

Evidence

Hazards from landspreading wastes

Rapid Evidence Assessment: effluent treatment
sludge from the soft drinks industry

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Miranda Kavanagh
Director of Evidence

Executive summary

The Environment Agency regulates the spreading of waste to agricultural land in England under the Environmental Permitting Regulations (EPR) 2010. Under EPR 2010 the operator is required to obtain a standard rules or bespoke permit, and to make a separate deployment application for waste to be spread on a specific area of land. The purpose of this Rapid Evidence Assessment (REA) is to identify the primary hazards associated with sludge from the on-site effluent treatment from soft drinks production (part of waste code 02 07 05) to support staff at the Environment Agency's National Permitting Service in their deployment review.

The REA addresses the overarching primary question: What key hazards are associated with sludge from the on-site effluent treatment from soft drinks production which could present a risk to critical receptors during or after landspreading on agricultural land? A series of secondary questions were used to obtain more detailed evidence to identify the relevant pathways and receptors for the use of sludge from the on-site effluent treatment from soft drinks production and to identify important hazards which may impact on them. The responses are given in the evidence extraction spreadsheet accompanying this report.

Various sources of evidence were identified and used to provide answers to the primary and secondary questions. These sources ranged from peer reviewed journal articles and reports to unpublished documents. A major limitation of the study was the inability, due to time constraints, to liaise with UK soft drinks producers and the absence of any data from deployments. The main findings of the evidence extraction process are summarised below.

Waste production and form

Effluent treatment sludge is the residual solids predominately associated with the primary and secondary phases of the wastewater treatment process. The sludge can be beneficial to land as a soil conditioner, providing organic matter as well as varying amounts of other nutrients.

Untreated wastewater sludge is unlikely to be suitable for landspreading or injection into soil. Pre-treatment can involve dewatering of the sludge and/or stabilisation. Depending on the level of pre-treatment and separation, the sludge can be in liquid, semi-solid or solid form when applied to land. As a result, the type of transport and application method to land depends on the nature of the particular sludge.

Sludge application can be restricted to particular times of the year (generally March to October) and is constrained by weather and site conditions. Hence, sludge may need to be stored on-site. A typical application rate for brewing and soft drink sludge is around 50 m³/ha, although the rate should be adjusted to take into account crop requirements and the sludge's composition. A European Commission report gives spreading rates (assumed to be per hectare) of 35–60 m³ for liquid sludge, 25 tonnes for viscid (semi-fluid) sludge and 20 tonnes for solid sludge.

Chemical and other hazards

Based on information on the wastewater from soft drinks production, on-site effluent treatment sludge has the potential to: be acidic (depends on type of soft drinks being produced); have a high ammonia, biological oxygen demand (BOD) and chemical oxygen demand (COD) content; contain metals (dissolved phase metals may mostly remain in the wastewater, post treatment); contain residual pesticides (as will the wastewater), if fruit juices are being produced; and contain chloride, sodium and other disinfectants associated with cleaning of the treatment system.

Based on the limited information obtained for the sludge itself, sludge may contain: high levels of organic matter and nitrogen, with a low carbon to nitrogen ratio; high concentrations of metals, notably cadmium and lead, particularly its pre-treatment prior to landspreading was inappropriate or insufficient; and polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH) and antimony.

Plant pathogens may be present initially or develop in the sludge if the organic matter present is transformed by moulds. The presence of pathogens is highly dependent on the type of soft drinks being produced. There is considered to be little potential for dust release during storage, transport or application of the sludge to land. However, the sludge can be extremely odorous due to it being rich in poorly stabilised organic matter, which can in turn attract pests such as flies and scavenging animals.

These findings were used to produce the following Master List of hazards.

