at: http://www.ivhhn.org./pamphlets.html [accessed March 2012]

4 Hesthagen, T. (1989). Episodic fish kills in an acidified salmon river in Southwestern Norway. Fisheries 14: 10-17.

5 Institute of Earth Sciences. Nordic volcanological centre. Available at: http://www.earthice.hi.is/page/IES-EY-CEMCOM and http://www.earthice.hi.is/page/ies_EYJO2010_Grain [accessed March 2012]

6 NIVA Communication (2010), Volcanic eruption under the ice of Eyjafjallajökull, Iceland April 2010: An evaluation of possible effects on freshwater resources in Norway and proposals for emergency preparedness and monitoring.

7 Offices of emergency management (2009) Municipality of Anchorage

8 OSHA (2003) Health and Technical Assistance for the world trade centre Dust Cleaning programme (final report). Available at: http://www.osha.gov/nyc-disaster/wtc-final-residential-dust-cleanup-programme.pdf [accessed March 2012]

9 Ramondetta M and Repossi A. Seveso: vent' anni dopo. Dall' incidente al bosco delle Querce. Capitolo 3: Le Richerche della fondazione No.32. Fondazione Lombardia per L'Ambiente.

10 Rubin, C.H., Noji E.K., Seligman, P.J., Holtz, J.L., Grande, J., Vittani, F. (1994). Evaluating a fluorosis hazard after a volcanic eruption. Archives of Environmental Health. 49, 395-401.

11 The international volcanic health hazard network [online] available at: www.ivhhn.org (accessed March 2012)

12 Volcanic ash- what it can do and how to prevent the damage. USGA Volcano Hazards programme site: http://volcanoes.usgs.gov/ash/index.html [accessed April 2012]

Appendix A Legislation and regulations Relevant to the UK Recovery Handbook for Chemical Incidents

A1 Ambient air

The Expert Panel on Air Quality Standards (EPAQS) was set up in 1991 to provide independent advice on air quality issues, in particular the levels of pollution at which no or minimal health effects are likely to occur. The UK Air Quality Strategy was developed in response to the Environment Act (1995)1 requiring the UK government and devolved administrations to develop objectives, standards and measures for improving ambient air quality.

More recent EU daughter directives on air quality were incorporated into law via the Air Quality Standards Regulations in June 2010 2. The most recent Air Quality strategy was published in July 2007 with the main objective of ensuring members of the public should have access to outdoor air without causing a significant risk to health where economically and technically possible 3.

A2 Soil

Part 2A of the Environmental Protection Act (1990) 4 is part of primary legislation which was introduced to provide a better way to identify and remediate contaminated land. It was inserted into the Environmental Protection Act (1990) by Section 57 of the Environment Act (1995)1, and came into force in April 2000 in England, July 2000 in Scotland and September 2001 in Wales. It was introduced to identify and regulate the remediation of land where contamination has resulted in significant harm or the potential for significant harm to human health or the environment.

The investigation and assessment of contaminated land is typically undertaken in a phased approach. To aid assessors with respect to human health risk assessment, the Environment Agency (and SEPA) has published non-statutory technical guidance and assessment software (i.e. the Contaminated Land Exposure Assessment (CLEA) model). As part of this work, they have published contaminant specific toxicological data and some generic assessment criteria (GAC) in the form of soil guideline values (SGVs) 5.

Other organisations and environmental consultancies have also produced GAC. The methodologies used to produce GAC/SGV can also be used to develop site specific assessment criteria (SSAC). These take into account areas where site conditions differ from the generic assumptions.

A3 Water environments

The regulations that govern the quality of water in the UK are listed in Table A3.

A3.1 Public water supplies

The government has set legal standards for drinking water quality. Most of these standards come directly from an obligatory European Community Directive and are based on World Health Organisation guidelines. The UK has adopted additional standards to ensure an extremely high quality of water. The standards are strict and generally include wide safety margins.

A3.2 Private water supplies

Private water supplies are monitored for water quality by local authorities under the Private Water Supplies Regulations (see Table A3). These Regulations apply to private supplies for purely domestic purposes, or are used in commercial food production, that is to say the making, processing, preserving, preparing or marketing of food or drink (including water) or sale for human consumption. The Regulations contain the same water quality standards as those for public drinking water supplies but the frequency of monitoring and the parameters tested will vary according to how many people use the supply, its use, the volume of water used daily and based on an assessment of the risks to the supply as determined by the relevant local authority. This is determined from a risk assessment undertaken by the local authority.

Owners and users of private water supplies need to be aware of the potential for water contamination and what can be done to reduce the risk. Private water supplies are not subject to the Directions issued by the Secretary of State in respect of national security or emergency planning, and any emergency arrangements are entirely dependent upon what an individual local authority might have in place. Local authorities may use powers under the Public Health Act (1936) 6 to close or restrict the use of water from contaminated private sources of supply. Sections 26 and 27 of the Water (Scotland) Act 1980 7 provide local authorities in Scotland with the power to apply to the Sheriff to make an order to close or restrict the use of water from a polluted source including wells. Section 80 of the Water Industry Act, 1991 8 could possibly be used to improve supplies but there is a 28 day minimum time on the notice that has to be given. Contingencies for the replacement of a private supply in the event of a chemical incident need further consideration.

