Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste to the Environment

Radioactive Substances Regulation under the Radioactive Substances Act (RSA-93) or under the Environmental Permitting Regulations (EPR-10)

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About this document

This updated principles document has been produced jointly by:-

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FOREWORD

Environment Agency, the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment Agency (the UK 'Environment Agencies') have responsibilities for regulating major industries under environmental protection legislation. These include the nuclear industry (on nuclear licensed sites) and other organisations using radioactive substances within their processes.

In 2002 the Environment Agencies in collaboration with the National Radiological Protection Board (now incorporated within the Health Protection Agency) and the Food Standards Agency produced a set of principles and interim guidance on the assessment of public doses for the purpose of authorising discharges of radioactive waste to the environment. As a consequence the document enabled radiological assessments to be produced in a more consistent and transparent manner.

In 2012 the Environment Agencies collaborated with the Health Protection Agency and the Food Standards Agency to produce an update of the 2002 interim guidance and principles for assessing doses. The 2012 update incorporates a number of revisions which are summarised.

Contents

1 Introduction

1.1 The Environmental Permitting Regulations 2010 (EPR 10) [Ref 1] and the Radioactive Substances Act 1993 (RSA 93) provide the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. In particular, EPR10 and RSA 93 require prior permitting or authorisation for the disposal or discharge of radioactive waste to the environment. Responsibility for granting a permit or authorisation rests with the Environment Agency in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland and the Northern Ireland Environment Agency in Northern Ireland. For simplicity, the term 'the Environment Agencies' is used within this document to represent all three of these regulatory bodies.

1.2 This document sets out principles and guidance for the prior assessment of doses to the public arising from exposure to ionising radiation which may arise from planned discharges to the atmosphere and to the aquatic environment. The results of assessments undertaken in accordance with these principles and guidance will be used as an input into the process of determining whether discharges of radioactive waste to the environment should be authorised. This document has been developed by the Environment Agencies in collaboration with the Health Protection Agency (HPA) (which incorporated the NRPB) and the Food Standards Agency.

1.3 Two primary types of dose assessment can be undertaken; a prospective assessment of doses which might be received by members of the public in the future and a retrospective assessment of doses as a result of discharges that have already been made. Retrospective assessments may also be made for discharges or disposals not covered by a permit (e.g. accidental releases or contaminated land). Although the principles and guidance contained within this document apply to prospective assessments, much of the advice given is consistent with the approach applied to retrospective assessments.

1.4 The **objectives** of this document are:

- To provide guidance to Environment Agencies' officers on the assessment of public doses for the purposes of determining radioactive waste discharge permits or authorisations, so that the approach to assessments is consistent and transparent.
- To inform holders of EPR10 permits or RSA 93 authorisations about the Environment Agencies' approach to the assessment of public doses and thus provide guidance on the preparation of radiological assessments in support of permit or authorisation applications.
- To provide information to the public on the Environment Agencies' methods of conducting public dose assessments

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1.5 The **scope** of this document is limited to the prospective assessment of doses to the public for the purpose of permitting discharges under EPR10 or authorising discharges under RSA93. It applies to all UK premises that are subject to EPR 10 permits or RSA 93 authorisations. It also can be applied to premises where Crown exemptions apply – the discharges from which are made in accordance with agreements which apply a comparable standard as a permit or authorisation

1.6 The document does not apply to the assessment of the impact of disposals of solid radioactive waste. Guidance already exists on the requirements for permit or authorisation of near-surface disposal facilities on land and geological disposal facilities on land for solid radioactive wastes [Refs 2, 3].

1.7 This document is mainly concerned with radiological assessments for the determination of effective dose arising from committed effective dose from intakes of radionuclides and external exposure and referred to as dose (see the glossary for full definition). It may in some circumstances be necessary to make additional calculations of the equivalent dose to particular organs or tissues (for example skin or lens of the eye) where effective dose may not an adequate assessment. Doses to the skin may need to be assessed where beta emitters are present in the environment at enhanced levels and there is scope for sustained

contact with the skin. Effective dose, committed effective dose and equivalent dose are defined in the glossary and have the units of sievert (Sv). The sievert is a relatively large unit and therefore doses are usually reported as fractions of a sievert, for example, millisievert (mSv), one thousandth of a sievert, or microsievert (μSv), one millionth of a sievert. Doses may be assessed for individual members of the public and also the sum of all doses to all the individuals in an exposed population, referred to as collective dose. The unit of collective dose is the man-sievert (manSv). Other terms used in this document are described in the glossary.

1.8 This document is an updated and revised version of the interim principles document published in 2002 [Ref 4]. The main changes to the principles made in this update are presented in Appendix A and other main changes are summarised in Appendix B.

2 Background

2.1 Requirement for guidance

2.1.1 The Environment Agencies, the Food Standards Agency, Health Protection Agency and the Office of Nuclear Regulation – ONR - (formerly the Nuclear Installations Inspectorate) have recognised the need for guidance on the methods to be used in assessing prospective public doses to ensure that such assessments are consistent and transparent. These organisations formed the National Dose Assessment Working Group (NDAWG) in 2002 to consider and understand the different approaches to radiological assessment with the aim of promoting best practice and improving consistency. NDAWG has representatives from the regulators, other government agencies, industry, non-governmental organisations and independent experts. NDAWG has published guidance notes on radiological assessment on its website (www.ndawg.org).

2.1.2 The formation of NDAWG was a key recommendation of the Consultative Exercise on Dose Assessment (CEDA) which was organised by the Food Standards Agency in October 2000 [Ref 5] to initiate a wider debate on assessment methods and to improve their transparency. The work of NDAWG has helped address concerns raised by one of the UK Government's advisory bodies, the Radioactive Waste Management Advisory Committee (RWMAC), who made the following comments [Ref 6]:

- "*It is not unusual for three different sets of dose calculations to be carried out (i.e. by the operator, one of the Environment Agencies and the Food Standards Agency and for these to result in three different estimates of dose*".
- RWMAC "*expressed concern about the pessimistic, often grossly pessimistic, assumptions made in these dose calculations". "Using grossly pessimistic assumptions in dose calculations is not, in the RWMAC's view, a sound basis for decision making".*

2.1.3 A further need for guidance arises from EPR 10 [Ref 1], a Direction to SEPA [Ref 7] and Regulations in Northern Ireland [Ref 8] which require the Environment Agencies to ensure that legal dose limits are not exceeded and the defined dose constraints are taken into account. These Regulations and Direction implement requirements of the Euratom Basic Safety Standards Directive 1996 (BSSD) [Ref 9]. The Euratom BSSD 1996 [Ref 9] requires the Environment Agencies to make realistic assessments of the doses to reference groups of members of the public. This requirement for realistic assessment is a key principle which has been addressed within this document. The Euratom BSSD 1996 is undergoing revision, and the revised BSSD is expected to be published in 2013. The revised BSSD has similar requirements for protecting members of the public including optimisation, the need for dose constraints during optimisation and a realistic dose assessment process.

2.2 Radioactive waste management policy

2.2.1 The current UK Government Policy on the management of radioactive waste is defined in a number of documents, including Cm 2919 (parts of which are still in force in the UK) [Ref 10], the UK discharge strategy [Ref 11], statutory guidance to the Environment Agency concerning

the regulation of radioactive discharges into the environment [Ref 12] and statutory guidance to SEPA on the control of radioactive discharges into the environment [Ref 13]. Cm 2919 has the principal aims of ensuring that:

- radioactive wastes are not unnecessarily created;
- such wastes as are created are safely and appropriately managed and treated;
- they are then safely disposed of at appropriate times and in appropriate ways;

so as to safeguard the interests of existing and future generations and the wider environment, and in a manner that commands public confidence and takes due account of costs.

2.2.2 This is similar to the fundamental principle of IAEA Safety Standards Series No. SF-1 "Fundamental Safety Principles" [Ref 14],

"People and the environment present and future must be protected against radiation risks"

2.2.3 The UK Strategy for radioactive discharges [Ref 11] aims to implement the OSPAR Strategy for radioactive substances which was agreed by Ministers of the Signatory countries (known as 'Contracting Parties') at Sintra, Portugal in 1998. The objective of the OSPAR strategy is to prevent pollution of the North East Atlantic maritime area through progressive and substantial reductions in discharges, emissions and losses of radioactive substances. By the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero.

2.2.4 The UK radioactive waste management policy and regulatory framework is underpinned by international recommendations made by the International Commission on Radiological Protection (ICRP) and national recommendations made by the HPA on radiation protection principles and criteria. The most recent formal recommendations are provided in ICRP Publication 103 [Ref 15] and the HPA's 2009 advice to the Government [Ref 16]. ICRP Publication 77 [Ref 17] provides specific guidance on the disposal of radioactive waste. For practices[1] involving the use of radioactive substances (e.g. medical diagnostics and treatment or nuclear power generation), the system of protection recommended by ICRP and HPA is based on the following principles:

- no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes (the **justification** principle);
- in relation to any particular source within a practice (e.g. an individual hospital with a nuclear medicine department or an individual nuclear power station), the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account (ALARA). This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements (the **optimisation** of protection);
- the exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of the risk in the case of potential exposures (individual dose and risk **limits**). These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible to control by action at the source (e.g. as a result of incidents or accidents) and it is necessary to specify the sources to be included as relevant before selecting a dose limit.

[1] ICRP, in its latest recommendations (ICRP Publication 103 [Ref 15]), has adopted the term 'planned exposure situation' rather than 'practice' in this context. However, the term practice will continue to be used in this document as this is referred to in current European and UK legislation. ICRP recommendations for planned exposure situations are substantially unchanged from those provide in ICRP Publication 60 [Ref 20] and subsequent publications for the normal operation of practices.

2.2.5 The UK discharge strategy sets out the following principles:

- regulatory justification of practices by the UK Government [and the Devolved Administrations, in particular circumstances] [Ref 18].
- optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle) (economic and social factors taken into account);
- application of limits and conditions to control discharges from justified activities;
- sustainable development;
- the use of Best Available Techniques (BAT) or Best Practicable Means (BPM) for Scotland and Northern Ireland];
- the precautionary principle;
- the polluter pays principle;
- the preferred use of 'concentrate and contain' in the management of radioactive waste over 'dilute and disperse' in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT [or BPM] is being applied and worker dose is taken into account.

2.2.6 The Environment Agency has published Radioactive Substances Regulation Environmental Principles [Ref 19]. One of the Fundamental Principles is concerned with protecting human health and the environment and states that:

"Radioactive substances should be managed to ensure an optimal level of protection to human health, wildlife, organisms and the wider environment, and compliance with relevant dose limits and constraints is achieved. Monitoring and assessment should be undertaken to inform decisions about radioactive substances and to establish the state of the environment".

2.3 Regulatory framework

2.3.1 EPR 10 and RSA 93 provide the framework for controlling the generation and disposal of solid, liquid and gaseous radioactive waste so as to protect the public and the environment. The key legal requirement is that no person may dispose of radioactive waste unless it is in accordance with a permit or authorisation, except where the waste is excluded from control under or exempted from provisions by an Exemption Order. The Environment Agencies are responsible for determining applications for permits or authorisations made by producers of radioactive waste and for reviewing those permits or authorisations on a regular basis.

2.3.2 Premises occupied by the Crown for defence purposes are exempt from EPR 10 and RSA 93. However, discharges from these premises are made in accordance with agreements which apply a comparable standard as a permit or authorisation.

2.3.3 The Euratom Basic Safety Standards Directive [Ref 9] provides the mechanism for the implementation of the 1990 recommendations of ICRP [Ref 20] within the European Union. The Euratom Basic Safety Standards Directive is being revised and will include implementation of the 2007 Recommendations of the ICRP [Ref 15]. Many of the Directive's provisions are implemented by the Ionising Radiations Regulations [Ref 21, 22] and with respect to the control of radioactive waste have been implemented within the UK through EPR 10, Regulations amending RSA 93 [Ref 8, 23] and a Direction to SEPA [Ref 7]. The principal aims of this legislation are to require the Environment Agencies, when exercising their duties and functions under radioactive substances legislation, to ensure that:

- All public ionising radiation exposures from radioactive waste disposal are kept ALARA. economic and social factors taken into account
- The sum of the doses arising from such exposures does not exceed the individual public dose limit of 1 mSv a year.
- The individual dose received from any new discharge source since 13th May 2000 (1st May 2003 in Northern Ireland), does not exceed 0.3 mSv a year.
- The individual dose received from any single site does not exceed 0.5 mSv a year.

- Estimates of doses are as realistic as possible (by requiring that Article 45 of the Euratom Basic Safety Standards Directive [Ref 9] is observed).

2.3.4 The Office of Nuclear Regulation (ONR) within the Health and Safety Executive (HSE) is responsible for regulating sites licensed under the Nuclear Installations Act 1965 [Ref 24] and is a statutory consultee in the process of determining permits or authorisations. On sites for which a nuclear site licence has been granted by the ONR, commonly referred to as 'nuclear sites', the accumulation of radioactive wastes are regulated via conditions attached to the licence. The HSE regulates the exposure of workers using radioactive substances under the Ionising Radiations Regulations [Ref 21, 22] (undertaken by the ONR on nuclear sites).

2.3.5 There are a number of advisory bodies involved in the regulatory process. The Food Standards Agency is responsible to Government and devolved administrations for providing advice on food safety, including the safety of radionuclides in food. The Environment Agencies seek advice from the Food Standards Agency on food safety as part of the process for determining applications for permits or authorisations to dispose of radioactive waste. The Food Standards Agency conducts radiological monitoring of food in England, Wales and Northern Ireland. In Scotland, the radiological monitoring of food and the environment is undertaken by SEPA which works closely with the Food Standards Agency in Scotland to develop a holistic monitoring programme. The Food Standards Agency and Environment Agencies food and environmental monitoring results are published jointly on an annual basis [Refs 25, 26, 27, 28 & 29]. The Food Standards Agency publishes food monitoring data on its web site.

2.3.6 The Health Protection Agency has a statutory role to give advice on the acceptability and the application in the UK of standards recommended by international or inter-governmental bodies. The functions of the HPA are to give advice, to conduct research and to provide technical services in the field of protection against both ionising and non-ionising radiations.

2.3.7 Other advisory bodies involved in the regulatory process include:

- Committee on Radioactive Waste Management (CoRWM) – Created in 2003 to review the options for managing the UK's higher activity solid radioactive waste, and to make recommendations on the option, or combination of options, that could provide a long-term solution, providing protection for people and the environment. The current role of CoRWM is to provide independent scrutiny and advice to UK Government and Devolved Administration Ministers on the long term management, including storage and disposal, of radioactive waste.
- The Committee on Medical Aspects of Radiation in the Environment (COMARE) – Created in 1985 to assess and advise the Government on the health effects of natural and man-made radiation in the environment and to assess the adequacy of the available data and the need for further research.