Master List of hazards of sludge from the on-site effluent treatment from soft drinks production when applied to agricultural land

Hazards	Relevant receptor
Chemical hazards	
Metals and metalloids	Soil quality, human, livestock/ecology, crops, surface water and groundwater
Low pH (that is, <pH 5)	Soil quality, crops, groundwater and surface water
PAHs	Soil quality, humans and livestock/ecology
TPH	Soil quality, humans and livestock/ecology
Phosphorus	Surface waters
Sodium	Crops and groundwater
Electrical conductivity	Crops and groundwater
Chloride (and potentially other disinfectants)	Crops and surface water and groundwater
Pesticide residues	Soil quality, humans, livestock/ecology, surface water and groundwater
Plant and animal pathogens	
Plant pathogens	Crops
Nuisance	
Odour	Humans
Attraction of pests and scavenging animals	Humans

There is insufficient evidence at this time to identify a Principal List of hazards associated with this type of sludge and it is unclear whether the risks from these hazards can be successfully mitigated by adherence to standard permit conditions and good practice in general. To enable adequate assessment of these factors during the deployment process, the deployment application should be accompanied by representative analytical data for the sludge for the Master List of hazards and an assessment of the risks noted above. Other items to consider during the preparation and review of any deployment application for this waste type are:

- application rate and frequency
- site sensitivity with respect to groundwater and surface water
- requirement for pre-treatment of the sludge, including stabilisation
- compliance with standard rules permit conditions
- and an odour management plan

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1 Introduction

1.1 Background

The Environment Agency regulates the spreading of waste to agricultural land in England under the Environmental Permitting Regulations (EPR) 2010. Under EPR 2010 the operator is required to obtain a standard rules or bespoke permit, and to make a separate deployment application for waste to be spread on a specific area of land.

On receipt of the deployment application, staff at the Environment Agency's National Permitting Service (NPS) must consider the potential adverse impacts on human health and the environment. This requires a clear understanding of the physical, biological and chemical hazards presented by a specific waste type, particularly in an agricultural context.

The purpose of this Rapid Evidence Assessment (REA) is to identify the primary hazards associated with sludge from the on-site effluent treatment from soft drinks production (part of waste code 02 07 05).

The operator must also demonstrate – and permitting staff must evaluate – the agricultural benefit from applying the wastes under a specific deployment. However, this is not the focus of this REA.

1.2 Structure of this report

Section 2 presents a summary of important information on sludge from the on-site effluent treatment from soft drinks production gathered for the REA and an REA roadmap. The latter provides an overview of the REA process and the location of specific information for the waste type. The summary and roadmap are intended to assist Environment Agency staff when reviewing the deployment application.

Section 3 describes the scope of the REA (with primary and secondary research questions), approach and methodology. This is supported by information presented in the evidence extraction spreadsheet in the Appendix.

Section 4 discusses the evidence collected for the REA under the defined headings of the secondary questions. This information was used to compile the Master List of hazards presented in Section 4.3, and the refined conceptual model described in Section 4.4. The answers to individual secondary questions and all quantitative data obtained as part of the REA are given in the evidence extraction spreadsheet in the Appendix.

Section 5 presents the conclusions and recommendations based on the information obtained.

2 REA summary and roadmap

This section provides:

- a summary of important information on the characteristics of sludge from the on-site effluent treatment from soft drinks production
- ranges of typical contaminant concentrations
- an REA roadmap

2.1 Summary table

Waste type: Sludge from on-site effluent treatment from soft drinks production	Waste code : 02 07 05 (part)
Is waste a SR2010 No. 4 permitted waste type?: Yes – Table 2.2B List B Waste (Environment Agency 2010)	
Waste Description: Sludge from the on-site treatment of wastewater from the production of soft drinks	
Date: March 2014	Version: 1.1
Assessment team : Amec Foster Wheeler (compiled by Becky Whiteley, reviewed by Tony Marsland)	
Methodology: 'Hazards from Landspreading (SR2010 No. 4 wastes): Methodology for Rapid Evidence Assessment' (draft report for Environment Agency, March 2014)	
Primary question: What key hazards are associated with sludge from on-site effluent treatment from soft drinks production which could present a risk to critical receptor during or after landspreading on agricultural land?	