Table A3: Regulations and legislation relevant to Water environments in the UKRHCI
Control of Pollution (Applications, Appeals and Registers) Regulations 1996 SS1 2971
Control of Pollution (Oil Storage) (England) Regulations 2001 SI 2954.
EC Groundwater Directive 80/68/EEC.
European Council directive 98/83/EC of 3 November 1998 on quality of water intended for human consumption. Official Journal L 330, 05/12/1998.
Environmental Damage (Prevention and Remediation) (Wales) Regulations 2009 SSI 995.
Environmental Damage (Prevention and Remediation) Regulations 2009 SI 153
Environmental Permitting (England and Wales) (Amendment) Regulations 2011 SI 2043.
Groundwater Regulations 1998 SI 2746.
Groundwater Regulations (Northern Ireland) 1998.
Nitrate Pollution Prevention (Wales) Regulations 2008 SI 3143.
Protection of Water Against Agricultural Nitrate Pollution (Scotland) Amendment Regulations 2005 SSI 593.
Trade Effluent (Prescribed Processes and Substances) (Amendment) Regulations 1990 SI 1629.
Sewerage (Scotland) Act 1968
Sewerage Services (Northern Ireland) Order 1973
Sewage Sludge Directive 86/278/EEC.
The Natural Mineral Water, Spring Water and Bottled Drinking Water (England) (Amendment) Regulations 2011.
The Private Water Supplies (England) Regulations 2009
The Private Water Supplies (Scotland) Regulations 2006
The Private Water Supplies (Northern Ireland) Regulations 2009.
The Water Supply (Water Quality) Regulations 2000
The Water Supply (Water Quality) Regulations 2001 (Wales)
The Water Supply (Water Quality) (Scotland) Regulations 2001
The Water Supply (Water Quality) Regulations (Northern Ireland) 2007
UK Parliament 1980, water (Scotland) Act
UK Parliament 1991, Water Industry Act 1991
Urban Waste Water Treatment (England and Wales) Regulations 1994 (as amended)
Urban Waste Water Treatment (Scotland) Regulations 1994 (as amended)
Urban Waste Water Treatment (Northern Ireland) 1995 (as amended)
Urban Waste Water Directive 91/27/EEC
Water Act 2003.

Water Environment (Controlled Activities) (Scotland) Regulations 2011 SSI 209.

Water Environment (Diffuse Pollution) (Scotland) Regulations 2008 SSI 54.

Water Environment (Groundwater and Priority Substances) (Scotland) Regulations 2009 SSI 420.

Water (Prevention of Pollution) (Code of Practice) (Scotland) Order 2005 SSI 63.

Water Environment and Water Services (Scotland) Act 2003.

Water (Scotland) Act 1980 (c.45) Sections 26 and 27.

Water Industry (Scotland) Act 2002.

Water Industry Act 1991 (England and Wales).

Water Industry Act 1999.

Water (Northern Ireland) Order 1999 (as amended).

Water Resources Act 1991 (Amendment) (England and Wales) Regulations SI 3104.

Water Resources (Abstraction and Impounding) Regulations 2006 SI 641.

Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (Wales) Regulations 2010 SI 1493.

Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (England) (Amendment) Regulations 2010 SI 1091.

Water Protection Zone (River Dee Catchment) (Procedural and Other Provisions) Regulations 1999 SI 916.

Water Resources (Environmental Impact Assessment) (England and Wales) Regulations 2003 SI 164.

Water and Sewerage Services (NI) Order 1973.

Water Services (Scotland) Act 2003.

Water Quality (Scotland) Regulations 2010 SSI 95.

Emergencies

Security and Emergency Measures (Water and Sewerage Undertakers) Direction 1998 and 2006

Security and Emergency Measures (Scottish Water) (Scotland) Directions 2002

Recreational and coastal waters

Control of Pollution Act (1974) as amended.

Council Directive 2000/60/EC establishing a framework for Community action in the field of water policy (Water Framework Directive).

Environment Protection Act 1990.

Environment Act (1995).

Environmental Damage and Liability Regulations 2009.

Flood and Water Management Act (2010).

Marine and Coastal Access Act 2009.

The Bathing Water Regulations (2008).
Transfrontier Shipment of Waste Regulations 2007 SI 1711.

A4 Waste categorisation and legislation in the UK

Some of the recovery options recommended in this Handbook will result in the generation of waste or waste by-products (e.g. water run-off) due to the nature of the recovery and clean-up process.

Remediation work may generate large quantities of waste which must be managed appropriately. When dealing with waste from the recovery phase of a chemical incident it is necessary to determine whether the contaminated material is hazardous or not, how it should be removed and whether it should be treated on site or off site. Hazardous waste is essentially any waste which contains hazardous properties that may render it harmful to human health or the environment. The determination should be based on the Hazardous Waste Regulations 2005 (HWR) and the List of Waste (LoW) Regulations 2005, also known as the European Waste Catalogue (EWC).

The Environmental Protection Act (1990) 9 imposes a duty of care on all those who import, produce, carry, keep, treat and dispose of controlled waste. In England and Wales, the Environment Agency (EA) is the competent authority in dealing with contaminated waste. If waste is determined as hazardous the Environment Agency must be consulted for the disposal of waste.

The Northern Ireland Environment Agency (NIEA) is the competent authority for dealing with contaminated waste in Northern Ireland. Details of transfer stations within Northern Ireland that are licensed to accept hazardous waste can be obtained from NIEA.

In Scotland, the Scottish Environment Protection Agency (SEPA) is the competent authority. Contaminated waste is classified as Special Waste and is essentially any waste with hazardous properties which may render it harmful to human health or the environment. Elsewhere in the UK and the EU, it is referred to as being Hazardous waste. Guidance on how to classify and assess special waste can be found in available national guidance 10.

When managing hazardous waste several methods may be considered. These would include:

- If necessary, temporary and safe storage of the waste.
- Preliminary treatment and decontamination.
- Preparation of waste for transport removal (i.e. packing appropriately).
- Transportation of the waste.
- Disposal or other treatment.

The broad categories of chemicals and how they are usually managed are:

- Agricultural Chemicals □ Disposed of at treatment plant or via incineration.
- Toxic Chemicals □ Disposed of at a treatment plant.
- Corrosive Chemicals □ Disposed of at a treatment plant.
- Organic Chemicals □ Normally incinerated, depending on strength.

A remedial action plan is required to deal with generated waste appropriately. Initially, laboratory analysis of the waste may be required to determine its chemical composition (if not known) and concentration to identify whether it falls into the hazardous or non-hazardous category, and to determine its ignitability, corrosiveness, reactivity and toxicity. Knowledge of these characteristics determines which precautions are necessary to ensure the safety of those involved in the proper treatment and disposal of the waste.

The regulations that govern the classification and management of waste in the UK are listed in Table A4.