2.4 Radiological protection criteria for public exposure

2.4.1 The following criteria are discussed in this section and illustrated in Table 1:

- Dose Limits.
- Site and Source Dose Constraints.
- Optimisation at low doses.

2.4.2 The main quantity that is calculated for comparison with the dose criteria expressed as effective dose in Table 1 is dose. Dose is a combination of external effective dose from 1 years exposure and committed effective dose from 1 years intake – as defined in the glossary

Table 1 Summary of Radiological Protection Criteria for Public Exposure

Criteria	Quantity	Doses to be Included in Assessments Against Criteria					
		Source of Radiation for Site Considered			Other Sources of Radiation (Excluding Medical and Natural)		
		Historical Discharges	Future Discharges	Future Direct Radiation	Historical Discharges	Future Discharges	Future Direct Radiation
Dose limit (effective dose)	1 mSv/y	✓	✓	✓	✓	✓	✓
Dose limit for the skin (equivalent dose)	50 mSv/y averaged over any area of 1cm^2	✓	✓	(a)	✓	✓	(a)
Dose limit for lens of the eye (equivalent dose)	15 mSv/y	✓	✓	(a)	✓	✓	(a)
Site constraint (effective dose)	0.5 mSv/y		✓	(b)			
Source constraint (effective dose)	0.3 mSv/y (max)		✓	✓			
Investigation level for Generalised Derived Constraint (GDC)	30% of GDC or 0.1 mSv/y		✓				
'Threshold of optimisation'(c) (effective dose) [Ref 10]	0.02 mSv/y		✓	✓			
Potentially 'of no regulatory concern' (effective dose) [Refs 12, 30, 31]	≤0.01 mSv/y		✓	✓			

(a) This need not be assessed as the effective dose limit is more restrictive than the equivalent dose limit for direct radiation. Also, the equivalent dose from direct radiation will only add a small contribution to the total equivalent dose, whilst the direct radiation effective dose is less than the effective dose limit.
(b) The derivation of this UK specific constraint strictly excludes consideration of future direct radiation [Ref 32].
(c) Only applicable in Scotland and Northern Ireland.

Dose limits

2.4.3 Legal dose limits are currently set out in the Euratom Basic Safety Standards Directive [Ref 9] and implemented in the UK through the Ionising Radiations Regulations [Ref 21, 22] (IRR 99). Doses to members of the public from all controlled sources (excluding occupational and medical exposure) should not exceed 1 mSv in a calendar year (in special circumstances this can be averaged over five consecutive years). The Environment Agencies are required to ensure that doses to members of the public from discharges of radioactive waste do not exceed 1 mSv per year [Ref 1, 7, 8]. There are also equivalent dose limits for particular organs (skin and lens of the eye) as shown in Table 1.

2.4.4 Dose limits apply when retrospective assessment of doses from past discharges are made. For prospective assessments the dose criteria are dose constraints. However a complete prospective assessment may include additional elements including an assessment of doses from past discharges and doses from other sites nearby as an additional check on the

prospective dose assessment outcome. The total outcome may then be compared with the dose limit.

2.4.5 HPA has recommended that doses from past planned releases should be included when making comparisons with the dose limit [Ref 16]. The Environment Agencies, HPA and Food Standards Agency consider that the dose from direct radiation should also be included when comparing with the dose limit.

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2.4.7 The recommendations of ICRP [Ref 15] advise that contamination arising from accidental discharges should be treated as an emergency exposure situation. The dose limit, as defined in the Euratom Basic Safety Standards Directive [Ref 9], applies only to practices (i.e. planned exposure situations). Therefore both ICRP and the Euratom Basic Safety Standards Directive indicate that doses to the public arising from past accidents are not normally compared with the dose limit for members of the public. However, monitoring of food and the environment will result in the detection of radionuclides arising both from past accidents and from authorised or permitted discharges. If the radionuclides from the accident and from discharges are the same it may be difficult to separate to levels arising from each component. Thus, where monitoring data is used to assess doses from historical discharges, the contribution from past accidents may be included and will inevitably be compared with the dose limit for the public. Where this has happened it should be made clear what has been included. It may be appropriate to carry out assessment work to estimate the contribution from the components.

Dose constraints

2.4.8 The HPA considers that there is a need for prospective constraints to assist in the optimisation of radiological protection. HPA has recommended the dose constraint – which was defined as an upper bound on the annual doses that members of the public may receive from the planned operation of a controlled source. The dose constraint is for comparison with the annual dose to the representative person, summed over all pathways from current and future operations. For proposed controlled sources the maximum dose constraint should be 0.3 mSv/y [Ref 16]. Some existing controlled sources may give rise to doses that exceed the dose constraint. In these cases there should be regular review and the regulators should ensure that doses are as low as reasonably achievable. The Government stated in Cm 2919 that a maximum constraint of 0.3 mSv/y should be used when determining applications for discharge permits or authorisations from a single new source, defined as "*a facility, or group of facilities, which can be optimised as an integral whole in terms of radioactive waste disposals*". This constraint is referred to as a source constraint. In the planning stage, the Environment Agencies are required to have regard to maximum doses to members of the public, which may result from a defined source, of 0.3 mSv/y, arising from discharges of radioactive waste first made on or after 13th May 2000 (1st May 2003 in Northern Ireland) [Ref 1, 7, 8].Taking the legislation and advise from HPA on the dose constraints together, unless there are exceptional circumstances that make compliance with these constraints impracticable, no option for the management of radioactive substances or radioactive wastes should be pursued if, in normal operation, its associated discharges would lead to doses above them. The HPA has also advised the Government (including the Devolved Administrations) that a lower dose constraint not exceeding 0.15 mSv/y should be applied at the design stage of new nuclear power stations and waste disposal facilities [Ref 16]. This advise will be taken into account where relevant.

2.4.9 Prior to the review of policy on the management of radioactive waste (Cm 2919), the UK Government had operated a site target of 0.5 mSv/y as part of its system of dose limitation for radioactive discharges. Under the re-structuring of the nuclear power industry, ownership at four power station sites has been split between the company owning or operating a Magnox station and that owning or operating an Advanced Gas-Cooled Reactor (AGR) or Pressurised Water Reactor (PWR). To provide reassurance that standards are not being relaxed as a result of restructuring, a site constraint of 0.5 mSv/y has been set [Ref 1, 7, 8]. Site and source

constraints include different exposure pathways as indicated in Table 1. This will apply to the aggregate exposure from a number of sources with contiguous boundaries at a single location, irrespective of whether different sources on the site are owned or operated by the same or by different organisations. Another example of a split ownership site is that of URENCO and Sellafield Ltd at Capenhurst.

2.4.10 The 0.5 mSv/y site constraint applies to doses arising from future exposures from discharges and not from exposures arising from direct radiation. This was clarified in the 1996 decision document for the AGR and PWR nuclear power station applications and was accepted at the time by the Department of the Environment [Ref 32].

2.4.11 In addition to the dose constraints used to assess the impact of planned releases, retrospective assessment of total doses to the public from all sources against the dose limit itself may be used as a final check on the appropriateness of the discharge limits set and on the doses assessments made. The assessment of total dose can make use of environmental measurements to confirm the fate of radionuclides already discharged into the environment. Environmental measurements and current understanding of population habits can be brought together to show that the total dose from all sources is within the dose limits and as low as reasonably achievable. As a further check the total dose can be compared with the dose constraints, which depending on the method used, will inform on the validity of the prospective dose assessment outcomes made using modelling.

Threshold of optimisation and below regulatory concern

2.4.12 The risks that people are prepared to accept and the degree to which risk is perceived vary from individual to individual. The HSE conducted a considerable amount of work on tolerable and acceptable levels of risk, culminating in the publication of The Tolerability of Risk from Nuclear Power Stations (TOR) [Ref 33], originally issued in 1988 and updated in 1992. More recently the HSE has published a document on 'Reducing Risks, Protecting People' [Ref 34] which extends the principles in the Tolerability of Risk document to other industries. The HSE recognised that there was an upper limit beyond which a risk would be intolerable, regardless of the benefit which society derived from the activity involved, and a lower level, below which the risk was negligible in comparison with other risks people run in their daily lives and therefore broadly acceptable. The area in between is where the risk is tolerable only if is as low as reasonably practicable (ALARP).

2.4.13 The HSE has published Safety Assessment Principles for Nuclear Facilities [Ref 35] which defines Basic Safety Limits and Basic Safety Objectives that form the upper and lower bounds respectively of the ALARP region. The HSE has set a Basic Safety Objective of 0.02 mSv/y for any person off the site receiving doses from sources of ionising radiation originating on the site.

2.4.14 In Cm 2919, the Government introduced a threshold or lower bound on optimisation for radioactive waste discharges, similar to the lower level defining broadly acceptable risk in TOR. The value for this threshold was set at 0.02 mSv/y. If exposures are calculated to be below 0.02 mSv/y, the regulators in Scotland and Northern Ireland are advised in Cm 2919 that they should not seek to secure further reductions in the exposure of members of the public, provided they are satisfied that the operator is using the best practicable means to limit discharges. The regulators need to ensure that discharges are properly controlled and monitored and the radiological assessments submitted to them by the operator are valid.

2.4.15 The International Atomic Energy Agency (IAEA) has presented dose criteria which are considered sufficiently low that doses arising from sources or practices that meet these criteria may be exempted from regulatory control. One of the criteria is that the dose should be less than about 10 μSv/y (0.01 mSv/y) per practice [Ref 30, 31].

2.4.16 The statutory guidance to the Environment Agency [Ref 12] states that where the prospective dose to the most exposed group of members of the public from discharges from a site at its current discharge limits is below 10 μSv/y (0.01mSv/y) the Environment Agency should not

seek to reduce further the discharge limits that are in place, provided that the holder of the permit or authorisation applies and continues to apply BAT.

2.4.17 Taking the internationally accepted assumption (for the purpose of radiation protection) that any dose, no matter how small, has the potential to cause harm, an annual dose of 10 to 20 μSv/y (0.01 to 0.02 mSv/y) can be broadly equated to an annual risk of death of about one in a million per year.

2.4.18 The dose criteria that are appropriate for prospective dose assessment are summarised at the end of section 3.5.

2.5 Radiological protection of the environment

2.5.1 The radiological protection system described in the previous sections is aimed primarily at the protection of humans. However, ICRP in its 2007 recommendations [Ref 15] concluded that there is a need for a systematic approach for the radiological assessment of non-human species to support the management of radiation effects in the environment. ICRP considers that this is needed to address a conceptual gap in the radiological protection system because ICRP subscribes to the need to maintain biological diversity, ensure conservation of species and to protect the health and status of natural habitats, communities and ecosystems.

2.5.2 ICRP acknowledged that, in contrast to human radiological protection, the objectives of environmental protection are both complex and difficult to articulate but it believes that there is a need to develop a system in order to assess the relationships between exposure and dose, and dose and effect, and the consequences of such effects, for non-human species, on a common scientific basis. ICRP Publication 91 [Ref 36] concluded that that any developments for non-humans species should draw upon the lessons earned from the development of the systematic framework for the protection of humans. In its recommendations ICRP has stated its intention to develop a small set of Reference Animals and Plants (RAPs) [Ref 37], and their relevant databases, for a few types of organisms that are typical of the major environments.

2.5.3 The RAPs can be considered as hypothetical entities with certain assumed basic biological characteristics of a particular type of animal or plant (described at the taxonomic level of Family) and with defined anatomical, physiological and life-history properties. The intention is that the RAPs can serve as points of reference which can be used as a basis for making some management decisions. ICRP has elaborated on the proposed framework in its publication 108 [Ref 38] on the use of RAPs. Given the current state of knowledge and the development of the RAPs, ICRP does not propose to set any form of ‘dose limits’ with respect to environment protection. However, it does intend to offer more practical advice than in the past.

2.5.4 This document does not provide guidance on assessment of doses to animals or plants. The European assessment tool, ERICA, is available to support decisions about radiological protection of the environment (www.wiki.ceh.ac.uk). Assessment methods and tools for noble gases (which are not currently covered by ERICA) may be found in References 39 and 40. Assessments of the impact of radioactive discharges on protected habitat sites in England and Wales are reported in Reference 41.

3 General dose assessment principles

3.1 Transparency of methods and data

3.1.1 The Radioactive Waste Management Advisory Committee (RWMAC) have stated that “An openly declared and consistent method of dose calculation should be sought” [Ref 6].

3.1.2 Prospective assessment methods and reported results should be transparent, by being clear and readily understandable. To achieve this, all methods and their underpinning data should be

made publicly available in a suitable form such that another party can repeat the assessment (taking into account data protection and security issues)

Principle 1	**Prospective dose assessment methods, data and results should be transparent and made publicly available.**

3.2 Nuclear sites and other premises discharging radioactive waste

3.2.1 Radioactive waste discharges are made from premises such as hospitals, research establishments, universities and industry (the so called 'non-nuclear sites') as well as from the nuclear industry. The requirements of the Euratom Basic Safety Standards Directive 1996 [Ref 9] make no distinction between nuclear and non-nuclear sites. It is the magnitude of the dose and hence risk which is important. Thus, the assessment principles within this document apply equally to nuclear and non-nuclear sites. It is expected that some non-nuclear sites will be able to undertake a simple source assessment to demonstrate that the doses arising from the discharges from the site are sufficiently low to be acceptable for regulatory purposes.

3.3 Members of the public and population groups

3.3.1 Doses to individuals are compared with dose limits and constraints. The Euratom Basic Safety Standards Directive 1996 [Ref 9] defines separate limits for workers and members of the public. The Basic Safety Standards Directive [Ref 9] defines members of the public as:

"*individuals in the population, excluding exposed workers, apprentices and students during their working hours and individuals during the exposures referred to in Article 6(4)(a), (b) and (c)*" (these articles relate to medical exposures).

3.3.2 The Ionising Radiations Regulations [Ref 21, 22] defines dose limits for employees, where the employer is undertaking work with radiation, as well as dose limits for 'other persons'. 'Other persons' includes employees who do not normally work with radiation and members of the public. The Approved Code of Practice for the Ionising Radiations Regulations [Ref 42] states that radiation employers should take particular steps to restrict the exposure of any employees who would not normally be exposed to ionising radiation in the course of their work. The dose control measures should make it unlikely that such persons would receive a dose greater than 1 mSv/y. This is the dose limit for 'other persons', which includes members of the public (see also 2.4.3).