Master List of hazards	Relevant receptor
Chemical hazards:	
Metals and metalloids	Soil quality, human, livestock/ecology, crops, surface water and groundwater
Low pH	Soil quality, crops and indirectly groundwater and surface water
Polycyclic aromatic hydrocarbons (PAHs)	Soil quality, humans and livestock/ecology
Total petroleum hydrocarbons (TPH)	Soil quality, humans and livestock/ecology
Phosphorus	Surface waters
Sodium	Crops and groundwater
Electrical conductivity	Crops and groundwater

Master List of hazards	Relevant receptor
Chloride (and potentially other disinfectants)	Crops and surface water and groundwater
Pesticide residues	Soil quality, humans, livestock/ecology, surface water and groundwater
Plant and animal pathogens:	
Plant pathogens	Crops
Nuisance:	
Odour	Humans
Attraction of pests and scavenging animals	Humans

Principal List of hazards

In the absence of sufficient published information relating to this waste type, it was not possible to determine a Principal List of hazards at this time.

Items to consider on deployment application

- Application rate and frequency
- Site sensitivity with respect to groundwater and surface water
- Analytical testing of waste for Master List of chemical hazards to prove their absence or concentrations to inform subsequent risk assessment by operator. Based on a consideration of the waste source(s) and receptors present on site, it may be possible to refine this list of determinands.
- Requirement for pre-treatment of the sludge, including stabilisation
- Compliance with standard rules permit conditions
- Odour management plan

2.2 Range of typical contaminant concentrations

Limited information on the chemical composition of effluent sludge from the soft drinks industry was identified in the literature. The information that was obtained tended to group the discussion on chemical composition with sludge from other sources in the food and beverage industry, which have differing feedstocks and associated hazards. It was therefore not considered possible to identify a range of typical contaminant concentrations for on-site effluent treatment sludge originating from the soft drinks industry.

2.3 Individual waste stream roadmap

Figure 2.1 shows a roadmap demonstrating the REA process and location of specific information in this report for sludge from the on-site effluent treatment from soft drinks production.