Table A4: Regulations and legislation relevant to management and transport of waste

Classification of waste
Control of Pollution Act 1974 40 Part III.
Control of Pollution (Amendment) Act 1989 c.14.
Environment Protection Act 1990.
European Waste Catalogue.
Hazardous Waste (England and Wales) (Amendment) Regulations 2009 SI 507.
Hazardous Waste (Amendment) Regulations (Northern Ireland) 2005 SR 461.
List of Wastes (England) (Amendment) Regulations 2005 SI 1673.
List of Wastes Regulations (Wales) 2005
List of Wastes (Amendment) Regulations (Northern Ireland) 2005 SR 462.
Planning (Hazardous substances) (Scotland) Act 1997.
Waste (England and Wales) Regulations 2011 SI 988.
Waste (Scotland) Regulations 2011 SSI 226.
Waste Information (Scotland) Regulations 2010 SSI 435.
Waste Management Licensing (Scotland) Regulations 2011 SSI 228.
Transport
Carriage of Dangerous Goods by Rail (Northern Ireland) Regulations 1998 SR 131.
Carriage of Dangerous Goods by Rail Regulations 1996 SI 2089.
Carriage of Dangerous Goods by Road Regulations (Northern Ireland) 1997 SR 248.
Carriage of Dangerous Goods by Road Regulations 1996 SI 2095.
Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 SI 1348.
Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) Regulations (Northern Ireland) 2011 SR 365.
Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 SI 716.
Chemicals (Hazard Information and Packaging for Supply) (Amendment) Regulations (Northern Ireland) 2008 SR 424.
Control of Major Accident Hazard (Amendment) Regulations 2008 SI 1087.
Control of Substances Hazardous to Health (Amendment) Regulations 2004 SI 3386.
Control of Substances Hazardous to Health (Amendment) Regulations (Northern Ireland) 2005 SR 165.

Controlled Waste (Duty of Care) (Amendment) Regulations (Northern Ireland) 2004 SR 277.

Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations 1991 SI 1624.

Controlled Waste (Registration of Carriers and Seizure of Vehicles) Regulations (Northern Ireland) 1999 SR 362.

Environment Protection (Duty of Care) Regulations 1991 SI 2839.

EU Regulation on Shipments of Waste 1013/2006.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) Regulations 2011

Transfrontier Shipment of Waste (Amendment) Regulations 2008 SI 9.

Disposal of waste

Control of Pollution Act 1974

Control of Pollution (Amendment) Act 1989 c.14

Control of Pollution (Application and Registers) Regulations (Northern Ireland) 2001 SR 284.

Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 2003 SSI 531.

Controlled Waste Regulations 1992 SI 588

Controlled Waste (Amendment) Regulations 1993 SI 566.

Controlled Waste (Amendment) Regulations (Northern Ireland) 2003 SR 404.

EC Framework Directive on Waste 75/442/EEC as amended by Council Directive 91/156/EEC and adapted by Council Directive 96/350/EEC.

EC Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC)

EC Landfill Directive 1999/31/EC

EC Waste Incineration Directive 2000/76/EC

EC Groundwater Directive 80/68/EEC

Environment (Northern Ireland) Order 2002 SI 3153 (including amendments up to 2004).

Environmental Permitting (England and Wales) (Amendment) Regulations 2011 SI 2043.

Environment Protection Act 1990

Environmental Protection (Prescribed Processes and Substances) Regulations 1991 (as amended)

Environment Protection (Disposal of Polychlorinated Biphenyls and other Dangerous Substances) (Northern Ireland) Regulations 2000 SR 232.

Industrial Pollution Control (Prescribed Processes and Substances) (Amendment) Regulations (Northern Ireland) 2003 SR 96.

Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC)

Groundwater Regulations 1998

Groundwater Regulations (Northern Ireland) 1998
Landfill (Amendment) Regulations (Northern Ireland) 2005 SR 101.
Landfill (Scotland) Regulations 2003 SSI 235
Landfill (Scotland) Amendment Regulations 2003 SSI 343.
Planning (Control of Major-Accident Hazards) (Scotland) Regulations 2009 SSI 378.
Pollution Control and Local Government (Northern Ireland) Order 1978 DR 1049 (NI 19).
Pollution Prevention and Control (England and Wales) Regulations 2000 (as amended)
Pollution Prevention and Control (Scotland) Amendment Regulations 2009 SSI 336.
Pollution Prevention and Control (Public Participation etc.) (Scotland) Regulations 2005 SSI 510.
Pollution Prevention and Control (Amendment) Regulations (Northern Ireland) 2011 SR 212.
Pollution Prevention and Control (Miscellaneous Amendments) Regulations (Northern Ireland) 2006 SR 98.
Pollution Prevention and Control Act 1999 (PPCT)
Rendering (Fluid Treatment) (England) Order 1991
Rendering (Fluid Treatment) (Scotland) Order 2001 (made under the Animal Health Act 1981).
Rendering (Fluid Treatment) (Northern Ireland) Order 2001 (made under the Diseases of Animals (Northern Ireland) Order 1981.
Sewerage (Scotland) Act 1968
Sewerage Services (Northern Ireland) Order 1973
Sewage Sludge Directive 86/278/EEC.
Sludge (Use in Agriculture) Regulations 1989 (as amended)
Sludge (Use in Agriculture) Regulations (Northern Ireland) 1990 (as amended)
Special Waste Regulations 1996 SI 972
Special Waste (Amendment) Regulations 2004 SSI 112
Special Waste Amendment (Scotland) Regulations 2004 SSI 112.
Urban Waste Water Treatment (England and Wales) Regulations 1994 (as amended)
Urban Waste Water Treatment (Scotland) Regulations 1994 (as amended)
Urban Waste Water Treatment (Northern Ireland) 1995 (as amended)
Urban Waste Water Directive 91/27/EEC
Waste and Contaminated Land (Amendment) Act (Northern Ireland) 2011
Waste (England and Wales) Regulations 2011 SI 988.
Waste (Northern Ireland) Regulations 2011 SR 127.
Waste (Scotland) Regulations 2011 SSI 226.

Waste Incineration (England and Wales) Regulations 2002
Waste Incineration (Scotland) Regulations 2003 SSI 170
Waste Incineration (Amendment) Regulations (Northern Ireland) 2004 SR 35.
Waste Information (Scotland) Regulations 2010 SSI 435.
Waste Management (England and Wales) Regulations 2006 SI 937
Waste Management Regulations (Northern Ireland) 2006 SR 280.
Waste Management Regulations 1996 SI 634.
Waste Management (Miscellaneous Provisions) Regulations (Northern Ireland) 2008 SR 18.
Waste Management Licensing (Amendment) 1995 SI 288
Waste Management Licensing (Amendment) Regulations (Northern Ireland) 2009 SR 76.
Waste Management Licensing (Scotland) Regulations 2011 SSI 228.
Water Environment and Water Services (Scotland) Act 2003
Water Industry Act 1991 (England and Wales)
Water (Northern Ireland) Order 1999 (as amended)
Water Resources Act (England and Wales) 1991
Water and Sewerage Services (NI) Order 1973
Water Services (Scotland) Act 2003

A4.1 Transport of waste

Transport and disposal of potentially substantial volumes of hazardous waste present particular challenges. The Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and Northern Ireland Environment Agency (NIEA) should be consulted for advice on the availability of suitable landfills and other possible options. The latter might include possible extension of any temporary storage arrangements already permitted.