3.3.3 Employers working with radiation are required to assess the dose to their employees under the Ionising Radiations Regulations [Ref 21, 22]. For the purposes of this document, employers working with radiation can be considered to be on sites that hold an RSA-93 or EPR-10 permit either registering radioactive sources or disposing of radioactive wastes. Workers who enter a site from which a radioactive discharge is being made (e.g. employees, contractors, employees on a co-located site) should be provided with information, where necessary, on their exposure arising from radioactive discharges. The Ionising Radiations Regulations [Ref 21, 22] requires employers to co-operate (by exchanging information etc) where work involving ionising radiation of one employer can give rise to the exposure of an employee of another employer. Therefore, it is not considered necessary to include these workers in the assessment of prospective doses made for members of the public.

3.3.4 There is another group of workers who may be exposed as a result of discharges of radioactive waste to the environment, but do not work directly with ionising radiation themselves or are employed by an organisation that does not normally make use of or dispose of radioactive materials. Thus they are workers who are regarded as not normally working with ionising radiation. These workers and their employer may not be familiar with the requirements of EPR 10, RSA 93 and the Ionising Radiations Regulations [Ref 21, 22]. This group of workers may include for example, farmers making use of sewage materials that may contain low levels of radioactivity, sewage workers at a sewage works that may take authorised discharges of radioactive waste but not authorised itself or fishermen who fish for a living in an environment affected by authorised discharges. It is appropriate that these workers

should be included in the prospective dose assessment processes for members of the public which is made as part of the authorising or permitting discharges of radioactive substances to the environment. If they are not included in this process doses to these groups may never be assessed.

Principle 2	**Workers, who are exposed to discharges of radioactive waste, but who do not work directly with ionising radiation and are therefore not normally exposed to ionising radiation, should be treated as if they are members of the public for the purpose of determining discharge permits or authorisations.**

3.3.5 Because it is not practicable to assess doses to each individual member of the public, the 'representative person' approach is used. The representative person is 'an individual receiving a dose that is representative of the more highly exposed individuals in the population' [Refs 15, 43]. ICRP and the HPA have stated that this term is the equivalent of and replaces the average member of the critical group [Ref 15, 16]. ICRP has recommended that the dose to the representative person can be compared with the public dose limit and with the public dose constraint [Ref 15].

3.3.6 The Euratom Basic Safety Standards Directive 1996 [Ref 9] requires doses to be assessed for reference groups of members of the public. Reference groups are defined as "*a group comprising individuals whose exposure to a source is reasonably uniform and representative of that of the individuals in the population who are the more highly exposed to that source*". This definition of a reference group is broadly equivalent to that of a representative person and can be taken to be the same as the representative person.

3.3.7 It is recommended that the dose to the representative person is assessed for the purposes of comparison with source constraints, site constraints and dose limits, in the process of determining discharge permits or authorisations.

Principle 3	**When determining discharge permits or authorisations, the dose to the representative person should be assessed.**

3.3.8 It should be assumed that all members of the population could be exposed, thus the most affected age group should be selected which will depend upon the radionuclides discharged and the environment around the source.

3.3.9 However, it is generally sufficient to consider four age groups: fetus; 1 year old infants; 10 year old children; and adults. Assessing doses to these four age groups is considered sufficient to represent all age groups. The fetus is taken to include the embryo, the fetus and the breastfed infant in the first 3 months after birth and doses are calculated taking into account intakes by the mother. Although well established data are available to enable doses to be assessed for other age groups of infants and children, these groups are representative of the range of habits, physiology and sensitivity to radiation of all children and infants.

3.3.10 The age groups of 1 year old infant, 10 year old children and adults should normally be considered in a prospective assessment even if there is evidence (e.g. from habit surveys) that there are no people of that age in the location of interest. Assessments of fewer age groups may be made if there is adequate evidence to support this decision (e.g. assessment of doses to adult sewage workers). Doses to the fetus (including embryo and breast fed infants in the first 3 months after birth) may need to be assessed as well if ^{32}P, ^{33}P, ^{45}Ca and ^{89}Sr are present in the discharge.

Principle 4	**Doses to the most affected age group should be assessed for the purpose of determining discharge permits or authorisations. Assessment of doses to 1 year old, 10 year old and adults (and fetus when appropriate) is adequate age group coverage.**

3.3.11 The ICRP has published dose factors for the embryo and fetus from intakes of radionuclides by the mother before and during pregnancy [Ref 44]. The HPA has provided advice on the application of these dose coefficients [Ref 45]. This guidance shows that doses to the fetus need only be considered for four radionuclides (i.e. ^{32}P, ^{33}P, ^{45}Ca and ^{89}Sr) in assessments where these radionuclides form a significant part of any release to the environment. In the case of other radionuclides, assessment of doses to the fetus is not warranted and therefore an assessment of doses to one of the other age groups (1 year old infants; 10 year old children; and adults) will be appropriate.

3.4 Assessment criteria and exposure pathways

3.4.1 All reasonably foreseeable and relevant future exposure pathways should be included in the assessment of doses for comparison with the source constraint (i.e. doses arising from the future discharges of radioactive waste from the source and future direct radiation exposure from the source).

3.4.2 The doses arising from future discharges of radioactive waste from a site (but not future direct radiation) should be assessed for comparison with the site constraint. Doses arising from exposure to radionuclides in the environment from historical discharges are not included in the comparison with the source or site constraint, but are included in the comparison with the dose limit (see **Principle 6**).

Principle 5	**The dose to the representative person which is assessed for comparison with the source constraint and, if appropriate, the site constraint, should include all reasonably foreseeable and relevant future exposure pathways.**

3.4.3 EPR 10 [Ref 1] and Direction to SEPA [Ref 1, 7] require that when permitting or authorising the discharge of radioactive waste, the sum of doses resulting from the exposure of any member of the public to ionising radiation should not exceed the dose limit. As previously discussed, HPA has also recommended that doses from past planned releases should be included when making comparisons with the dose limit [Ref 16].

3.4.4 Hence, if there are significant additional future exposure pathways as a result of other sources of radioactive discharges or direct radiation or accumulation of radionuclides in the environment from historical discharges (i.e. discharges prior to current year), then it will be necessary to undertake an assessment of these for comparison with the dose limit for members of the public.

3.4.5 Past experience of dose assessments for radioactive waste discharges in the UK [e.g. Refs 46 & 47] indicates that, if the dose to the representative person for a single source is less than 0.3 mSv/y, it is extremely unlikely that the dose limit would be exceeded once other sources are included.

Principle 6	**Significant additional doses to the representative person from historical discharges from the source being considered and doses from historical and future discharges and direct radiation from other relevant sources subject to control should be assessed and the total dose compared with the dose limit of 1 mSv/y.**

3.5 Realistic and cautious assumptions

3.5.1 Prospective assessments require assumptions to be made regarding the behaviour of radionuclides in the environment and the habits of people who may be exposed to those substances. One approach is to make an assessment using simple cautious assumptions to ensure that the dose is very unlikely to be underestimated. In general, assessment assumptions are simplified by using generic representative persons and associated generic behaviour or habit data which is used to determine their exposure. Cautious assessments are designed to ensure that the calculated doses will be an overestimate of those that would

actually be received for a given discharge of radionuclide or level of activity concentration in the environment.

3.5.2 An alternative approach is to make a realistic or best-estimate assessment of doses using knowledge and data for known population groups around the site of interest (i.e. a site specific assessment). The aim is to be as close as possible to the actual doses that would be received from discharges at the proposed future limits, by making efforts to be as comprehensive and accurate as possible.

3.5.3 Article 45 of the Euratom Basic Safety Standards Directive [Ref 9] requires that the assessment of doses to 'reference groups' should be made as realistic as possible. This requirement has been included in EPR 10 [Ref 1], Direction to SEPA [Ref 7] and Regulations in Northern Ireland [Ref 8]. EC Guidance on radiological assessment has further promoted the need for realistic assessments [Ref 48].

3.5.4 The HPA has previously given formal advice [Ref 49] that when dose assessments are made for comparison against dose constraints:

"*Where the application of dose constraints will influence the operating regime of a controlled source, it is important that assessments provide estimates of doses that are as realistic as practicable (as opposed to over estimation or under estimation), otherwise operational decisions may be taken which result in much smaller doses to members of the public, but with higher costs and possibly higher doses to workers than would be the optimum. This requirement for realism applies at all stages of the dose assessment, including estimates of discharges and levels of direct irradiation, the modelling of pathways by which individuals are exposed, and the assumptions made concerning the location, habits and characteristics of those exposed*".

3.5.5 For the purposes of setting discharge permits or authorisations, future doses from discharges at the proposed limits have to be assessed. As indicated, this means that various assumptions have to be made, for example about the behaviour of the representative person in the future. It is common practice to start with relatively cautious generic assumptions and then refine these assumptions, where doses are high, to take account of more realistic site specific exposure pathways and habit data.

3.5.6 HPA has published generalised derived constraints (GDC) [Refs 50 and 51], which can be used to assist the assessment of planned discharges. GDCs relate discharges (in Bq) to the dose constraint of 0.3 mSv/y via a fixed and cautious model. HPA recommends that when GDCs are used, further site specific investigation should be carried out if the discharges planned are more than about 30% of the GDC. The implied dose level for further investigation is 0.1 mSv/y. Further investigations would include consideration of site specific factors, the source of the activity, the dispersion to be considered and the length of time for which the discharges are likely to persist.

3.5.7 The Euratom Basic Safety Standards implies that all assessments should be realistic. However, the Environment Agencies, HPA and the Food Standards Agency recognise that where doses are below the threshold of optimisation (<0.02 mSv/y) or are below regulatory concern (<0.01 mSv/y) (see Section 2.4) then the effort to make assessments more realistic may not be warranted. Historically, further investigation and use of more realistic data in the dose assessment should be undertaken when doses exceed a few tens of microsieverts per year (i.e. 0.02 mSv/y). The publication of statutory guidance to the Environment Agency indicating lower regulatory concern below 0.01mSv/y could allow the adoption of 0.01 mSv/y as the threshold which will apply in England and Wales. This would lead to 0.01mSv/y being adopted in England and Wales and 0.02 mSv/y in Scotland and Northern Ireland as the threshold below which the dose assessment process does not require further refinement. However, 0.01 mSv/y and 0.02 mSv/y can be considered to be broadly equivalent for the purposes of this principle and so 0.02 mSv/y has been retained to ensure consistency of this guidance across the UK and with the approach adopted previously.

3.5.8 It is important to recognise that a distinction cannot always easily be drawn between a cautious assessment and a realistic assessment. Assessments will have a number of assumptions which will vary in their degree of caution or realism. The Environment Agencies, HPA and Food Standards Agency recognise that some caution will be required in prospective assessments. This caution will arise from a number of sources including: assessment of discharges at limits rather than expected discharges; use of cautious surrogate radionuclides to represent groups of radionuclides; locations of exposure and food exposure near to the release point; and high occupancy levels and rates of consumption of food.

3.5.9 When undertaking realistic prospective assessments (where the dose exceeds 0.02 mSv/y), sufficient caution should be retained to provide confidence that actual doses received from all sources of radiation by the representative person will be below the dose limit. However, the level of caution between doses assessed prospectively and those assessed afterwards (i.e. retrospectively) should not exceed a factor of about ten, unless this is due mainly to the difference between actual discharges and discharge limits. The level of caution that has been applied may be assessed as a result of an investigation into the uncertainty and variability in an assessment. Consideration should be given to reviewing prospective assessments, if excessive caution is subsequently identified as a result of a retrospective assessment.

Principle 7	**Where a cautious estimate of the dose to the representative person exceeds 0.02 mSv/y, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by the representative person will be below the dose limit.**

3.5.10 The Environment Agencies will assess doses received by members of the public and compare this with the dose limit by undertaking retrospective assessments after the discharge has occurred, mainly using the results of environmental monitoring. Programmes of regular monitoring are carried out by the Environment Agencies, Food Standards Agency and the site operator and reported annually (e.g. Refs 25, 26, 27, 28, 29, 52).

3.5.11 The dose criteria and their application in prospective dose assessments are summarised in Table 2.

Table 2 The dose criteria and their application in prospective dose assessments

Effective dose criteria	Dose quantity	Application to prospective dose assessments	Purpose of assessment
Dose limit	1 mSv/y	One or more future discharges is planned and the radioactivity will combine with the residues of past discharges from one or more sources and direct radiation.	To show that total doses from one or more past and present and future sources will not exceed dose limit.
Site constraint	0.5 mSv/y	Future discharges from the planned operation of more than one source where the sources are on sites that are adjacent. Direct radiation is not included.	To assist optimisation of the planned operation of sources where the sources are under separate control but located close together.
Source constraint	0.3 mSv/y	Upper constraint on future discharges and direct radiation from the planned operation of a single source. Dose assessment should be refined until it is considered to be sufficiently realistic or falls below 0.02 mSv/y	To assist constrained optimisation of the planned operation of a single source. Provide a realistic assessment of doses to act as an input to the optimisation process.
Between threshold of optimisation and source constraint	0.02 to 0.3 mSv/y	Future discharges and direct radiation from the planned operation of a single source. Dose assessment should be refined until it is considered to be sufficiently realistic or the assessed dose falls below 0.02 mSv/y	To assist constrained optimisation of the planned operation of a single source. Provide a realistic assessment of doses to act as an input to the optimisation process.
Level of dose below which the dose assessment requires no further work.	0.02 mSv/y	Future discharges and direct radiation from the planned operation of a single source. If doses are below this threshold, the dose assessment need not be refined further.	To assist constrained optimisation of the planned operation of a single source. Doses sufficiently low to be used as an input to the optimisation process without further refinement.

3.6 Accumulation in the environment

3.6.1 For assessments of individual dose, it is appropriate to take account of accumulation of radionuclides in the environment, usually by undertaking the assessment for the year in which the highest dose to the representative person is likely to occur. This ensures that future generations are afforded the same level of protection as the current generation. Assuming no change in discharge limits, the highest dose to the representative person is generally predicted to occur during the last few years of discharges from a plant/site. Once discharges cease or are reduced significantly, the highest environmental activity concentrations near the discharge point generally start to decline. An accumulation time-scale of the life-time of the plant/site should be used, although 50 years is usually selected for new plants and for plants/sites where it is difficult to specify a closure date. For plants, which are unlikely to be replaced or replaced with plants having significantly lower discharges, then it may be appropriate to limit this to the lifetime of the plants.