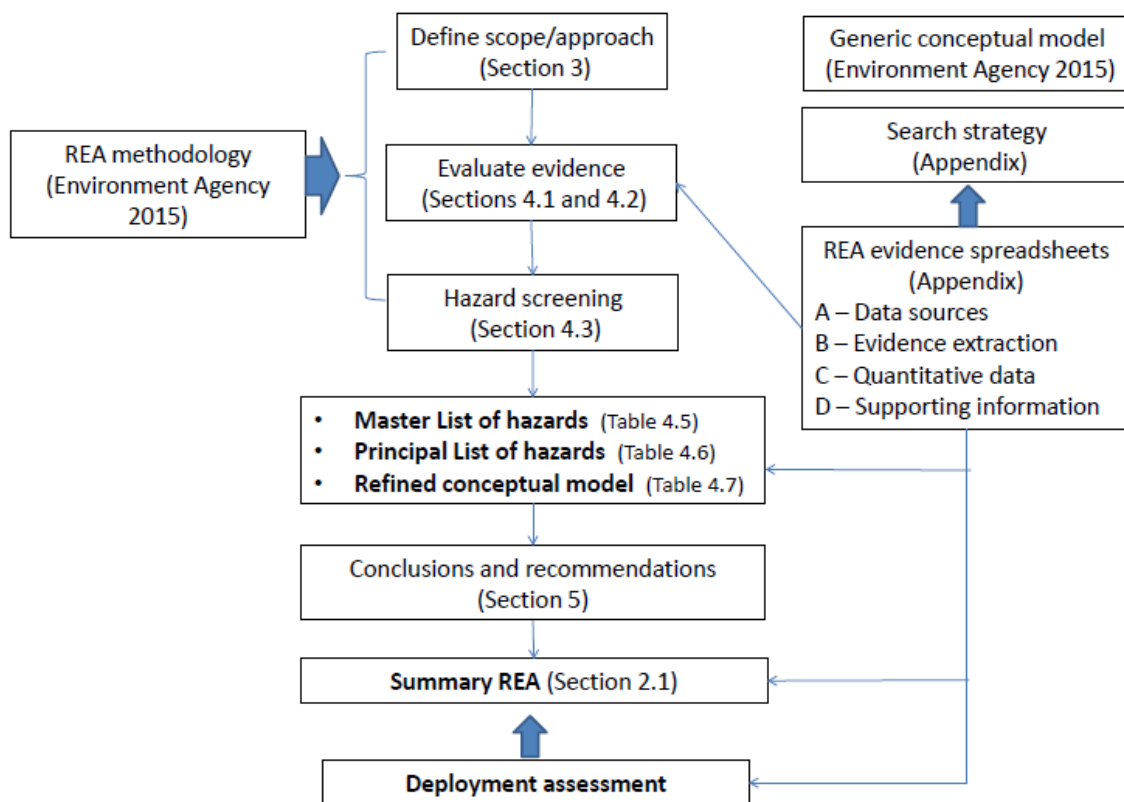


Figure 2.1 REA roadmap for sludge from the on-site effluent treatment from soft drinks production

3 REA scope, approach and methodology

The REA was produced between January and March 2014 following the version of the methodology set out in a draft, unpublished report provided to the Environment Agency in March 2014. The methodology described below may therefore differ slightly from the final published version (Environment Agency, 2015).

3.1 Research questions and scope

3.1.1 Primary question

The REA addressed the overarching primary question:

What key hazards are associated with sludge from on-site effluent treatment from soft drinks production which could present a risk to critical receptors during or after landspreading on agricultural land?

‘Critical receptors’ is the collective term for humans, controlled waters and dependant ecosystems, wildlife, soil (quality), air quality and property in the form of livestock and crops. The critical receptors will depend on the type of waste and the site-specific information for each deployment application.

3.1.2 Secondary questions

A series of secondary questions¹ (Table 3.1), common to all individual waste streams, was used to obtain more detailed evidence to identify:

- relevant pathways and receptors for the waste stream
- key hazards which may impact on these pathways and receptors

The secondary questions are based on the generic conceptual understanding of the landspreading process to agricultural land (Environment Agency 2015, Table 3.1).

Table 3.1 Secondary questions

No.	Question
WASTE PRODUCTION AND FORM	
1	How many producers are there for this waste in the UK?
2	Is the waste from a single producer or as a result of a collection of waste from a number of producers?
3	Are there different production processes for this waste and how long have these been followed?

¹ See Table A.1 in Appendix A of the methodology report (Environment Agency 2015) for details of the rationale for each secondary question.

No.	Question
4	Is the waste produced as part of a treatment process (for example, effluent treatment)?
5	If yes, please provide details for the primary treatment process, particularly whether this has the potential to introduce contaminants such as disinfectants and so on.
6	Is there any information on the primary product for this waste (for example, from material safety data sheets or similar)?
7	How variable is the waste between batches and what factors influence this variability?
8	How variable is the waste between producers and what factors influence this variability?
9	Is the waste to be applied as a solid, sludge or liquid?
10	What is the method of application of this waste to land?
11	Why is this material to be spread to land?
CHEMICAL HAZARDS	
12	Are there any analytical data available for this waste?
Groundwater assessment	
13	Does the waste contain any hazardous substances (as defined by JAGDAG)?
14	Does the waste contain any non-hazardous pollutants in concentrations substantially above (greater than twice) typical natural background for shallow groundwater or drinking water standards?
Surface water assessment	
15	Does the waste contain any Priority or Priority Hazardous Substances ¹ ?
16	Does the waste contain any Specific Pollutants ² ?
Soil etc. assessment	
17	Does the waste contain potentially toxic elements (PTEs) or other contaminants?
18	What substances does the waste contain that could benefit the soil?
General assessment	
19	Does the waste contain any contaminants which are considered to be toxic to human health (that is, have proven or suspected carcinogenic, mutagenic, reproductive toxic effects and so on)?
20	Does the waste contain any contaminants with a high bioaccumulation potential?
21	Are there any contaminants present in the waste that are proven or suspected to be persistent in the environment?
22	Does the waste contain any contaminants which are proven or suspected of being endocrine disrupting?
23	Describe any speciation or the form of contaminants identified in the waste which could influence the hazards associated with these.
24	Are pesticides, herbicides or fungicides likely to be present in the waste?
25	Are there any breakdown products or metabolites associated with these contaminants, which could present a significant hazard?
26	Does the waste contain any contaminants which could potentially have cumulative/additive effects?
27	Does the waste contain any contaminants which could present a significant hazard due to their volatility?
28	Does the waste have a biological oxygen demand (BOD) of >6 mg/l?
29	Does the waste have a pH <5.0?
30	Does the waste have the potential to contain any emerging contaminants of concern?