Debris contaminated with material that in its self would be classified as dangerous in transport (e.g. asbestos) is subject to the transport of dangerous goods legislation whatever the mode of transport used.

Transport of material from the site must be carried out safely and securely in suitable road, rail or inland waterway transport units, particularly if contaminated material is involved. Where such material is classified as dangerous in transport, transport units specified in modal regulations must be used in accordance with any provisions applying to them. For other contaminated material, the transport must be capable of entirely containing the material to prevent any loss during transport. A Dangerous Goods Safety Advisor should be appointed to provide competent and professional advice.

Experience has shown that there may be a need to identify and establish an intermediate temporary site, or sites, between the site of the incident itself and the ultimate final destination(s) of debris. Such sites may be required to aid forensic investigation as well as sorting large amounts of contaminated waste. Solids should be transported in bulk transport units fitted with liners that can be closed for transport or in sift-proof receptacles.

A4.2 Waste disposal

Several options exist for waste disposal and these must be determined upon the advice of the appropriate Environment Agencies. The 2 major options would be:

- Off-site treatment and disposal: Waste is accumulated into containers/ tanks and sent off-site for disposal. The types of containers/ tanks to be used and their labelling is dependent on the physiochemical composition of the constituents of the waste. Appropriate guidance would be provided. Restrictions on transportation and disposal facilities and these would be permitted by the relevant Environment Agencies, or taken over by themselves.
- On site management: Waste is treated, stored or disposed of on-site utilising temporary units or corrective action management units. This may require the use of mobile plants (Part B)*.

A4.3 Management of solid and liquid waste arising from remediation

Clean-up will result in the generation of solid and liquid waste. It is imperative to manage this waste in an environmentally acceptable and responsible way to minimize the risks to health and safety of workers, the public and the environment. The management of a site during recovery will potentially produce large quantities of contaminated aqueous slurries and solid rubble. Additionally, if statutory measures are put in place to restrict food consumption, there may be large volumes of biodegradable waste crops and farm produce, including animal carcasses and milk, requiring disposal.

For solid wastes, the responsible authority (which for many emergencies will be the local authority (LA)) needs to consider an interim recovery strategy such as the temporary storage of hazardous waste (i.e. in containers at a sports stadium or military site). This would give operators sufficient time to receive, store, treat and dispose of the wastes. Throughout the procedure, the LA should be in constant communication with the relevant Agencies and community to inform them about the temporary storage of this waste, the intended transportation routes and disposal locations and risks in order to maintain public confidence and cooperation.

Contaminated soils and solid residues from liquid slurries are likely to be disposed at hazardous waste landfills. Disposal arrangements would need to be discussed with the landfill operator.

A4.4 Management of contaminated waste (refuse), goods and personal items

During the recovery operations there will be other significant waste generated because of the nature of the work itself, such as lightly contaminated bags holding contaminated clothing and protective equipment which has been used. This waste will also require appropriate decontamination or treatment/destruction (usually incineration). In principle these wastes are similar to other hazardous substances which are commonly disposed from hospitals and research laboratories and are therefore treated as ‘clinical waste’. Such wastes would be taken to incineration plants around the UK with the appropriate permits or licences.

A4.5 Management of contaminated waste water: rain and natural run-off

The UK Water Protocol for the disposal of contaminated water 11 provides useful guidance on dealing with incidents involving CBRN contamination of water and disposal of waste water resulting from decontamination work. Run-off water and rinse water from decontamination may contain high concentrations of chlorine (if washing with sodium hypochlorite solution has been undertaken). The wastewater must be intercepted and treated to neutralise its chlorine content since this is hazardous to the environment and water treatment works. In urban areas, road drainage systems are particularly vulnerable. Storm water drains may need to be blocked or diverted to holding tanks before decontamination is carried out, in accordance with the UK guidance[11].

The water supplies and sewerage services to a particular area are provided by the local water companies, although it should be noted that in some areas 2 separate companies may be involved in the provision of services. Their expertise on local drainage systems and effluent interception will be very important when planning wet decontamination operations, especially to predict and avoid impacts on watercourses and drinking water supplies[12].

A5 Worker exposure limits

Three categories are mentioned in the ‘Personal Protective Equipment at Work Regulations 1992, I being Simple, II Intermediate and III Complex, corresponding to increases in the level of protection. However, excessive, unnecessary and clearly visible worker protection may contribute to the anxiety of local inhabitants of the area; therefore its use of PPE should be justified[13]. Following a large scale chemical incident it may be the case that volunteers are acting as recovery workers and hence require increased and intense training in the use of PPE.

Occupational exposure limits (OELs) were first introduced in 1989 via the Control of Substances Hazardous to Health Regulations (COSHH)[14, 15]. This included the setting of Maximum Exposure limits (MELs) and Occupational Exposure Standards (OESs).

WELs are specified in national guidance[16] and this should be referred to for up-to-date values. However, WELS are not available for a large proportion of chemicals. In these cases expert advice should be sought and a risk assessment undertaken.

Certain chemicals have separate regulations to control exposure in the workplace. For example, Asbestos is considered separately[17].

Secondary exposure of workers following implementation of recovery options also needs to be considered. For instance, if a decision is taken to asphalt over an area of chemical contamination, workers may be required access this area again in the future for other purposes (e.g. maintenance of water pipes)[12].

A6 Food

Slaughterhouses, cutting plants and other meat plants produce material that is either unfit or not intended for human consumption, at which point it is defined as animal by-products (ABP). ABP are the entire body, part of an animal or a product of animal origin which is not intended for human consumption. For example, material may still be fit for human consumption but have no commercial value or not be intended for use on aesthetic grounds. Once material becomes ABP it cannot later revert to being a foodstuff.