3.6.2 Generally, the highest radionuclide concentrations in the environment, from a given site, tend to decline following a reduction in discharges. A key exception is where there is in-growth of a daughter radionuclide from its parent (e.g. americium-241). The effect of a reduction in discharges is clearly demonstrated in the Irish Sea around Sellafield. Discharges from Sellafield of many radionuclides, including radiocaesium and isotopes of plutonium have

declined by a factor of 100 or more between the mid 1970s and present day [Ref 53]. Following the discharge reductions, concentrations of these radionuclides in sea water, sediments and marine organisms in the Irish Sea have also generally declined [Ref 25, 26 & 27, 28, 29]. The decline commenced at the time or shortly after the reduction in discharge occurred. Where there is relevant information available about the accumulation and other reasonably foreseeable effects in the environment, which are likely to have significant implications for the doses which might be received, this should be considered in radiological assessments.

3.6.3 Environmental models (e.g. for the marine environment) should be sufficiently well developed to be able to provide estimates of future average environmental concentrations for key radionuclides over time-scales of about 50 years with a reasonable degree of confidence.

Principle 8	**The assessment of dose to the representative person should take account of accumulation of radionuclides in the environment from future discharges.**

3.7 Representative persons and their habits

3.7.1 There are two broad approaches to the identification of representative persons. The first method identifies the representative person for a particular controlled source by carrying out localised surveys. The alternative method uses a generalised approach that leads to the specification of a generic representative person based on national or regional survey data.

3.7.2 The important factor is that the characteristics of the representative person are applicable to the time period of the dose constraints and dose limits and the time period for which the dose assessment will apply. For prospective assessments of the dose to the representative person relating to the permit or authorisation of radioactive waste discharges, annual doses are required for comparison with the dose constraints and dose limits. The Environment Agencies, HPA and Food Standards Agency have taken the view that the assessments should remain valid for a period of about 5 years.

3.7.3 The reason for this period of validity is that the Environment Agencies regularly review permits and authorisations to ensure that they remain effective. Reviews are usually carried out on a timescale of every one to five years where the dose to the representative person is greater than 0.02 mSv/y. These reviews will include examining whether any new information is available which may affect the results of the dose assessment. However, the reviews will not necessarily lead to a revision of the dose assessment or permit/authorisation. The Environment Agencies, the Food Standards Agency and the HSE also commission habit surveys around nuclear sites. These surveys provide information to allow realistic retrospective assessments of total dose around the sites. The habits information can also be used as inputs to prospective assessments of dose. The frequency of the surveys is about every 4-6 years for sites where the total retrospective dose to the representative person exceeds 0.02 mSv/y. Where total dose is consistently lower than 0.02 mSv/y the surveys may be less frequent. The results of these habit surveys are considered as part of the review of permits and authorisations. The Environment Agencies also keep abreast of significant developments around nuclear sites through engagement with local stakeholders, in particular local authorities. Where such developments could have a significant impact on the effectiveness of a permit or authorisation, this will initiate a review of that permit or authorisation.

3.7.4 To afford future generations the same level of protection as the current generation, it is important that the habits observed for the current generation are assumed to continue into the future. There is also a need to consider potential changes of habits in the future. Cm 2919 [Ref 10] states that "*the regulators should not exclude from consideration any pattern of behaviour which a reasonable person might adopt, whether or not anyone actually engages in such behaviour at a given time*".

3.7.5 The Environment Agencies, HPA and Food Standards Agency recognise that prospective assessments should consider reasonably foreseeable patterns of behaviour for the

representative person (e.g. their habits and location). The difficulty is in balancing this requirement with that of the assessment of doses to be realistic [Ref 9, 48]. ICRP Publication 103 [Ref 15] states that "*the representative person may be hypothetical, but it is important that the habits…used to characterise the representative person are typical habits of a small number of individuals representative of those most highly exposed and not the extreme habits of a single member of the population. Consideration may be given to some extreme or unusual habits, but they should not dictate the characteristics of the representative person considered*".

3.7.6 In practice, an acceptable way to proceed is to make plausible assumptions based on habits and behaviour observed currently or in the recent past for the site in question. It may be appropriate to assume that activities which happened at a location in the recent past (say 5 years), continue into the future, or re-commence, if they do not currently occur. It is reasonable to assume that habit data will not vary significantly over a time period of about 5 years into the future. However, if there are changes around a site which are reasonably likely to occur in the near future (i.e. more than 50% probability of occurring in the next 5 years) and could lead to significant changes to habits, these should be taken into account. Examples might include, the construction of new houses, marinas or allotments. Where habit data suggests that no members of the public are exposed to a major exposure pathway (e.g. fish consumption, external radiation from sediment, consumption of fruit and vegetables etc), then it may be appropriate to use generic habit data for these exposure pathways.

3.7.7 In some situations, a new pattern of behaviour can arise which delivers a significant exposure over a short time period (e.g. consumption of unusual by-catches of seafood). These patterns of behaviour should be considered in assessments where the habits were reported within a period of about 5 years.

3.7.8 The future habits assumed for a representative person should not be influenced by the potential exposures to be received (i.e. it should be assumed that representative persons are unaware of the potential exposures). However, it is not necessary to consider exposures resulting from malicious actions that would lead to a breach of UK law (including statutes, common law and bylaws). For example, occupation of land that would involve trespass does not need to be considered. Also, deliberate actions taken by members of the public with the prime intention to cause themselves to receive radiation exposures should not be included in these dose assessments.

3.7.9 When deciding upon the habits of the representative person, it is appropriate to consider that the representative person is representing a small group of the more highly exposed individuals in the population and that the dose to the representative person should be the average dose to this group [Refs 15, 43]. ICRP Publication 43 [Ref 54] states that this "*group should be small enough to be relatively homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received"*.

3.7.10 ICRP Publication 43 also advises that the degree of homogeneity in this group depends on the magnitude of the mean dose in the group as a fraction of the relevant source upper bound (or dose constraint). In cases where the mean dose is less than about one tenth of the dose constraint, the group should be regarded as relatively homogeneous, if the distribution of individual doses lies substantially within a total range of a factor of ten (i.e. a factor of about three on either side of the mean). Where the mean dose of the group is more than one tenth of the dose constraint, the total range of doses to individuals in the group should be less than a factor of ten, preferably no more than a factor of three. The Environment Agencies, Food Standards Agency and HPA consider that these homogeneity criteria may also be applied to the habits of the group of more highly exposed individuals.

3.7.11 In some cases, the 'normal behaviour' of only one or two individuals may result in them being the more highly exposed individuals (e.g. person living in single dwelling close to the site). The HPA has advised that in these situations, the group of more highly exposed individuals might comprise only these one or two individuals [Ref 49]. What constitutes normal or realistic behaviour for these individuals is considered later.

Principle 9	**The realistic habits adopted for the representative person should be those which have actually been observed at the site, within a period of about 5 years. Changes to habits which are reasonably likely to occur should be taken into account.**

3.7.12 Many representative person habits will be supported by particular land use or infrastructure requirements (e.g. allotments or small holdings for supply of food produce; appropriate anchorage, road access and, usually, mains services power supplies for houseboat owners). The capacity of the infrastructure, land or region of sea to support the representative person for a period of about 5 years is particularly important for the provision of food. When deciding upon where local food might be produced in the future, it is important that there is sufficient land or marine area to support the production of all the food types assumed to be consumed by the representative person.

3.7.13 Where a change of land use or provision of infrastructure is considered for the representative person then this should be reasonably likely over a period of about 5 years and be sustainable year on year. Where planning applications have been made involving a change in land use, then it would be expected that this would be taken into account in an assessment. However, it would not be appropriate to include unconstrained speculation on planning applications which have not been made.

3.7.14 Changes in agricultural practice (e.g. introduction of milk production) which allow consumption of food not currently produced should be considered within future representative person habits, unless it can be demonstrated that factors such as the soil type or climate preclude a particular agricultural practice.

Principle 10	**Land use and infrastructure should have sufficient capacity to support the habits of the representative person. Any changes to land use and infrastructure should be reasonably likely to occur over a period of about 5 years and be sustainable year on year for them to be considered.**

3.7.15 Some specific examples of the identification of future representative person habits are given below:

- A holiday cottage is identified as being at a location which would lead to the highest doses. Under its present use, there will be no single group of individuals who will be exposed continuously throughout the year. However, it is reasonably likely that the cottage could be sold over the next 5 years and a single group of individuals take up residence.
- A derelict dwelling is at a location which would lead to the highest doses. It should be considered reasonably likely that the building could be renovated to achieve legitimate occupation during the next 5 years, unless there are planning controls which prevent this from happening.
- There is a derelict plot of land near to an urban hospital with a large nuclear medicine department. It would not be reasonably likely for the plot of land to be converted to a small holding from which a family source all their food (milk, meat, vegetables and fruit) on a sustainable basis over the next 5 years. However, if there are local residents nearby with gardens, it would be appropriate to assume that these residents grow their own fruit and vegetables within their gardens.
- An estuary with contaminated sediments, currently has no occupation as reported in a habit survey. Generic occupancy habits on these sediments should be used which will provide a cautious estimate of public dose based on activities such as bait digging or dog-walking. It is reasonably likely that such habits could arise during a 5 year time period even if they are not observed at present. For house-boat dwelling, to be considered as likely over this time period, there would need to be a recent history of such occupancy habits, or an appropriate provision of facilities and adequate physical characteristics (e.g. protection from storm conditions in respect of house-boat owners) to enable the habits to be adopted.
- A piece of privately owned land close to a source of radioactivity is normally fenced off from public access and trespass notices displayed. However the fencing and has been degraded and a pathway has been formed across the land which is used by some

members of the public for recreational use. The habits of dog walking on the land have been identified but are contrary to the law and thus any exposure should not be included.

4 Overview of the dose assessment process

4.1 A staged approach to the assessment of the dose to the representative person is advised (see Figure 1) which implements the principles in the previous section. The first stage (Initial Source Assessment) would be to make a simple and cautious assessment of the dose to the representative person. If the resulting dose to the representative person is less than the 0.02 mSv/y (see **Principle 7**), then no further assessment would be warranted for the purpose of authorising the discharge of radioactive waste to the environment.

4.2 Where the cautious dose to the representative person exceeds 0.02 mSv/y, then a detailed assessment should be carried out with the following stages:

- **Detailed Source and Site Assessment -** To determine the dose to the representative person for comparison with the source and site constraints and the dose limit.
- **Short Term Release Assessment** - To determine acceptability of short term release limits, where appropriate.
- **Collective Dose Assessment** - To provide an assessment of the population doses for different discharge/disposal options.
- **Variability and Uncertainty Assessment** - To establish how much caution has been applied at each stage of the assessment.

5 Initial source assessment

5.1 The NDAWG has published guidance on initial radiological assessments [Ref 55]. A simple and cautious assessment methodology has been developed by the Environment Agency, utilising dose per unit release factors based on generic assumptions [e.g. Refs 56 & 57]. The assessment should consider direct radiation where it is known from monitoring or the type of process being operated that direct radiation dose-rates above background levels can or will be measured at the site perimeter.

5.2 A dose assessment methodology for non-nuclear sites has been provided by HPA [Ref 58]. In addition, HPA has published Generalised Derived Constraints [Ref 50, 51] which have been produced using cautious generic assumptions and therefore may be used to make an initial source assessment. The GDCs give the annual discharge for particular radionuclides which if they are not exceeded are unlikely to result in a dose to the representative person greater than 0.3 mSv/y (i.e. the maximum source constraint). If the discharges are greater than 30% of the appropriate GDC (a dose of 0.1 mSv/y) for a single radionuclide, a detailed assessment will be necessary. The dose threshold of 0.1 mSv/y used with GDCs to trigger a more detailed assessment is higher than the dose threshold of 0.02 mSv/y recommended in this document for the same purpose. The GDCs are calculated conservatively and therefore the dose criteria of 0.1 mSv/y is appropriate for use with the GDCs.

6 Detailed source and site assessment

6.1 Steps of detailed assessment

6.1.1 The general steps for a detailed and hence more realistic assessment of the dose to a representative person for a particular source or site are as follows (see Figure 2):

- **Identify / quantify source term -** The amount of each radionuclide released, its chemical form (if important) and the mode of release.
- **Model radionuclide transfer in the environment -** Estimate activity concentrations and dose-rates arising from the discharged radionuclides in environmental media such as air, water, sediment, soils and foods.

- **Determine exposure pathways -** Identify the relevant exposure pathways to people from the activity concentrations and dose-rates in environmental media.
- **Identify habits and data for exposure pathways** – Identify those habits and behaviours together with the associated habit data that could lead to exposure of people through all relevant pathways. Examples of habit data include intake rates of particular foods and the time spent at particular locations.
- **Determine candidates for the representative person from realistic combinations of habits** – A number of different groups of people should be determined for a particular source with their habits relating to the different exposure pathways. These groups of people could receive doses that are representative of the most highly exposed individuals in the population. The determination process should be based on local knowledge and plausible assumptions. Candidates for the representative person expressed in terms of the their habits can then be identified to represent each group.
- **Estimate doses to the candidates for the representative person –** Calculate doses for each group for all relevant exposure pathways. This should include identification of the most important exposure pathways and radionuclides in terms of their contribution to the overall dose.
- **Determine the representative person –** This is the candidate for the representative person expected to receive the highest mean dose.
- **Total dose** - Calculate the additional dose arising from historical discharges from the site being considered and the dose from historical and future discharges and direct radiation from other sources subject to control to enable comparison of the total dose with the dose limit.

6.1.2 Methods and guidance for the detailed assessments of doses from all exposure pathways [Refs 60, 59] and via the food chain [Ref 5, 60. J R Simmonds, G Lawson and A Mayall (1995). *Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment.* European Commission, Luxembourg, EUR 15760 EN, Radiation Protection 72.

6.1.3 61, 62] are available.

6.2 Identify / quantify source term

6.2.1 Prospective dose assessments are made to provide input to the permit determination process. One key requirement is to understand the radiological impact if discharges occur at the limits that are to be set. These might be the limits proposed by the Environment Agencies or the limits applied for by the operator. Actual discharges are likely to be lower than the authorised limits and where doses are above 0.02 mSv/y it may be appropriate to provide an estimate of the doses from the likely or expected discharges in addition to the assessment at the limits. This is more likely to be appropriate where additional evidence of the impact of discharges from the site is required for example if the site is contentious; or predicted doses approach 0.3 mSv/y or additional assurance is required for the local population.

6.2.2 Discharge permits and authorisations contain discharge limits for specific radionuclides and, commonly in the past, for groups of radionuclides with the same type of activity (e.g. total alpha activity or total beta activity). Assessments of doses can only be carried out on a radionuclide specific basis and so where limits for groups of radionuclides remain, it is necessary either to split the discharge for the groups of nuclides between the radionuclides known to be discharged or to use a 'representative' radionuclide. Thus, in some circumstances, it might be cautious to assume that plutonium-239 is representative of total alpha activity or caesium-137 is representative of total beta activity. However, in most cases it is more realistic to adopt a site specific approach based on the radionuclides known to be discharged from the site. In cases where a discharge permit or authorisation is being set for a new facility, the assumed radionuclide composition will have to be based on a knowledge of the processes that will be undertaken or from considering discharges from similar facilities already in operation.