No.	Question
PLANT AND ANIMAL PATHOGENS AND TOXIC COMPOUNDS	
31	Are <i>Salmonella</i> , <i>Listeria monocytogenes</i> , <i>Escherichia coli</i> , <i>Clostridium botulinum</i> and/or <i>Bacillus cereus</i> , or other bacteria or pathogens, or diseases such as bovine spongiform encephalopathy (BSE) and scrapie likely to be present in the waste, post spreading?
32	Are plant pathogens, fungus and/or soil-borne diseases likely to be present in the waste, post spreading?
33	Are toxic or injurious plants likely to be present in the waste, post spreading?
INVASIVE WEEDS	
34	Is there potential for invasive weeds to be present in the waste, post spreading?
35	Is there potential for exotic species to be present in the waste, post spreading?
PHYSICAL CONTAMINANTS	
36	Is non-biodegradable material, such as plastics, metal, brick, concrete or glass likely to be present in the waste, post spreading?
NUISANCE	
37	Are unpleasant odours likely to be associated with the waste?
38	Is dust likely to arise from this waste?
39	Is the waste likely to attract pests such as flies or scavenging animals?
OTHER ENVIRONMENTAL HAZARDS	
40	Does the waste have a high fat or oil content (that is, >4% by weight)?
41	Is the waste likely to cause anoxic soil conditions?
42	Is there the potential for the stability of the waste to come into question?
43	Provide any further details on hazards identified in this waste which are not covered in the questions above.

Notes: ¹ Substance of concern to surface water identified in Directive 2008/105/EC on Environmental Quality Standards (EQSs) (as amended).
² Those contaminants identified in the UK to support the aim of achieving 'good status' by 2015 under the Water Framework Directive.
JAGDAG = Joint Agencies Groundwater Directive Advisory Group
(www.wfduk.org/stakeholders/jagdags-work-area-0)

3.2 Data search

A comprehensive search was made using multiple information sources so as to provide a variety of evidence sources and to minimise potential bias.

3.2.1 Sources used

The data search took into account the hierarchy of information sources listed in Table 4.1 of the REA Methodology (Environment Agency 2015). This is summarised below, starting from the most preferred sources:

1. Producer – specific waste stream data
2. Representative case-specific/compliance data
3. Environment Agency or Defra database
4. European Commission database

5. Generic producer data (UK based)
6. UK published literature, grey literature, expert knowledge and UK academic research
7. European and overseas data

The time constraints for this project meant it was not possible to approach any waste producers for information about sludge from on-site effluent treatment from soft drinks production or similar wastes. This was discussed and agreed with the Environment Agency before beginning work on the REA.

The databases and websites listed in Table 3.2 were reviewed as part of the data search, in addition to a keyword search on Google and Google Scholar.

Table 3.2 Databases and organisation websites reviewed during the data search

Databases	Institution/organisation	Waste producers/treatment facilities
Scopus	WRAP	Veolia
Science Direct	Environment Agency	Coca-Cola UK
BioOne	British Soft Drinks Association	
OpenSIGLE	European Commission	
	European Food Safety Authority	
	Food Standards Agency	
	ADAS	
	Health Protection Agency	
	Association of Organics Recycling	
	Biogas	
	FERA	
	Soft Drinks International	
	Food and Drink Federation	

3.2.2 Keywords

The keywords used for this REA are listed in Table 3.3.