There are regulations (see Table A6) that lay down strict animal and public health rules for the collection, transport, storage, handling, processing and use or disposal of all animal by-products (ABPs). These regulations are in place to ensure animal by-products:

- Do not compromise the hygienic production of meat by being inadvertently or fraudulently diverted away from the disposal route back into the food chain.
- That human and animal health is protected and pathogens are not inadvertently spread.
- That they are safely and suitably handled and disposed of.

Animal by-products can be split into 3 categories and examples are given below:

Category 1: pose a risk to animal or human health and may contain SRM (specified risk material).

- Products suspected of containing EC prohibited non-medicinal treatments or illegal substances. This includes chemical contaminants that exceed permitted levels laid down in community legislation e.g. elevated dioxin or heavy metal contaminants (but does NOT include products containing residues of permitted veterinary drugs).

Category 2: pose a risk to animal or human health.

- Sludge collected from 6mm waste water drain screenings in non-ruminant (pig and poultry) slaughterhouse.
- Products containing residues of veterinary drugs and contaminants.
- Animals and parts of animals that die other than by being culled for human consumption, including those killed for disease control purposes (unless these fall into Category 1).
- Any meat found to have residues of substances which may pose a risk to animal or human health.

Category 3: Less of a risk to human/animal health - may be used in pet food.

- Foodstuffs containing meat or products of animal origin no longer intended for human consumption due to commercial reasons or packaging defects.

This categorisation will influence potential waste disposal options. Any waste falling into the above categories could not normally be disposed of to landfill. Options for disposal would include rendering, incineration, or disposal at an approved biogas or composting plant. Certain category 1 products may only be disposed of by incineration. Category 2 wastes may be disposed of to kennels or packed hounds if relevant authorisations are obtained. Category 3 hides and skins may be returned by producers to their own premises after an animal has been taken to a slaughterhouse. Category 2 wastes may be disposed of to kennels or packs of hounds if relevant authorisations are obtained. Certain category 1 products may only be disposed of by incineration.

For discharge to sewers, premises undergoing slaughtering of animals are required to have drain traps or gratings with a maximum size of 6mm in place to collect category 1 and 2 material. If waste water is discharged to a sewer in plants processing ruminant carcases the premises should have drain traps or gratings with a maximum size of 4mm in place [18].

The regulations that govern the classification and management of contaminated food produce in the UK are listed in Table A6.

Table A6: Regulations and legislation relevant to Food Production Systems in the UKRHCI

General food safety
Food and Environment Protection Act (FEPA) 1985 (including updates).
The Food Safety Act 1990 (as amended)
The General Food Law Regulation (EC) 178/2002.
The General Food Regulations 2004 (as amended).
The Food and Environment Protection Act 1985 (c48).
The Contaminants in Food (England) Regulations 2010
The Contaminants in Food (Scotland) Regulations 2010
The Contaminants in Food (Wales) Regulations 2009
The Contaminants in Food (Northern Ireland) Regulations 2009
Food Irradiation (England) Regulations 2009
Food Protection (Emergency Prohibitions)(Radioactivity in Sheep)(England) Order 1991
Food Protection (Emergency Prohibitions)(Lead in Ducks and Geese)(England)Order 1992
EU White Paper on Food Safety (EU Regulation 882/2004)
Arsenic in Food Regulations 1959
Chloroform in Food Regulations 1980
Animal by-products
Animal By-Products (Enforcement) (England) Regulations 2011 SI 881.
Animal By-Products (Enforcement) (Amendment) Regulations (Northern Ireland) 2011 SR 258.
Animal By-Products Regulation (Wales) 2006.
Animal By-Products Regulations (Northern Ireland) 2003.
EU Regulation laying down health rules as regards animal by-products and derived products not intended for human consumption 1069/2009.
Regulation (EC) No. 1774/2002 (ABPR) made under the European Communities Act 1972.
Animal Welfare
Animal Welfare Act 2006
Agriculture (Miscellaneous Provisions) Act 1968 (c34)
EU General Directive 98/58/EC.

EU Laying Hens Directive 99/74/EC.

EU Calves Directive 91/629/EEC

EU Pigs Directive 91/630/EEC (as amended).

The Welfare of Farmed Animals (England) regulations 2009.

The Welfare of Farmed Animals (Scotland) regulations 2000.

The Welfare of Farmed Animals (Wales) regulations 2001.

The Welfare of Farmed Animals (Northern Ireland) regulations 2000.

The Protection of Animals Act 1911

The Welfare of Animals (Transport) (England) Order 2006

The Welfare of Animals (Transport) (Scotland) Order 2006

The Welfare of Animals (Slaughter or Killing) Regulations 1995 (as amended) (England, Scotland and Wales)

The Welfare of Animals (Slaughter or Killing) Regulations 1996 (as amended) Northern Ireland.

EU Directive 93/119/EC

Animal Feed (England) Regulations 2010

Feed (Hygiene and Enforcement) (England) Regulations 2005

Foraging, hunting and fishing

The Wildlife and Countryside Act 1981 (as amended)

The Game Act 1970 (as amended).

Game preservation (Northern Ireland) 2002.

Salmon and Freshwater Fisheries Act 1975 (as amended).

Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003.

Land restrictions (including conservation)

Action programme for Nitrate Vulnerable Zones (England and Wales) Regulations 1998 (as amended)

Action programme for Nitrate Vulnerable Zones (Scotland) Amendment Regulations 2009 SSI 447.

Action programme for Nitrate Vulnerable Zones (Northern Ireland) Regulations 1999 (as amended).

Conservation of Habitats and Species Regulations 2010 SI 490.

Countryside and Rights of Way Act 2000.

EC Nitrate Directive 91/678/EEC.

Environmental Liability (Scotland) Regulations 2009.
EU Regulation on the Protection of Species of Wild Fauna and Flora by Regulating Trade 338/1997.
Environment Act 1995.
Environmental Damage (Prevention and Remediation) Regulations 2009 SI 153.
Environmental Impact Assessment (Agriculture regulations for semi-natural and uncultivated land)
Environmental Impact Assessment (EIA) (Agriculture) Regulations 2007
The Environmental Impact Assessment (Agriculture) (Scotland) Regulations 2006
Nitrate Pollution Prevention (Amendment) Regulations 2009 SI 3160.
Environmental Impact Assessment (Agriculture) Regulations (Northern Ireland) 2007
Wildlife and Countryside Act 1981 (as amended).
Ancient Monuments and Archaeological Areas Act (England, Wales and Scotland) 1979.
Historic Monuments and Archaeological Objects (Northern Ireland) Order 1985.
EC Habits Directive 92/43/EEC.
EC Wild Birds Directive 79/409/EEC.