6.2.3 In some cases the chemical form of the discharged radionuclide can have a significant effect on the radiation doses. The operator will be required to provide information on specific or

general chemical form, particularly when it is important in the dose assessment (e.g. organic or inorganic form of radionuclides).

6.3 Model radionuclide transfer in the environment

6.3.1 A variety of models and data are required to predict the transfer of radionuclides through the environment and the resulting doses to people. It is important that any models used are robust and fit for the purpose. Measures should have been taken to ensure that the models are valid. This means that the models should have been tested to ensure that they are behaving as intended and where possible they should be compared with measurement data to ensure that they are an adequate representation of reality. For permitting or authorisation purposes it is normally adequate to use generic models and parameter values although occasionally there may be sufficient evidence to warrant using a site specific value for a particular parameter. Empirical models may also be used which relate environmental activity concentrations to discharges, although care has to be taken due to the accumulation of radionuclides in the environment.

6.3.2 Permits and authorisations are mainly concerned with routine discharges and it is assumed that discharges are continuous over a year. Where this is not the case and a significant proportion of the authorised limits are utilised in a short time period, say a few days (e.g. depressurisation of gas cooled reactors or iodine-131 discharges to sewer from thyroid treatment at a hospital), then short term releases will need to be assessed (see later section on Short Term Releases).

6.3.3 Although the dose assessment is carried out for a year's discharge there is the possibility that radionuclides will build up in the environment from continuous discharges over more than one year. Account should be taken of this in the modelling (see **Principle 8**), by assuming that the discharge continues for the lifetime of the plant or 50 years, with the dose assessed for the final year of discharge.

6.3.4 There are a number of environmental dispersion and dose assessment models available. The Environment Agencies make no specific recommendation on model application, but require any model to be appropriate for the application. The European Union code system, PC-CREAM [Ref 63] is a suitable model for many applications. The code is based on a methodology for assessing the radiological consequences of routine releases published by the Health Protection Agency in 2009 [Ref 59], which is an update of the original methodology published in 1995 by the EC [Ref 60]. It should be noted that currently PC-CREAM does not have a model for the assessment of doses to sewage workers as a result of discharges to sewer. Also, it cannot be used directly to assess the impact of the disposal of sewage sludge to land, where the sludge contains radionuclides. Alternative models for the assessment of doses from discharges to sewer are available [Refs 50, 51, 58, 64, 65, 66].

Atmospheric Discharges

6.3.5 For releases to atmosphere, models are required to estimate activity concentrations in air and the subsequent deposition of radionuclides to the ground. Further models are then required to predict the transfer of radionuclides through terrestrial foodchains, the behaviour of radionuclides deposited on the ground and, where relevant, the resuspension of radionuclides from the ground back into the air.

6.3.6 The model used to predict activity concentrations in the air and on the ground should take account of the effective particle size of the radionuclides, the effective release height, the range of meteorological conditions that occur in the course of a year, wet and dry deposition as well as radioactive decay. All significant routine radioactive releases of radionuclides to atmosphere are filtered, generally using High Efficiency Particulate in Air (HEPA) filters. The filters generally trap all particles with an activity mean aerodynamic diameter (AMAD) of greater than 1 μm. The model used will need to be appropriate for the remaining discharged particle size range. Models used may simplify the modelling by assuming that all that particles have an AMAD of 1 micrometer for the purpose of the assessment – which needs to match to the assumption about particle size for the dose coefficients for inhalation.

6.3.7 The meteorological conditions should be appropriate for the site in question and should preferably be averaged from several years of data. Such data may be available for the site itself or from nearby meteorological stations. The atmospheric dispersion model also needs to take into account the height of the release, the effects of nearby buildings and any plume rise due to the thermal buoyancy and/or momentum of the released material. Gaussian plume dispersion models [Ref 67] are currently still acceptable for public dose assessment purposes, although new generation dispersion models (e.g. ADMS [Ref 68], AERMOD [Ref 69]) are available.

6.3.8 It is common practice to a use a generic model for the transfer of radionuclides through terrestrial foodchains. In such models similar foods are grouped together for modelling purposes, for example green vegetables and root vegetables are considered rather than specific crops such as cabbage or carrots. In most cases it will be acceptable to use generic parameter values for the foodchain model. However, if extensive measurements have been made close to the site then it may be appropriate to use site specific values for particular parameter values. The PC-CREAM code contains the FARMLAND model for undertaking such modelling [Ref 59] and the Food Standards Agency uses its own model, SPADE [Ref 70].

6.3.9 For modelling the resuspension of radionuclides deposited on the ground two approaches are possible. The first uses a resuspension factor to relate the ground deposition to the activity concentration in air while the second uses a dust loading approach [Ref 59]. Resuspension factor models can take account of the ageing process for deposited activity, including weathering of the deposit and migration into deeper soil layers. The dust loading model is particularly appropriate for scenarios in which the concentrations of radionuclides in soil or dust have arisen from processes other than atmospheric deposition (e.g. sewage sludge conditioning of land) or there are higher than normal dust loadings in air (e.g. due to agricultural activities).

6.3.10 A model may also be required to calculate external radiation exposures from radionuclides in the passing cloud and deposited radionuclides. The latter should allow for the downward migration of radionuclides in the soil as well as the build up of activity due to continuous deposition. Dose-rate factors per unit air concentration or deposition rate are available [Ref 59, 71] and are provided in PC-CREAM data files.

Aquatic discharges

6.3.11 Radioactive wastes may be discharged to a freshwater, estuarine or marine environment. In the UK there are also discharges of radionuclides to the sewer system from hospitals, universities and research establishments and a few nuclear sites.

6.3.12 Radionuclides discharged to water bodies are dispersed due to general water movements and sedimentation processes. Much depends on the local characteristics of the receiving environment and it is not possible to have a totally generic model for these releases. For example, for rivers information is required on the size of the river and its flow rate. Models are required to predict the activity concentrations in water and in sediment. From these data activity concentrations in aquatic foods, such as fish and crustaceans, can be estimated together with external radiation doses from exposure to sediments.

6.3.13 In assessing doses to the candidates for the representative person, the highest activity concentrations and hence doses will generally arise close to the discharge point. However, there is the possibility of exposures arising from further downstream, for example where drinking water is abstracted or where there is a major fishery. Freshwater may be used for irrigation of agricultural land and then the transfer of radionuclides to the terrestrial foodchains needs to be considered. The models discussed above for releases to atmosphere may be adapted to derive concentrations of radionuclides in food, where the source of radionuclides is via irrigation water, modelling deposition by rain. For discharges to the marine environment exposures may also arise from radionuclides in sea spray being blown onto land and inhaled.

6.3.14 When assessing discharges to sewers, it is necessary to model the transfer of the radionuclides to the sewage works and their subsequent release into the environment. At the sewage works the doses to workers need to be estimated from external irradiation as well as inhalation and inadvertent ingestion. Radionuclides could be discharged from the sewage works with the treated effluent, to rivers or coastal waters, where the models discussed above would be required. In addition radionuclides may be associated with the sewage sludge which is disposed of in various ways including its use as a land treatment and disposal by incineration. Appropriate models are then required for the transfer of radionuclides through terrestrial foodchains and for atmospheric releases (as discussed previously).

6.4 Determine exposure pathways

6.4.1 The relevant exposure pathways depend on the radionuclides discharged and the particular circumstances. The following pathways should normally be considered although calculations will not necessarily be carried out for them all for all cases:

- Internal irradiation following inhalation of radionuclides in the air either following releases to atmosphere or following the resuspension of radionuclides from the ground or in seaspray.
- External gamma irradiation from radionuclides in environmental media including air, soil and sediments.
- External radiation direct from the site of interest.
- Internal irradiation following the ingestion of radionuclides in terrestrial and aquatic foods and drinking water.
- Internal irradiation following inadvertent ingestion (e.g. soil, sediment or seawater).
- External beta irradiation of skin from exposure due to radionuclides in environmental media.
- Internal irradiation from direct absorption of radionuclides through the skin (e.g. tritium).

6.4.2 Where unusual pathways relating to authorised discharges exist at a site then they should be included in the assessment.

6.4.3 NDAWG has published guidance on common and unusual exposure pathways [Ref 72].

6.5 Identify habits and data for exposure pathways

6.5.1 Particular habits and behaviours which could lead to exposure of people through the pathways outlined above should be identified. This may be accomplished through local knowledge, commissioning of habit surveys or by reference to generic studies of such habits.

Atmospheric discharges

6.5.2 The key exposure pathways are inhalation, irradiation from deposited activity and consumption of food. The radiation exposures will depend on the concentrations of radionuclides in air and on the ground around the site resulting from the discharges. This depends in turn on the location of the discharge points, the effective height of the release and the atmospheric conditions.

6.5.3 For inhalation of radionuclides in the plume, locations with the highest air concentration are required while for external irradiation from deposited material it is the highest ground deposition that leads to the highest exposures. Locations for assessment might include homes, places of work or places for leisure (e.g. dog walking, fishing). Only occupation of existing buildings need be considered. It is not normally necessary to consider the possibility of additional buildings being erected unless the land is within a planned development area. Where there are no planned developments, a substantial period of occupancy in a new building is unlikely during the course of the permit or authorisation period.

6.5.4 Account should be taken of the degree of shielding offered by the building, to reduce the external irradiation exposure, and also occupancy of the building. Generic occupancy data is available for time spent at home by different age groups [Ref 73], detailing time spent indoors and outdoors in the garden. If the building is a workplace only, then assuming occupancy

during working hours only is sufficient [e.g. 2000 hours per year, Ref 73]. The combination of occupancy and shielding may mean that the nearest building to the source is not the location for the most exposed group.

6.5.5 For discharges to atmosphere it is also necessary to include the transfer of radionuclides to terrestrial foods and their subsequent ingestion by people. The areas of land currently used for agricultural production or where it is reasonably likely that food production could occur, over a period of about 5 years, need to be identified. The assessment will be concerned with those agricultural areas where the deposition from atmosphere is highest. It is possible for people to grow vegetables in their gardens and so it is reasonable to assume that any house nearby could have vegetables growing. It is important to consider the intake of products such as milk and meat from animals such as cattle and sheep that graze outdoors for significant periods. It is also reasonable to assume that any agricultural land nearby could be used for cattle and sheep in the future even if this is not currently the case. It is not normally necessary to consider products from pigs and poultry where they are housed inside and fed from a number of sources most of which will be some distance from the site of interest. However, it is unlikely that a house could change to become a small holding with cattle or sheep so this possibility does not need to be considered. It is also considered unlikely that someone would grow their own grain and so this possibility does not normally need to be considered. Habit surveys may be used to ascertain what food has been produced locally over a period of about the last 5 years.

6.5.6 Agricultural production occurs over significant areas and so it is unrealistic to assume that all food consumed could be produced close to the source of the discharge, unless this is shown to be the case by habit surveys. It might be cautiously assumed that a few foods could be produced over an area which has a centre at a distance of few hundred metres from a premises' boundary. However, where it is assumed that a number of different types of foods (e.g. milk, meat and vegetables) are produced close to the source of discharge, then it is more realistic to take account of the need for larger grazing areas, movement of livestock around a farm and rotation of crops. Thus, a distance of 500 m from the premises' boundary would be a more realistic minimum distance for the production of food, unless there is evidence to indicate that significant production occurs at a closer distance. It is important that models used in the determination can provide an assessment at these distances.

6.5.7 There is evidence from national and regional habit surveys that people rarely consume more than two foods at high rates [Ref 74]. In assessments where consumption rates for each food type are used, then two foods are assumed to be consumed at high rates while other foods are assumed to be consumed at average rates. The two foods chosen are those which give rise to the highest dose. If assessments utilise data-sets of actual consumption rates for individual people obtained from site specific habit surveys, then it is not necessary to make such assumptions about which foods are consumed at the highest rates. It is normally cautiously assumed that all terrestrial foods are locally produced. The degree of caution resulting from these assumptions can be investigated as part of an uncertainty/variability review (see later).

Aquatic discharges

6.5.8 For marine discharges, the habits to use in the assessment are likely to include consumption of higher than average amounts of locally caught seafood (fish, crustaceans and/or molluscs) and spending a relatively large amount of time on areas of sediment or sand – leading to exposure to external irradiation (this could also include handling sediment or sand). The candidates for the representative person for marine discharges do not necessarily live close to the source of the discharge.

6.5.9 The habits to use in an assessment of discharges to freshwater can include consumption of drinking water abstracted from the freshwater environment, angling on riverbanks into which radionuclides have been incorporated and give rise to an external dose rate, consumption of freshwater fish, and consumption of food irrigated by the freshwater. The selection and application of habits data should be informed by location specific information on land and water use and by site specific habit data where available.

Direct radiation

6.5.10 For direct radiation exposure, the habits will generally be living or working close to the source of radiation. As for external irradiation from deposited atmospheric discharges, factors such as occupancy and the shielding effects of buildings influence the location of the most exposed group [Ref 75]. It is only necessary to consider existing buildings for assessing direct radiation doses, for the same reasons as atmospheric discharges.

6.5.11 The Environment Agencies do not have regulatory responsibility for ensuring the control of direct radiation from nuclear sites, this being a duty of the HSE. However, direct radiation exposure should be considered as an additional dose at the locations where members of the public are exposed to atmospheric and/or aquatic discharges. The Environment Agencies will liaise with the HSE over the assessment of direct radiation doses from nuclear sites, including the publication of direct radiation dose-rates.

6.5.12 NDAWG has published a guidance note on the assessment of direct radiation [Ref 76].

Habit data

6.5.13 A variety of habits data is required to assess radiation doses. These include intake rates of terrestrial and aquatic foods, water and air together with occupancies of different environments, such as time spent indoors or near sediments. As discussed earlier it is possible to use generic or site specific data and the important factor is that the data are applicable over a period of about 5 years. Both average habit data and higher than average habit data are required to assess doses.

6.5.14 A compilation of intake rates for a range of foods has been published jointly by the then MAFF and NRPB [Ref 77]. These data include the mean and median intake for consumers that could be used to represent the average and also the 97.5 percentile that can be used for the higher than average habit data. This compilation is based on national surveys and is appropriate for use where there are unlikely to be strong local differences in intakes.