Table 3.3 Keywords

Waste type	Activity/characteristic	Similar waste types/processes
Soft drinks	Landspreading	Industrial sludge
Soft drinks production	Agriculture	Industrial waste
Soft drinks industry	Soil conditioner	Industrial waste sludge
Beverage	Fertiliser	Waste water treatment
Beverage industry	Composition	Recycling
Beverage production	Sludge disposal	
Non-alcoholic beverage		
Waste code 02 07 05		

Waste type	Activity/characteristic	Similar waste types/processes
Sludge		
Effluent treatment sludge		
Effluent sludge		
Waste water sludge		
Fruit juice		

These keywords were combined to form strings using 'AND' when searching on the internet and individual databases and organisation websites.

Generally, the first 50 hits from the search were screened. However, where it was obvious that unrelated or inappropriate hits were being brought up the number of hits reviewed was reduced.

It became apparent during the search that there was a large amount of research and information available for the primary waste treatment process (that is, wastewater treatment) and on sewage sludge and its application to land. However, there was very little information on sludge originating from the production of soft drinks or the wider area of industrial waste sludge uses.

Further details of the keywords searches, number of hits per search and so on are given in the Appendix.

3.2.3 Evidence screening

The evidence collected consisted of a mixture of peer reviewed, grey literature and unpublished information. This evidence was screened against the inclusion and exclusion criteria given below to identify the most important evidence for review. This was done by reviewing the title and/or the abstract or executive summary (as appropriate) for each piece of potential evidence.

Inclusion criteria

- Sludge from on-site effluent treatment forms at least part of the subject of the evidence.

In addition, at least one of the following also had to apply.

- The evidence provides information on the upstream production processes and any pre-treatment that the waste goes through prior to landspreading.
- The evidence provides qualitative or quantitative information about the waste's chemical composition.
- The evidence provides information on the potential microbiological or physical hazards associated with the waste.
- The evidence considers the spreading of the waste to agricultural land.
- The evidence provides a comparison between waste types and/or application to different land types.

Exclusion criteria

- The evidence is not published in English
- A full text version of evidence is not available.

Number of sources of evidence identified

Following this initial screening, 22 sources of evidence were identified for review in the REA. Following a more thorough evaluation, however, two of these sources were deemed to hold little value and were therefore not taken forward.

The references for the sources used and a brief description of their content are provided in the Appendix.

4 Evaluation of evidence

4.1 Introduction

Numerous sources of evidence were identified and used to provide answers to the primary and associated secondary questions. These sources ranged from peer reviewed journal articles and reports to unpublished documents.

Where possible, priority was given to evidence which provided information in the context of the UK and Europe. Other information from sources across the world was used to support these findings and, where relevant, identify any gaps or contradictory evidence.

Several evidence sources provided quantitative data. These data generally related to a mixture of sources which included sludge from on-site effluent treatment from soft drinks production. Very little data were found that related directly to sludge originating from the soft drinks industry, with again limited information on the analysis approach and methodology used to obtain these data. Due to the limited information provided in these sources on the analytical testing performed, it was difficult to assess the strength and quality of the data. The type of data obtained has presented an issue for synthesising data for the REA. Consequently, no statistical analysis of the data was made. All quantitative data identified are discussed below and provided in the Appendix.

The responses to the secondary questions are given in Section 4.2. These findings were subsequently used to answer the primary question and to produce a Master List of hazards (Section 4.3) which could potentially be associated with sludge from the on-site effluent treatment from soft drinks production. A refinement of the generic conceptual model for landspreading of waste, based on the Master List of hazards, is presented in Section 4.4.

4.2 Responses to secondary questions

The responses to the 43 secondary questions (Table 3.1) are given in the evidence extraction spreadsheet in the Appendix. Where appropriate, evidence was synthesised using the guidance from the REA methodology, both in the secondary question responses and in the detailed discussion below.

For each response, an evidence confidence rating was determined using the quality indicators matrix in Table 4.1. This is based on the strength of the information provided, the number of evidence sources which gave similar findings and the type of evidence source(s) identified. The rating for each secondary question answer is given in the evidence extraction spreadsheet in the Appendix.

The findings with regard to waste processing, form and the hazards associated with sludge from the on-site effluent treatment from soft drinks production are summarised and discussed in Sections 4.2.1 to 4.2.7.