A7 References

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14 Statutory Instrument 2010 No 1001. Environmental Protection. The Air Quality Standards Regulations (2010). Available [April 2012] at; http://www.legislation.gov.uk/uksi/2010/1001/pdfs/uksi_20101001_en.pdf

15 Security and Emergency Measures (water and sewerage undertaker) Direction 1998- Notification and Guidance. Available [April 2012] at: http://dwi.defra.gov.uk/stakeholders/guidance-and-codes-of-practice/SEMD%20DIRECTION%201998.pdf

16 UK Parliament. The Environmental Protection Act (1990) (c.43). Available [April 2010] at; http://www.legislation.gov.uk/ukpga/1990/43/contents

17 The Environment Agency. Using science to create a better place. Using Soil Guideline Values. Available [April 2012] at; http://www.environment-agency.gov.uk/static/documents/Research/SCHO0309BPQM-e-e.pdf

18 UK Parliament (1936). Public Health Act 1936. Available [April 2012] at; www.legislation.gov.uk/ukpga/Geo5and1Edw8/26/49

19 UK Parliament 1980, water (Scotland) Act. Available [April 2012] at: www.legislation.gov.uk/ukpga/1980/45

20 UK parliament 1991, Water Industry Act 1991. Available [April 2012] at: www.legislation.gov.uk/ukpga/1991/56/contents

21 UK Parliament. The Environment Protection Act (1990). Available [April 2012] at http://www.legislation.gov.uk/ukpga/1990/43/contents

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23 Water UK. Protocol for the disposal of contaminated water (2003). Available [April 2012] at; http://www.water.org.uk/home/policy/positions-old/disposal-contaminated-water

24 Nisbet A, Brown J, Jones A, Rochford H, Hammond D and Cabianca T. HPA-RPD-064 – the UK Recovery Handbooks for Radiation Incidents v3: 2009. Available [March 2012] at; https://www.gov.uk/government/publications/uk-recovery-handbooks-for-radiation-incidents-2015

25 HSE (1992). Personal protective equipment (PPE) at Work Regulations (1992) as amended (2005). Available [April 2012] at; http://www.hse.gov.uk/press/2005/e05116.htm

26 UK Parliament (2002). The Control of Substances Hazardous to Health Regulations 2002. Available [April 2012] at; http://www.legislation.gov.uk/uksi/2002/2677/regulation/1/made

27 HSE (2004). Control of Substances Hazardous to Health Regulations 2002 (as amended in 2004). Available [April 2012] at; http://www.hse.gov.uk/foi/internalops/fod/oc/200-299/273_20.pdf.

28 HSE (2005). EH40 Workplace Exposure Limits. Available [April 2012] at; http://www.hse.gov.uk/pubns/books/eh40.htm

29 UK Parliament (2006). The Control of Asbestos Regulations 2006. Available [April 2012] at; http://www.legislation.gov.uk/uksi/2006/2739/introduction/made

30 FSA (2006). Waste management: MHS Manual for Official Controls Chapter 2.8: Animal By-Products. Food Standards Agency.

Appendix B Experimental techniques

What are experimental techniques?

These are techniques that have been used in small scale to assess their efficiency and applicability. In most cases these techniques are not yet available for use in large scale incidents and are still undergoing field trials. In other cases, the techniques have rarely been implemented and thus lack sufficient evidence of effectiveness and as a result are not directly recommended for consideration in the main section of the Handbook. However, experimental techniques may be applicable to some incidents, and would require discussion and consideration on a site and incident specific bases.

B1 Constructing a monolith

Construction of a monolith involves casting the contaminated building and equipment in concrete - effectively sealing in the contamination. The principal advantage of this approach is that virtually all recovery worker contact with contaminated equipment or surfaces is eliminated once the loose debris has been cleared and the surfaces have been coated with lacquer (to prevent the migration of contamination during the construction effort). However the disadvantages of this option are numerous:

- Technically, it may be difficult to ensure that pipes are not broken while the concrete is being poured and is setting.
- The effects of weathering and/or flooding might lead to fissuring of the concrete and water ingress - eventually posing a risk of contaminated water leaking from the structure.
- Environmentally, the monolith would be aesthetically unattractive and would afford only a temporary solution.
- The option does not actually remove the contaminant, instead sealing it into a visible structure; this is likely to be perceived negatively by the local population of the affected area, serving as a constant reminder of the incident.

This option was considered during the chemical explosion incident in Seveso Italy (1976)[1], but was never actually implemented.

B2 Phytoremediation

Phytoremediation can be identified as the use of the natural ability of vegetation to extract, accumulate, store and/or degrade organic and inorganic contaminants in soils and groundwater. This process can occur via a number of mechanisms which are described in Table B2.

Phytoremediation is used for the remediation of metals radionuclides, Pesticides, explosives, and Volatile Organic Compounds (VOCs). For radioactive substances, chelating agents are sometimes used to make the contaminants amenable to plant uptake.

Table B2: Phytoremediation techniques

Method	Description
Phytoextraction	The use of plants which can take up contaminants via the roots and store them in other parts such as leaves and stem. This method is used primarily for wastes containing metals such as lead. The metals are stored in the plants aerial shoots; which are harvested and either smelted for potential metal recycling/recovery or are disposed of as a hazardous waste [2]
Phytocontainment	The use of plants to establish a cover layer on sites with the aim of reducing the migration of contaminants and restricting the availability of contaminants to humans by minimising surface erosion, runoff and dust generation. Phytocontainment can also be used to reduce groundwater contamination through the interception of soil water by plant roots. Additionally some chemical compounds produced by certain plants immobilise contaminants rather than degrade them- thus effectively containing them.
Rhizosphere biodegradation	In this process, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil, these microorganisms enhance biological degradation.
Phytodegradation	In this process, plants actually metabolize and destroy contaminants within plant tissues.
Phyto-volatilization	In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
Rhizofiltration	Rhizofiltration is similar to phytocontainment, but the plants used for clean-up are raised in greenhouses with their roots in water, this system can be used for ex-situ groundwater treatment.
Hydraulic Control	In this process, trees indirectly remediate by controlling groundwater movement. Trees act as natural pumps when their roots reach down towards the water table and establish a dense root mass that takes up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day and a cottonwood can absorb up to 350 gallons per day.