6.5.15 For aquatic foods there are likely to be regional or local differences, for example between the intakes of people living in a coastal community and the UK population as a whole. Also the availability of particular seafood species, varies around the UK. Site specific habit surveys have been carried out for many years to determine the intakes of aquatic foods [Refs 25, 26, 27, 78, 79 & 80]. These surveys are available for the major nuclear sites and a range of different locations for marine, estuarine and freshwater environments. The surveys show existing or past habits and care is required in applying them to prospective permits or authorisation assessments. It is possible to use these site specific data to obtain a more generic set of intakes for use in permit or authorisation assessments (for example, see Reference 73).

6.5.16 Habit surveys have shown that there are generally less local and regional differences in intakes for terrestrial foods compared to aquatic foods. Therefore the use of generic intake rates for terrestrial foods [e.g. Refs 73 & 77] is unlikely to lead to unrealistic assessments. Where site specific studies identify higher intake rates that are reasonably likely to continue over a period of about 5 years, then these should be used.

6.5.17 Generic and site specific data on occupancies are also available [Refs 73 & 78]. As for terrestrial food intakes, generic habit data may be used, unless site specific studies identify higher occupancy.

6.5.18 Further guidance on the evaluation and use of habits data for prospective assessments including site specific and generic data has been presented by the NDAWG [Ref 81]

6.6 Determine candidates for the representative person from realistic combinations of habits

6.6.1 Candidates for the representative person will need to be identified with particular combinations of habits, both higher than average and average, based on local knowledge and plausible assumptions. These combinations of habits will need to be realistic and not lead to implausible situations such as a full-time working person spending an equal proportion of the day on leisure activities or a person having an excessive calorie intake.

6.6.2 A full range of exposure pathways should be considered for each of the candidates for the representative person. For example, the people who are candidates for the representative person due to their direct radiation exposure from the site will also be exposed due to any atmospheric discharges and depending on the circumstances could be exposed due to the aquatic discharges. However, in most cases it is not realistic to assume that the same people are most exposed from all pathways and so a simple addition of doses attributed to different pathways is not necessarily appropriate. Instead, a combination of habits typical of average and most exposed people may be assumed. For example, the candidates for the representative person who eat locally produced terrestrial foods at higher than average rates, could be assumed to eat a proportion of locally produced aquatic foods at average rates.

6.6.3 Candidates for the representative person may be located in areas remote from the site as a result of discharge to sewer or the interplay of dispersion and accumulation mechanisms in the environment. Sometimes, it may be necessary to consider candidates for the representative person from different countries within the UK and to assess doses to the population of other European countries close to the UK.

6.6.4 The Environment Agencies, Food Standards Agency and the Office of Nuclear Regulation have commissioned combined (terrestrial and marine pathway and direct radiation pathway) habit surveys in England, Wales and Scotland to provide information on real cases of combinations of exposure pathways. The results of these studies are published (see the RIFE series of reports [Ref 29] for the references to the most recent habit surveys) and form the basis for defining the habits of the representative person.

6.6.5 Typical candidates for the representative person may include the following:

- Consumers of shellfish and fish who spend time on contaminated sediments collecting shellfish.
- Fisherman who dig bait, and catch and eat fish.
- People who eat local terrestrial produce and walk dogs on a beach.
- People who eat local fish and shellfish and local terrestrial produce.
- Farmers who work outdoors close to site and eat local terrestrial produce.

6.7 Estimate doses for candidates for the representative person

6.7.1 Dose coefficients are required to calculate the radiation doses arising from intakes of radionuclides into the body. A full range of dose coefficients for intakes by inhalation and ingestion has been published with the Euratom Basic Safety Standards Directive 1996 in the Official Journal of the European Communities [Ref 9]. It is a requirement of this Directive that the dose coefficients are used. They are the same dose coefficients for intakes by inhalation and ingestion that have been published by ICRP [Ref 82] and by IAEA [Ref 83]. From time to time HPA may advise the use of different dose coefficients to those provided in Euratom Basic Safety Standards Directive for certain situations. Where HPA provide such advise it will be taken into account.

6.7.2 The dose coefficients for internal irradiation relate the intake of activity (Bq) to the committed effective dose (Sv) and are available for a number of ages and, in the case of inhalation dose coefficients, common chemical forms for each radionuclide. If specific information on chemical form is not available then the defaults recommended in ICRP Publication 72 [ref 80] should be used. It is not appropriate to use the chemical form that leads to the highest dose coefficient in

all cases. Based on an understanding of the processes involved, expert judgement should be used to determine the most appropriate chemical form for use in the assessment.

6.7.3 For calculating effective doses and equivalent doses from external irradiation, standard models exist as well as compilations of dose coefficients [e.g. Ref 59, 71]. It is important to note that when calculating equivalent doses to the skin this should be the average dose over an area of 1 cm^2 to compare to the dose limit.

6.8 Determine the representative person

6.8.1 The term 'representative person' is used solely to refer to an individual receiving a dose that is representative of the more highly exposed individuals in the population. The dose to the representative person will result from a combination of exposure pathways arising from all routes of discharge and include exposure due to direct radiation from the site. It is not appropriate to define separate representative persons for discharges to different environmental media. The dose to the representative person will be compared with the source or site constraint as appropriate.

6.9 Total dose

6.9.1 In order to make a comparison with the dose limit, significant future exposures arising from historical discharges from the site, historical and future discharges from other sites in the locality and future direct radiation from other sites will need to be added to future discharges and direct radiation from the site. Expert judgement will be required to determine those discharges and direct radiation sources which are likely be significant, but those which are likely to give rise to a dose greater than 10% of the dose arising from the source under consideration might be regarded as requiring an assessment. The representative person for total dose may be different to that assessed for comparison against the source or site constraint.

6.9.2 Modelling of the transfer of radionuclides in the environment and foodchain can be used. However, it may be possible to use the results of published retrospective assessments which utilise radiological environmental monitoring data, such as those produced by site operators, Environment Agencies [e.g. Ref 52]; the Environment Agencies and the Food Standards Agency [Refs 25, 26, 27, 28 & 29];or the HPA [e.g. Ref 46].

7 Short term release assessment

7.1 Operational short term releases of a significant proportion of the 12-month discharge limit, can occur as a result of variations in site production, restricted nuclear medicine treatment days within hospitals or particular projects (e.g. decommissioning activities).

7.2 The dose to the representative person which is assessed for releases at the annual or 12-month rolling discharge permit or authorisation limits, assumes that the activity is discharged continuously and uniformly throughout the year. In practice, discharges are unlikely to be entirely uniformly continuous. Indeed, radioactive waste discharged to the aquatic environment, is generally accumulated in tanks prior to discharge which then occurs over a short period each day. Given the other uncertainties in the assessment process, the results based on continuous release are appropriate for these normal operational daily variations in discharges.

7.3 However, if a significant proportion of the 12-month permit or authorisation limit (e.g. ≥2% of 12-monthly actual or expected discharges) was released operationally in a short time period (e.g. ≤1 day), this could lead to a higher annual dose to the representative person than that assessed for a uniform release rate over the year for the following reasons:

- Over the short time period that the release occurred, dispersion in the environment could be more localised than average dispersion over a year. This could lead to higher activity concentrations in a few parts of the environment, including areas where food is produced. In

the case of discharges to atmosphere, this might be due to occurrence of meteorological conditions leading to poor dispersion (e.g. inversion conditions at night or during anticyclones) and the wind blowing in one direction for the duration of the release. For discharges to water, this could be a result of low flow conditions in rivers etc, such as can occur during summer months.

- For releases to atmosphere during rainfall this will lead to greater local deposition of radionuclides.
- Occupancy habits may change through the seasons. For example, swimming in the sea or angling may occur more frequently in summer.
- Food may be ready for harvesting shortly after the release leading to higher activity concentrations in the food than would have been assumed. Also, some foods (e.g. root vegetables and fruit) may be stored for consumption for many months after harvesting, giving prolonged exposure.

7.4 It should be noted that, conversely, short term releases could occur at times which would lead to lower doses (e.g. during winter when milk is produced by cows which are not grazing outdoors).

7.5 The Environment Agencies may decide to impose short term (i.e. daily, weekly, monthly or quarterly) notification levels or limits as a preventative measure to constrain doses from operational short term releases. Dose assessments for discharges at short term limits or notification levels will need to follow the same principles as those used to assess doses from annual discharges. The assessment process may start with an initial assessment and then adopt more realistic assumptions if the cautiously estimated doses exceed 0.02 mSv/y.

7.6 The dose from operational short term discharges which might occur during a year at notification levels or limits may be compared with the source dose constraint of 0.3 mSv/y and the dose limit of 1 mSv/y. Where the total discharges from short term releases in the year are less than the 12 month discharge limits, the dose assessment should take into account continuous discharges during the remainder of the year up to the 12-month discharge limits.

Principle 11	**The dose assessed for operational short term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3 mSv/y) and the dose limit (1 mSv/y), taking into account remaining continuous discharges during the remainder of the year and contributions from other relevant sources under control.**

7.7 The National Dose Assessment Working Group has produced guidance on assessing doses from short term releases [Ref 84]. This provides guidance on how to make the short term release assessment realistic (e.g. number of short term releases in a year, duration of release, harvesting and storage of food etc) and where to obtain data for the assessment.

7.8 As with continuous discharges of radioactivity, there will be a build up of radioactivity in the environment from short duration releases which occur many times throughout the lifetime of the plant. Unless there is evidence to the contrary, environmental conditions (e.g. wind direction) will not be the same for every short term release. Thus, the averaging assumptions used in the assessment for discharges at the annual or 12-month limit will be applicable. For short duration releases that occur beyond one year, the assessment can adopt the assumptions of continuous releases. The assessment will take into account build-up in the environment by using doses for the 50^{th} year of discharge. Consequently, there is no need to consider short term releases that continue for one year or more. Discharges beyond one year can be assessed as a continuous release.

7.9 Uncontrolled short term releases may also occur as a result of incidents or accidents. Doses arising from these uncontrolled releases are not assessed as part of the process of authorising routine discharges of radioactive waste to the environment. The doses and risks from uncontrolled releases are addressed as a requirement of the Ionising Radiations Regulations [Ref 21, 22] and, where relevant, the nuclear site licence conditions. The Environment Agencies and the Health and Safety Executive inspect operators on a regular

basis to ensure that engineered and administrative protection systems are in place to minimise the likelihood and consequences of such uncontrolled releases. Radiological assessments would be carried out as part of post-accident recovery operations, but this guidance document does not strictly apply to this situation.

8 Collective dose assessment

8.1 Collective dose has been defined by ICRP as the sum of doses received by members of the exposed population from all significant exposure pathways from a given source [Refs 15, 20, 85]. Radionuclides with long radioactive half-lives, such as carbon-14, can give rise to doses over extended periods of time, long after a release has stopped. To account for this the annual individual doses to the exposed population are summed over various time periods following the year of release. Doses are summed up to a specified time, for example, 500 years and the quantity is referred to as collective dose truncated at 500 years.

8.2 There is no legal limit for collective doses. Instead, collective doses are normally used to assess different process or discharge/disposal options (e.g. for the abatement of discharges). The Environment Agencies use the outcome of collective dose assessments for this purpose. The International Atomic Energy Agency (IAEA) has presented dose criteria which are considered sufficiently low that doses arising from sources or practices that meet these criteria may be exempted from regulatory control. One of the criteria is that collective dose should be less than about 1 man Sv per year of practice [Ref 30, 31].

8.3 Collective dose to an exposed population of members of the public is often the result of the summation of very small individual doses to very large number of people. Thus, although the resultant collective dose may be numerically large, from the perspective of the individual the risks from the exposure may be insignificant. Both the magnitude of the individual doses and the size of the exposed population become increasingly uncertain as the time increases [Ref 86]. Also, current judgements about the relationship between a radiation dose and the consequent health effects may not be valid for future generations. For these reasons, ICRP has recommended that, generally "*forecasts of collective dose over periods longer than several thousands of years and forecasts of health detriment over periods longer than several hundred years should be examined critically*" [Ref 17]. ICRP also recommends [Ref 15] that "*to avoid inappropriate aggregation of, for example, very low individual doses over extended time periods and wide geographical regions, limiting conditions need to be set*". These limiting conditions will include the time period of integration. In general, the rate of increment of collective dose is highest when discharges are occurring and begins to slow when discharges cease. Therefore, the rate of increment of collective dose will be highest in the first few hundred years.

8.4 It is therefore appropriate to draw comparisons of process/disposal options on the basis of truncated collective doses [Refs 87, 88]. HPA has previously noted that calculations of collective dose extending beyond around five hundred years into the future are of little value for estimating health effects [Refs 89, 90]. The HPA continues to recommend that collective doses estimated for discharge permitting or authorisation purposes should be truncated at 500 years [Ref 16]. In estimating collective doses the population of the UK should be considered together with the populations of Europe and the World.

Principle 12	**For permitting or authorisation purposes, collective doses to the populations of UK, Europe and the World, truncated at 500 y, should be estimated.**

8.5 Estimating collective doses requires appropriate models together with information on the spatial distributions of population and agricultural production over the region of interest [Ref 59]. The code system PC-CREAM [Ref 63], for example, can be used to estimate collective doses for discharges to atmosphere and discharges to the sea. HPA has published the results of a study to determine the radiological impact of routine discharges from UK civil nuclear sites in the mid 1990s [Ref 90]. This report gives collective doses per unit discharge for a range of radionuclides for a number of locations in the UK. These collective doses can be scaled by the actual discharges to obtain collective doses for authorised discharges. If

the site of interest is not included then it is acceptable to take another similar site, preferably nearby, and to use the collective doses from there. In general, the world collective dose need only be considered for globally circulating radionuclides (e.g. tritium, carbon-14) as all other radionuclides will not be dispersed significantly beyond Europe. Collective doses per unit activity concentration in sewage sludge and unit production rate of the sludge are also available for some radionuclides [Ref 64].

8.6 By its nature, collective dose is an aggregated quantity and even in the case of collective doses truncated at 500 years, useful information for decision-making may be hidden. For example, the magnitude of the individual doses comprising the collective dose and when these doses are received are useful items of information. ICRP recommends that when exposures occur over large populations, areas and time periods with the range of individual doses spanning several orders of magnitude the distribution of individual doses should be characterised by division into ranges. However HPA considers that the disaggregation of collective doses by ranges of individual doses is not usually possible. A study carried out for the European Union [Ref 91] found that consideration of individual dose distributions is not possible if ingestion of food is an important exposure pathway. HPA has suggested that the use of the per-caput dose may provide an alternative useful input.

8.7 It can be shown that the collective dose truncated at a particular time from one year's operation of a practice is numerically equal to the maximum annual collective dose-rate if the practice operated unchanged for that time period provided all other factors remained the same [Ref 92]. Thus, division of the maximum annual collective dose by the number of individuals in the exposed population gives the highest average annual individual dose in the exposed population from operation of the practice over the particular time period. A realistic approach would be to assume that proposed new practices operate unchanged for a period of 100 years. However it is suggested that proposed new practices are assumed to operate unchanged for a period of not more than 500 years and that the highest average individual doses are calculated for 500 years. Individual facilities, of course, will not exist for such an extended time period; it is assumed, however, that they would be replaced by similar facilities.

8.8 For a practice that operates for a shorter time period, the collective dose truncated at 500 years may be greater than the maximum annual collective dose, but will, in any case, be no less. In the case of existing facilities that may have been designed to meet less stringent standards than apply today and which would operate for only a limited period of time, it might be appropriate to estimate average annual individual doses from collective doses truncated at time periods much shorter than 500 years. An appropriate truncation period for these calculations would be 100 years.

8.9 The highest annual average individual dose is a useful quantity for decision-making purposes. Taken together with estimated representative person doses, it gives an indication of the health risks to individuals in the exposed population and also allows an evaluation of the radiological implications of build-up of radionuclides in the environment.

8.10 In this respect, calculated average annual individual doses for a population group in the nanosievert (nSv/y) range or below should be ignored in the decision making process as the associated risks are minuscule and the contribution to total doses to individuals will be insignificant. Higher annual doses, up to say a few microsievert (μSv/y) can be considered trivial but may require some consideration particularly if at the higher end of the range. Calculated annual average individual doses in excess of these values should prompt careful consideration of the discharge options being considered.

9 Variability and uncertainty assessment

9.1 As discussed above, assessments of doses necessarily entail a series of assumptions about the identification and behaviour of candidates for the representative person and about the transfer of radionuclides in the environment. Different groups of people will have different behaviours and this is considered through the process of selecting a number of known or plausible candidates for the representative person. This process allows different exposure

pathways and habits to be explored in a realistic manner. These different habits lead to a distribution of different doses and the estimated mean dose to the representative person is therefore within this distribution. There are two significant aspects to this distribution referred to as the uncertainty and the variability.

9.2 The uncertainty reflects the amount of knowledge about the system being investigated and relates to how accurately the dose can be estimated. For example, the extent of knowledge on the parameters used in the calculation of doses. The NDAWG has published guidance on considering uncertainty and variability in radiological assessments [Ref 93].

9.3 The variability refers to the genuine differences that occur both in radionuclide transfer in different environments and between individuals within a group. For example, there are differences in how much of a particular food is consumed per individual within a defined group of consumers. This topic is discussed in more detail in Reference 94 and a number of studies have been carried out by the HPA, Food Standards Agency and EC to investigate uncertainty and variability [e.g. Refs 47, 95 & 96]. In addition, a study carried out for the Environment Agency by the HPA [Ref 97] investigated the variability in the radiation doses and risks received by critical groups. The study looked at the spread on the distribution of doses to critical groups from authorised discharges from the Sellafield and Sizewell nuclear sites. The spreads on the dose distributions as represented by the ratios between the 5^{th} and 95^{th} percentile were estimated. The ratios were generally between 3 and 5 depending on the group and site considered.

9.4 The scale of uncertainty and variability should be reviewed and this should include:

- Expected discharges compared with limits – the extent of headroom.
- Representative radionuclides – the effect of different radionuclides selected to represent a group and effect of different chemical forms.
- Environmental modelling – effect of different models and parameter values used for atmospheric dispersion modelling, marine dispersion modelling and food chain modelling.
- Selection of exposure locations and source of food production.
- Selection of habits – effect of different consumption and occupancy patterns.
- Dosimetric data.

9.5 The purpose of this review would be to provide confidence that an appropriate level of caution has been applied to the assessment. The review will ensure that sufficient caution has been retained such that the dose limit is unlikely to be exceeded on the basis of a retrospective assessment (see **Principle 7**) but balancing this against ensuring that there has not been an undue level of caution applied in the assessment. Such a review will only be necessary when the cautiously estimated dose to the representative person exceeds 0.02 mSv/y and a more detailed assessment is required. The approach taken to assessing uncertainty should be proportionate taking into account the level of dose estimated and the degree of confidence in the robustness of the assessment. Consideration of how to manage the scientific, financial and presentational aspects of an uncertainty assessment will be needed if a more complex approach involving multiple inputs and leading to multiple results is to be carried out.

Principle 13	**Where the assessed mean dose to the representative person exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions used for the dose assessment should be reviewed.**

10 Conclusions

10.1 This document provides guidance on the assessment of doses to members of the public for the purposes of permitting or authorising discharges of radioactive waste to the environment. The guidance has been developed by the UK Environment Agencies in collaboration with the Health Protection Agency and the Food Standards Agency as a result of a recognised need to ensure that the methods used in assessing public doses are consistent and transparent. The Euratom Basic Safety Standards Directive 1996, which has been largely implemented in

UK law through various Regulations, amendments to the Radioactive Substances Act and a Direction placed on SEPA, provides particular requirements for the assessment of public doses.

10.2 Principles have been established which relate to the following:

- Population groups to be considered in assessments and the use of the representative person concept.
- Exposure pathways to be included for comparison of doses against the source constraint, site constraint and dose limit.
- Accumulation of radionuclides in the environment.
- The need for realistic dose assessments, based upon the selection of realistic habits, but taking account of reasonably likely changes over a period of about 5 years.
- The need to assess doses from short term releases, assessment of collective doses and investigation of variability and uncertainty in the assessment.

10.3 A staged approach to dose assessments is recommended. An initial cautious assessment may be undertaken using, for example, published dose per unit release factors. If the assessed dose is less than 0.02 mSv/y then no further dose assessment will be necessary. This is likely to be the case for most non-nuclear premises. Where the assessed dose exceeds 0.02 mSv/y, a more detailed and realistic site specific assessment should be carried out. Assessed doses will be compared with the source and site constraints of 0.3 mSv/y and 0.5 mSv/y respectively. Significant additional doses from historical discharges and other sources will need to be assessed and compared with the dose limit of 1 mSv/y.

10.4 Assessments for short term releases may be required to enable short term (e.g. daily, monthly or quarterly) limits or notification levels to be set.

10.5 Collective doses for the UK, European and world populations may be assessed to consider different process/disposal options, but should be truncated at 500 years.

10.6 The variability and uncertainty in the dose to the representative person should be investigated to establish how much caution has been applied at each stage of the assessment and to ensure this level of caution is appropriate.

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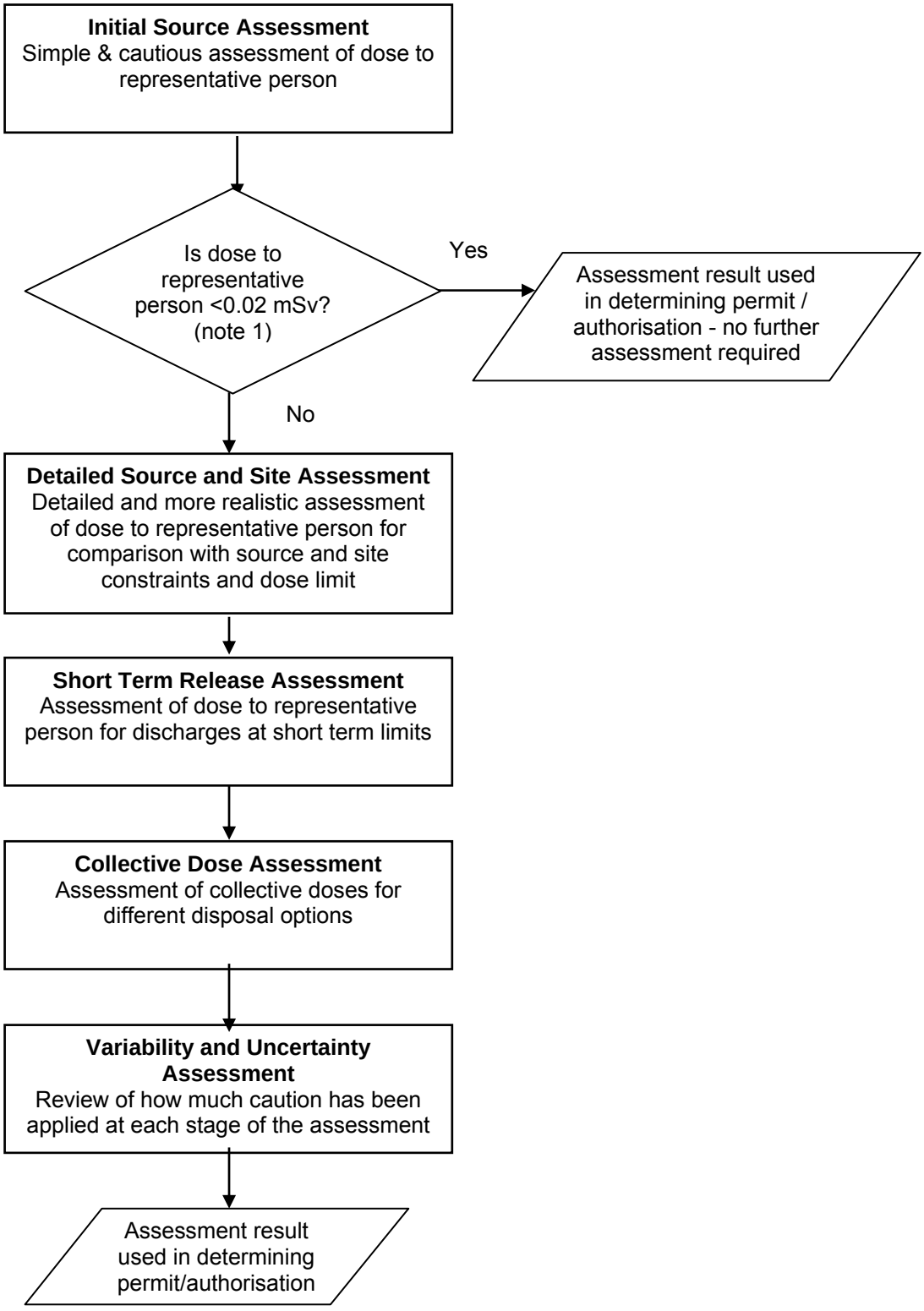

Figure 1 Stages of Dose Assessment Process

Note 1 – Collective dose may need to be considered from global circulation of carbon-14 where discharge > 100 GBq/y

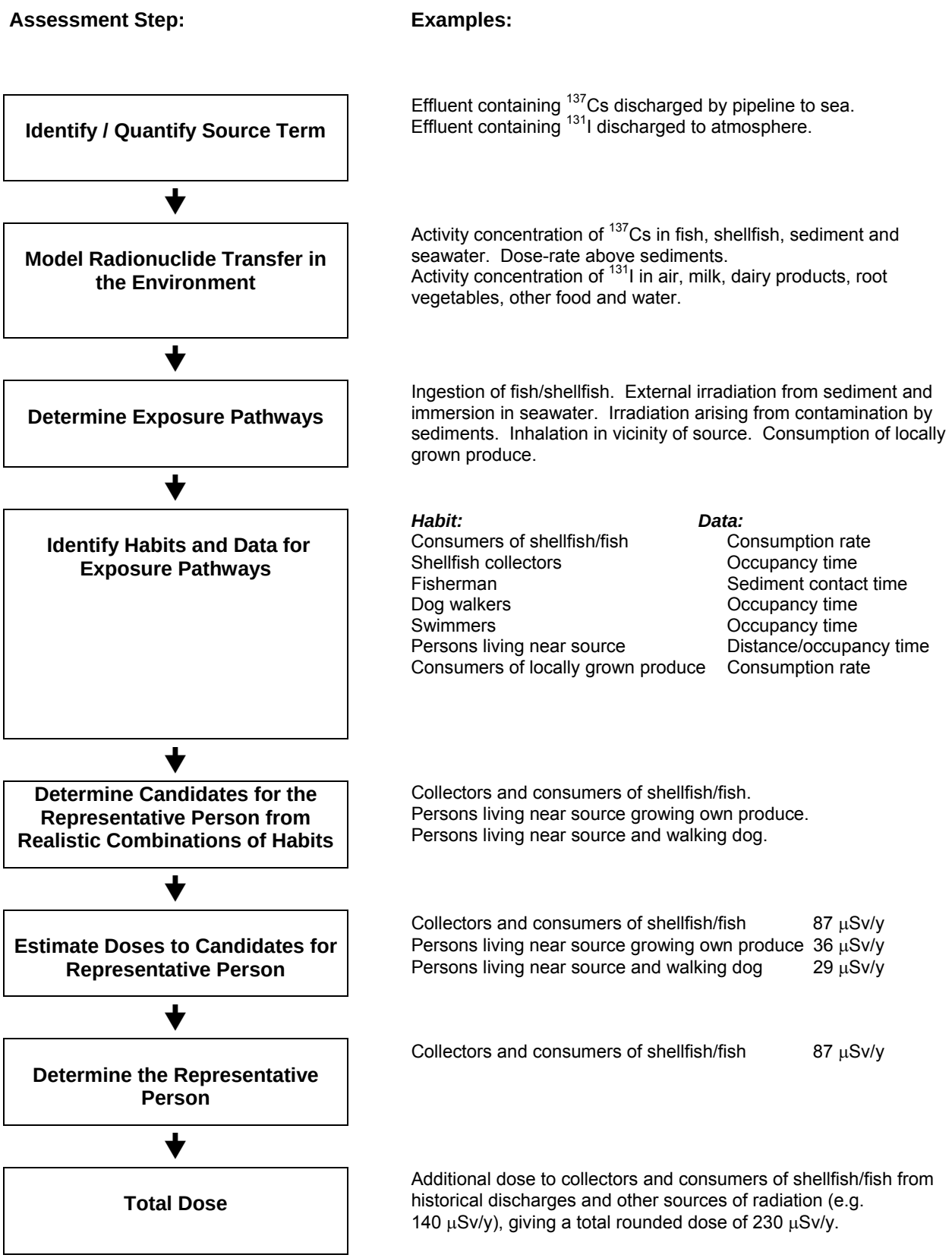

Figure 2 Detailed Source and Site Assessment

Appendix A Relationship between the 13 new principles in this document and the 12 previous principles (2002)

New principles (this document)		**Previous principles 2002** [Ref 4]	
1	Prospective dose assessment methods, data and results should be transparent and made publicly available.		N/A
2	Workers, who are exposed to discharges of radioactive waste, but do not work directly with ionising radiation and are therefore not normally exposed to ionising radiation, should be treated as if they are members of the public for the purpose of determining discharge permits or authorisations.	1	Workers who are exposed to discharges of radioactive waste, but do not receive direct tangible benefits from the organisation making the discharge, should be treated as if they are members of the public for the purpose of determining discharge authorisations.
3	When determining discharge permits or authorisations, the dose to the representative person should be assessed	2	The mean critical group dose should be assessed for the purpose of determining discharge authorisations.
4	Doses to the most affected age group should be assessed for the purpose of determining discharge permits or authorisations. Assessment of doses to 1 year old, 10 year old and adults (and fetus when appropriate) is adequate age group coverage	3	Doses to the most exposed age group should be assessed for the purposes of determining discharge authorizations
5	The dose to the representative person which is assessed for comparison with the source constraint and, if appropriate, the site constraint, should include all reasonably foreseeable and relevant future exposure pathways	4	Critical group doses to be assessed for comparison with the source constraint and, if appropriate, the site constraint should include all relevant future exposure pathways.
6	Significant additional doses to the representative person from historical discharges from the source being considered and doses from historical and future discharges and direct radiation from other relevant sources subject to control should be assessed and the total dose compared with the dose limit of 1 mSv/y	5	Significant additional doses to the critical group from historical discharges from the source being considered and doses from historical and future discharges and direct radiation from other relevant sources subject to control should be assessed and the total dose compared with the dose limit of 1 mSv/y.
7	Where a cautious estimate of the dose to the representative person exceeds 0.02 mSv/y, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by the representative person will be below the dose limit	6	Where estimates of the critical group dose exceed 0.02 mSv/y, the assessments should be refined and, where appropriate, more realistic assumptions made. However, sufficient caution should be retained in assessments to provide confidence that actual doses received by a representative member of the critical group will be below the dose limit.