Advantages of phytoremediation:

- The cost of the phytoremediation is lower than that of traditional processes both in situ and ex situ
- Plants can be easily monitored
- The method is associated with the possibility of the recovering and re-using valuable metals.
- Phytoremediation is a naturally occurring method which is solar driven and thus preserves the environment in a more natural state.

Limitations and considerations of phytoremediation:

- Plants often grow slowly due to chemical toxicity, and thus do not provide sufficient biomass for ’rapid’ remediation. If contaminant concentrations are too high, plants may die.

- The toxicity and bioavailability of biodegradation products is not always known.
- Degradation by-products may be mobilized in groundwater or bio-accumulated in animals. Additional research is needed to determine the fate of various compounds in the plant metabolic cycle to ensure that plant droppings and products do not contribute toxic or harmful chemicals into the food chain.
- Disposal of harvested plants can be a problem if they contain high levels of heavy metals.
- The depth of the contaminants limits treatment. The treatment zone is determined by plant root depth. In most cases, it is limited to shallow soils, streams, and groundwater. Pumping the water out of the ground and using it to irrigate plantations of trees may treat contaminated groundwater that is too deep to be reached by plant roots. Where practical, deep tilling, to bring heavy metals that may have moved downward in the soil closer to the roots, may be necessary.
- Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. However, researchers are finding that the use of trees (rather than smaller plants) allows them to treat deeper contamination because tree roots penetrate more deeply into the ground.
- The success of remediation depends in establishing a selected plant community. Introducing new plant species can have widespread ecological ramifications. It should be studied beforehand and monitored. Additionally, the establishment of the plants may require several seasons of irrigation. It is important to consider extra mobilization of contaminants in the soil and groundwater during this start-up period.
- Some phytoremediation transfers contamination across media, (e.g., from soil to air).

B2.1 Technology development status

Phytoremediation is a broad technology type that has been successfully demonstrated for some contaminants and is experimental for others. Research is underway to understand the role of phytoremediation to remediate perchlorate, a contaminant that has been shown to be persistent in surface and groundwater systems.

Plants frequently used include: Apocnum Cannabinum, Barley, Festuca Arundinacea, Hydrilla and poplar trees [2].

B3 Photochemical degradation

Photochemical degradation involves intense ultraviolet (UV) light to be applied to a contaminated surface for some period of time. Photochemical degradation should be applicable to a wide range of contaminants, but will depend on the photodegradability of chemicals. This method is potentially applicable to all surfaces, although best results would be expected on smooth surfaces 1, including chlorinated dioxins (TCDD in particular) 3.

Three conditions have been found to be essential for the process to proceed:

- The ability of the contaminant to absorb light energy.
- The availability of light at appropriate wavelengths and intensity.

- The presence of a hydrogen donor.

Photodegradation has many different potential applications depending on the nature of the contaminated substrate:

- Use of portable UV light and hydrogen donor to decontaminate interior surfaces and structures, or initially water washing, then applying a hydrogen donor and UV light to the wet residue.
- Destruction of residues in inaccessible places with a UV laser stream.
- Use of other decontamination techniques (e.g. steam cleaning, hydro-blasting) followed by solvent collection and the application of photodegradation techniques to the liquid wastes.

Advantages:

- Photochemical degradation operations can be relatively simple or scaled up (accompanied by increased technical efforts).
- It can be inexpensive when sunlight is used as the UV light source.
- Waste disposal costs should be negligible unless this method is used in conjunction with another decontamination method.
- There are various UV light sources and hydrogen donors which may be used. Possible light sources include mercury and xenon-arc lamps. Possible hydrogen donors include the majority of organic liquids that have a large proportion of hydrogen atoms and that are not highly UV-absorbing in the same range as the target contaminants, these include: methanol, benzene, glycol, glycol ethers (Carbitols and Cellosolves) natural vegetables and mineral oils, furniture polish and petroleum distillates.

Limitations/considerations:

- Photochemical degradation will not work on contaminants imbedded in dense particulate matter (such as thick carpets or deep soil) as UV light cannot penetrate through such surfaces.
- Exposure hazards to workers may result from intense UV radiation when sources other than the sun are used additionally exposure hazards may also arise from the use of flammable solvents as hydrogen donors. PPE must be worn when using this method. In addition eye protection should be worn if using artificial UV light.
- UV light may cause bleaching of fabric surfaces- resulting in additional repair costs.

B3.1 Technology development status

Evidence shows that this technique is frequently used in cases of dioxin contamination3. Research is still ongoing to further establish specific UV light/ hydrogen donor contaminant procedures.

B4 Atmospheric gas plasma

A high voltage electrical discharge is used to generate gas plasma. Energising air at atmospheric pressure into plasma results in the generation of chemically highly reactive oxygen free radical species and ozone. Airflow through the system delivers these short-lived species from the point of generation to the contaminated surface to rapidly degrade chemical contamination [4]. This technology can be used for compounds which release noxious fumes such as volatile organic compounds (VOCs) converting them into compounds which can be easily scrubbed, or fixing them durably in glossy materials [5]. The technology has also proven to be useful in the decontamination of personal effects (keys, spectacles, credit cards, phones) following a chemical incident.

Advantages:

- Effective performance at very low concentrations at ambient temperature conditions and low maintenance.
- It does not require auxiliary fuel and eliminates disposal problems and sensitivity to poisoning by other chemicals.

Limitations/considerations:

- Various gas plasma technologies are available: pulsed-corona, packed bed, silent corona and surface discharge plasma. Power consumption and by-product analysis are 2 key issues that must be addressed before determining which technology to use.
- Atmospheric gas plasma must be contained in costly air tight enclosures (vacuum reactors) making them highly expensive.

B4.1 Technology development status

The last couple of decades have seen rapid growth in the field of atmospheric gas plasma research. The application of this technology in recovery however is still a relatively new aspect.