Continued. Relationship between the 13 new principles in this document and the 12 previous principles (2002)

New principles 2012 (this document)		**Previous principles 2002** [Ref 4]	
8	The assessment of dose to the representative person should take account of accumulation of radionuclides in the environment from future discharges	7	The assessment of critical group doses should take account of accumulation of radionuclides in the environment from future discharges.
9	The realistic habits adopted for the representative person should be those which have actually been observed at the site, within a period of about 5 years. Changes to habits which are reasonably likely to occur should be taken into account	8	The realistic habits adopted for the critical group should be those which are actually observed year on year at the site, or at similar sites elsewhere, either currently or in the recent past. Sustainable habits leading to greater exposure, that are reasonably foreseeable over the period until the next review of the authorisation (about 5 years), should be considered.
10	Land use and infrastructure should have sufficient capacity to support the habits of the representative person. Any changes to land use and infrastructure should be reasonably likely to occur over a period of about 5 years and be sustainable year on year for them to be considered	9	Land use and infrastructure should have sufficient capacity to support the habits of the critical group. Any changes to land use and infrastructure should be reasonably foreseeable over the period until the next review of the authorisation (about 5 years) and be sustainable year on year for them to be considered.
11	The dose assessed for operational short term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3 mSv/y) and the dose limit (1 mSv/y), taking into account remaining continuous discharges during the remainder of the year and contributions from other relevant sources under control	10	The dose assessed for operational short term release at proposed notification levels or limits should be compared with the source constraint (maximum of 0.3 mSv/y) and the dose limit (1 mSv/y), taking into account other relevant contributions.
12	For permitting or authorisation purposes, collective doses to the populations of UK, Europe and the World, truncated at 500 y, should be estimated	11	For authorisation purposes, collective doses to the populations of UK, Europe and the World, truncated at 500 y, should be estimated.
13	Where the assessed mean dose to the representative person exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions used for the dose assessment should be reviewed	12	Where the assessed mean critical group dose exceeds 0.02 mSv/y, the uncertainty and variability in the key assumptions for the dose assessment should be reviewed.

Appendix B Main updates made between the 2002 principles document and this document.

Version no	Date	Part of report	Amendment
1.0	December 2010	All	Updated as a result of Environmental Permitting Regulations coming into force in England and Wales.
1.0	December 2010	All	Updated as a result of Statutory Guidance to the Environment Agencies.
1.0	December 2010	All	Updates relating to ICRP Publication 103 (2007 Recommendations), in particular use of representative person rather than critical group.
1.0	December 2010	All	Reference to NDAWG guidance notes included.
1.0	December 2010	Para 1.0, 6.7	Inclusion of consideration of equivalent dose to skin and the lens of the eye in certain circumstances.
1.0	December 2010	Para 3.1	New principle 1 - transparency of methods, data and results.
1.0	December 2010	Sections 3 to 8	Existing principles 1 to 12 renumbered 2 to 13.
1.0	December 2010	Para 3.3	Explanation of population groups used in prospective assessments revised using advice from HSE.
1.0	December 2010	Para 3.7	Guidance on use of habit data for prospective assessments changed from habits which are reasonably foreseeable to habits which are reasonably likely to occur – to take account of advice of NDAWG habits sub-group.
1.1	May 2011	Title of the document	Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste to the Environment.
1.1	May 2011	1, 2.4, glossary	A definition of the quantity ‘dose’ used in the document has been added to the glossary and referred to from paragraphs 1.7 and 2.4.2.
2.0	March 2012	Section 1	Amendments to paragraphs 1.3;1.4;1.5; and 1.7 after consultation.
2.0	March 2012	Section 2	Amendments to paragraphs 2.12; 2.13; 2.33 2.45; 2.46 and 2.49 after consultation
2.0	March 2012	Section 2	Amendments to table 1 after consultation.
2.0	March 2012	Section 2	New paragraph 2.4.16 after consultation.
2.0	March 2012	Section 3	Amendments to paragraphs 3.1.2; 3.3.3; 3.3.4; 3.3.9; 3.4.1; 3.5.6; 3.5.7; 3.5.11; 3.7.3 and 3.7.15 after consultation
2.0	March 2012	Section 3	Amendments to Principle 4 and Principle 5 after consultation.
2.0	March 2012	Section 3	New Table 2 after consultation.
2.0	March 2012	Section 5	Amendments to paragraph 5.2 after consultation.
2.0	March 2012	Section 6	Amendments to paragraphs 6.1.1; 6.2.1; 6.3.6; 6.3.13; 6.5.9; 6.6.3 and 6.7.1 after consultation.
2.0	March 2012	Section 6	Deletion of paragraph 6.5.18 after consultation.
2.0	March 2012	Section 7	Amendments to paragraphs 7.5 and 7.8 after consultation.
2.0	March 2012	Section 8	Amendments to paragraph 8.7 after consultation.
2.0	March 2012	Section 9	Amendments to paragraph 9.5 after consultation.
2.0	March 2012	Figure 1	Insertion of footnote
2.0	March 2012	Various	Smaller textual changes made
2.0	March 2012	Glossary updated	ALARA, ALARP, BAT, BPM, Nuclear site, radioactive waste

2.0	March 2012	List of abbreviations	Extended and changes made
3.0	May 2012	Comparison of principles	Appendix A added comparing old and new principles
3.0	May 2012	Section 8 Collective dose	Para 8.7 and Para 8.8 amended
3.0	May 2012	Table 1	Lens of the eye dose limit entry restored to table 1
3.0	May 2012	Section 2 Dose limits	New paragraph at 2.4.4 related to dose limits in prospective assessments added.
3.0	May 2012	Section 1 Introduction	New linking paragraph 1.8 to the changes and to the 2002 principles document.
3.0	May 2012	Header and table of contents	Updated
3.0	May 2012	Section 6 - Habits	Reference to habits group report on prospective assessments added
3.0	May 2012	References	Reference to short duration releases amended
3.0	May 2012	Summary of changes	Appendix B summarising changes added

Glossary of terms

Absorbed Dose

Is the ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J/kg.

ALARA

As low as reasonably achievable. Radiological doses or risks from a source of exposure are as low as reasonably achievable when they are consistent with the relevant dose or target standard and have been reduced to a level that represents a balance between radiological and other factors, including social and economic factors. The level of protection may then be said to be optimised.

ALARP

As low as reasonably practicable. To satisfy the ALARP principle, measures necessary to reduce risk must be taken until or unless the cost of those measures, whether in money, time or trouble, is disproportionate to the reduction in risk.

BAT

The term "best available techniques" means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste.. In determining whether a set of processes, facilities and methods of operation constitute the best available techniques in general or individual cases, special consideration shall be given to:

- comparable processes, facilities or methods of operation which have recently been successfully tried out;
- technological advances and changes in scientific knowledge and understanding;
- the economic feasibility of such techniques;
- time limits for installation in both new and existing plants;
- the nature and volume of the discharges and emissions concerned.

BAT is made use of in England and Wales

BPM

“Best Practicable Means” - Operators are required to take all reasonable measures in the design and operational management of their facilities, in order to minimise discharges and disposal of radioactive waste, and to achieve a high standard of protection for the public and the environment. BPM takes account of availability, costs, operator safety and the benefits of reduced discharges and disposals. This is applicable to Scotland and Northern Ireland.

Cautious assessment

An assessment of dose which is designed not to underestimate the dose received by the representative person. It will normally involve using generic assumptions about locations of people, food production and the habits of people which lead to exposure. See also realistic assessment.

Collective Dose

The sum of all of the individual effective doses to members of the population. If the doses continue for longer than a year, then the annual individual effective doses must also be integrated over time. Unless otherwise specified, the time over which the dose is integrated is infinite; if a finite upper limit is applied to the time integration, the collective dose is described as ‘truncated’ at that

	time. The special name for the collective dose quantity is the 'man sievert'.
Committed Effective Dose	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv).
Committed Equivalent Dose	Is the integral of the absorbed dose-rate over time for a tissue or organ, weighted for the type and quality of the radiation by a radiation weighting factor. For adults and children the default time integration period is 50 years and 70 years respectively. The unit of committed equivalent dose is the sievert (Sv).
Direct Radiation	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.
Dose	The quantity calculated for comparison with the annual dose limit; source dose constraint; site dose constraint; threshold of optimisation or 'dose of no regulatory concern' is dose. The dose quantity calculated is the sum of the committed effective dose from internal exposure (from intakes of radionuclides into the body) and external dose from radionuclides remaining outside the body. The quantity is for one year's exposure to external dose and committed dose (over 50 years for adults and to age 70 years for children) from one year's intake of each radionuclide. In some circumstances, equivalent doses to skin or lens of the eye may be calculated for comparison with the dose limits for skin and lens of the eye.
Dose Coefficient	Committed effective dose per unit acute intake. Committed doses are evaluated over 50 years for adults and from intake to age 70 years for children. Also effective dose from external irradiation due to unit activity.
Dose Constraint	A restriction on annual dose to an individual from a single source or site such that when aggregated with doses from all sources, excluding natural background and medical procedures, the dose limit is not likely to be exceeded. The dose constraint places an upper bound on the outcome of any optimisation study and will therefore limit any inequity which might result from the economic and social judgements inherent in the optimisation process. Source constraints will be set by the Environment Agencies for new sources, the maximum constraint being 0.3 mSv/y. A site constraint of 0.5 mSv/y has been set by the UK Government and this applies to the aggregate exposure from a number of sources with contiguous boundaries at a single location, irrespective of whether different sources on the site are owned or operated by the same or by different organisations.
Dose Limit	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv/y for the UK.

Effective Dose	The sum of the equivalent doses from radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the sievert (Sv).
Equivalent Dose	Is the absorbed dose in a tissue or organ, weighted for the type and quality of the radiation by a radiation weighting factor. The unit of equivalent dose is the sievert (Sv).
Nuclear Site	A site licensed by the Office of Nuclear Regulation – ONR - (formerly the Nuclear Installations Inspectorate) under the Nuclear Installations Act 1965 and Nuclear Installations Regulations 1971.
Planned Exposure Situation	Everyday situations involving the planned operation of sources including decommissioning, disposal of radioactive waste and rehabilitation of the previously occupied land. Practices in operation are planned exposure situations. Planned exposure situations may give rise both to exposures that are anticipated (normal exposures) or not anticipated to occur (potential exposures).
Practice	Human activity which can increase the exposure of people to radiation. Practices can be activities such as a business, trade, industry or any other productive activity; it can also be a government undertaking, or a charity.
Prospective Assessment	Estimation of the doses that may be received by a representative person from future sources of radiation.
Radiation Weighting Factor	Factor used to weight the tissue or organ absorbed dose to take account of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactive Waste	Legal definitions of radioactive material and radioactive wastes are contained in Sections 1 and 2 of the Radioactive Substances Act 1993 and paragraph 4 of part 2 schedule 23 of the Environmental Permitting (England and Wales) Regulations 2010 the effect of the definitions is that radioactive waste generally includes: a. scrap, surplus or spoilt radioactive material; and b. any other waste substance or article which has become radioactive or has acquired an increased concentration of radioactivity.
Realistic assessment	An assessment of dose which is designed to provide a best estimate of the dose received by the representative person. However, for prospective assessments, the dose should not be underestimated. It will normally involve using site specific information on the location of people, food production and the habits of people which lead to exposure. See also cautious assessment.
Representative person	An individual receiving a dose that is representative of the more highly exposed individuals in the population. This term is equivalent to, and replaces, ‘average member of the critical group’.
Retrospective Assessment	Calculation of doses that have actually been received by the representative person group.

Source	A facility, or group of facilities, which can be optimised as an integral whole in terms of radioactive waste disposals (e.g. an individual hospital with a nuclear medicine department or an individual nuclear power station).
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung= 0.12; bone marrow= 0.12; skin= 0.01.

List of abbreviations

AGR	Advanced Gas-Cooled Reactor
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BPM	Best Practicable Means
CEDA	Consultative Exercise on Dose Assessment
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
COMARE	Committee on Medical Aspects of Radiation in the Environment
CoRWM	Committee on Radioactive Waste Management
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (responsibility for the environment has now passed to DEFRA)
EPR-10	Environmental Permitting (England and Wales) Regulations 2010
FSA	Food Standards Agency
GDC	Generalised Derived Constraints
HEPA	High Efficiency Particulate Air
HPA	Health Protection Agency (including the former NRPB)
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRR	Ionising Radiations Regulations
MAFF	Ministry of Agriculture, Fisheries and Food (a government ministry absorbed into DEFRA in 2002).
NII	Nuclear Installations Inspectorate (now known as Office for Nuclear Regulation - ONR)
NRPB	National Radiological Protection Board (now part of the Health Protection Agency – HPA)
ONR	Office for Nuclear Regulation (formerly the Nuclear Installations Inspectorate NII)
OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
PWR	Pressurised Water Reactor
RAPS	Reference Animals and Plants
RIFE	Radioactivity in Food and the Environment
RSA-93	Radioactive Substances Act 1993
RWMAC	Radioactive Waste Management Advisory Committee
SEPA	Scottish Environment Protection Agency
TOR	The tolerability of Risk from Nuclear Power Stations 1988

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