B5 Heat gas / steam

Also referred to as hot steam air decontamination. Turbine engines are used to deliver hot exhaust gases at high velocity on to the surface of large contaminated items. It works on the principle of increasing the rate of hydrolysis for most chemical warfare agents. Hot air blowers and steam generators can be easily applied to smaller items. Larger items such as vehicles may require additional complimentary methods such as hot air/steam and emulsion systems. There is anecdotal evidence that applying hot exhaust gas generated by jet turbine engines to increase hydrolysis and evaporation rates off surfaces such as runway surfaces and aircraft 'pans' behind the engines.

This method can potentially be applied to a wide range of traditional chemical warfare agents and toxic industrial chemicals (with guidance) to decontaminate, aid decontamination or simply increase the rate of evaporation and off gassing from surfaces.

Advantages:

- Simple technology easily acquired via COTS (commercial off the shelf) with a sound scientific basis and relative low cost.
- Can be easily applied to other methods as part of a system or combined with other reagents such as emulsifiers both with, or without, steam.
- Scalable for very small items to potentially large areas depending on the technology used.
- Can reduce the waste hazard level and therefore total waste disposal costs if successful.

Disadvantages:

- Sampling and monitoring is still required afterwards to prove the area/item has had the contamination load reduced.
- Methods can be hard to deploy externally e.g. may require tenting of external surfaces.
- Some of the hydrolysis products e.g. those of V class nerve agents, are almost as toxic and ideally should be pH adjusted to aid decontamination.
- Jet turbine engine methods have anecdotal data to remediate runways and related areas but are difficult to acquire unless an airframe is put at risk.

B5.1 Technology development status

Generators are commonly available covering small to medium incidents as COTS items, often with business behind them potentially willing to undertake the work as well, depending on threat and risk assessment. The technology, with the exception of jet engine exhaust, is also applicable to some biological applications.

B6 Laser treatment

This is another form of thermal treatment. It uses laser techniques for non-contact removal of embedded contamination down to depth of 4mm thick construction materials such as concrete amongst other types of building surfaces. Various types of lasers, such as carbon dioxide lasers and yttrium aluminium garnet (YAG) Lasers have been experimented with. The techniques investigated include laser vaporisation removal, laser combustion/ decomposition removal, laser thermal fracture removal and heat affected zone (HAZ) delamination [6].

There is limited evidence to suggest that laser vaporisation is effective on materials such as brick, concrete and stone. Laser combustion/decomposition was found to be effective on organics such as epoxides, plastics and mosses. Laser based thermal shock fracture and HAZ delamination are methods that could be used for decontaminating building material such as concrete, cement, mortar and plaster.

Advantages:

- Laser vaporisation was found to be highly accurate, provided high efficiency with very low power requirements.
- Laser based thermal shock fracture produces minimal damage to the surface being decontaminated.
- HAZ delamination requires no extraction and waste removal is uncomplicated.

Disadvantages:

- Laser vaporisation produces noxious vapours and could damage the contaminated surface.
- Laser combustion/ decomposition presents a fire hazard.
- Laser based thermal shock fracture produced waste for collection which is complicated to handle and the whole process was found to be difficult to control.
- HAZ delamination damages the surface being decontaminated.

B6.1 Technology development status:

This technology is commercially available in the United States and Canada and has only been applied experimentally. There is no information on the availability of this technique in the UK 6.

B7 Microwave discharge plasma reactor

This is another thermal treatment technique under development. It uses microwave discharge plasma to detoxify chlorinated hydrocarbons at low concentrations. This method is still at its experimental stages, and is being developed for consideration in cases where there are low concentrations of chlorinated hydrocarbon contamination.

Advantages:

- The destruction of chlorinated hydrocarbons (at low concentrations) observed when using this method was between 95%- 99%
- A wide range of reactants can be used to achieve high efficiency- including Oxygen, Water vapour or a mixture of both.
- Primary breakdown products are carbon monoxide, carbon dioxide, hydrochloric acid, chlorine and hydrogen.

Disadvantages:

- Incomplete reactions can result in incomplete oxidation of carbon to carbon dioxide, formation of soot and non-parent chlorinated hydrocarbons.

B7.1 Technology development status

This technology is commercially available in the USA and Canada [6]. There is no information on the availability of this technique in the UK [6].

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Appendix C Wide Area Sampling and Analysis (WASA)

This recovery Handbook only intends to provide a general overview of the important factors to consider when developing a monitoring strategy. An ongoing project (WASA) being conducted by Defence Science and Technology Laboratory (DSTL) is looking at this sampling and monitoring in more detail.

C1 Aim/scope

The aim of the WASA project is to provide technical guidance for planning and executing wide area sampling and analysis (WASA) following the deliberate release of chemical, biological, radiological and nuclear (CBRN) materials in large urban or rural environments.

The WASA Technical Guidance Document sets out the principles and conditions for WASA and presents options for the protocols, standards and techniques to be employed. It provides a single point of focus for the management and conduct of WASA activities and offers clear, practical, and consistent sampling and analysis guidance to support strategic decision-making in the event of a wide area CBRN contamination event

C2 Capability

The vision for WASA is a robust, timely and scalable capability to inform the assessment of the residual hazard following any CBRN terrorism incident anywhere in the UK. Sampling and analysis should provide data on agent spread and levels of contamination to support decontamination, protection of public health and the environment, and restoration of business continuity.

WASA will take place in response to a functioned CBRN device to fulfil obligations under the UK's strategy for countering the threat from international terrorism. It is likely to be initiated in the Recovery and Restoration phases of the Model Response to support the activities that take place in those phases in efforts to manage an ongoing CBRN attack and recover from its aftermath.

The agent of concern will be known prior to the deployment of the capability and computational modelling (or equivalent) will have been undertaken to provide an initial estimate of the impact area and / or contaminant distribution.

WASA will be a tiered response to address the different sampling and analysis goals that are evident throughout the lifetime of an incident. Tier 1 is the verification of contaminant deposition and extent (from modelling or alternative estimates of the hazard area to reduce uncertainty. Tier 2 constitutes site characterisation to prioritise areas requiring action. Tier 3 is to give confidence that an area thought to be clean is clean in support of a return to normality. To put the WASA project in context, the primary use of the UKRHCI would be between tier 2 and tier 3, after a site has been characterised but before clean-up has been initiated.