Table 4.1 Quality indicators for the REA

Quality ranking	Robustness of evidence	Primary evidence category	Objectivity
High	Strong evidence with multiple references Most authors and experts come to the same opinion or conclusion Supporting quantitative data	Peer reviewed	No discernible bias
Medium	Evidence provided in a small number of references Authors and experts vary in their opinion or conclusion Limited supporting quantitative data	Grey literature	Weak to moderate bias
Low	Scarce or no evidence Authors/experts opinions/conclusions very considerably No supporting quantitative evidence	Unpublished	Strong bias

4.2.1 Waste production and form

Waste description and pre-treatment

The soft drinks industry produces a large quantity of wastewater which, depending on its chemical composition, can require treatment prior to disposal or reuse (Environment Agency 2013). Sources of this wastewater include bottle washing, floor and equipment cleaning, and syrup storage tank drains (Visvanathan and Asano 2007, Table 7).

This REA focuses on sludge from the on-site treatment of wastewater in the soft drinks industry. However, there is the potential for wastewater from some UK producers to be sent off-site for treatment at wastewater treatment facilities. The resultant sludge is likely to be a composite from the different wastewater sources. This sludge is covered by separate waste codes (19 05 99 and 19 06 06), but would not normally be suitable for spreading under a standard rules permit. As a result, these types of sludge are not considered further in this REA.

Effluent treatment sludge is the residual solids from the various phases of wastewater treatment (Tebai and Hadjivassilis 1992, Casey 2006, WRAP 2013). These are summarised below.

- **Preliminary treatment** normally consists of screening and separation, removing any gross solid and fibrous material (for example, factory debris, lids and gloves).
- **Primary treatment** involves a simple sedimentation to remove settleable solids or insoluble material (suspended solids). This can be undertaken using gravity settlement or dissolved air flotation (DAF).
- **Secondary treatment** aims to reduce the organic pollution load of the water using biological treatment. This can reduce the chemical oxygen demand (COD) and biological oxygen demand (BOD) of the wastewater,

with this being removed as a biological sludge. Biological treatment can be either a 'fixed film' system (for example, biological filters) or a 'suspended growth' system (for example, activated sludge process). Either process is possible under aerobic (in the presence of oxygen) or anaerobic (in the absence of oxygen) conditions.

- **Tertiary treatment** is the final stage, which can consist of a further period of sedimentation or solids removal, microbiological disinfection or removal of specific chemicals such as nutrients. There are a number of tertiary treatment methods including macro filtration (for example, microstrainers, sand filtration), membrane techniques (for example, reverse osmosis, ultra filtration), sterilisation and disinfection (for example, ultraviolet irradiation, chlorination) and chemical removal (for example, activated carbon, specific ion exchange).

The majority of effluent treatment sludge will be associated with the primary and secondary treatment processes.

Effluent sludges are characterised by high water content, which can be up to 95% by weight, and are mainly biodegradable in nature (Casey 2006). The size and composition of the solids and water content can vary between the different stages of the wastewater treatment and between the types of soft drinks being produced. The wastewater from soft drinks manufacture tends to have a low amount of solids compared with wastewater from other sources in the food and beverage industry (WRc and European Commission 2001).

The wastewater itself can be beneficial when applied to land, as the nitrogen present tends to be in the liquid fraction, making it more available for plant uptake and enabling it to be good substitute for inorganic fertiliser (Environment Agency 2013). In addition, the solid fraction, in the form of sludge, can be higher in phosphorus and organic matter, allowing it to act as a soil conditioner. The sludge can also contain varying amounts of other nutrients (potassium, sulphur, calcium, magnesium and pH), although wastes resulting from the production of alcoholic and non-alcoholic beverages generally have very low agronomic values, relative to other sludge types, and particularly with respect to nitrogen (Sukumar 2011).

Untreated wastewater sludge is unlikely to be suitable for landspreading or injection into soil (DELG 1999). The type of pre-treatment needed will depend on the proposed use and method of application to land. Dewatering can improve sludge handling, as well as concentrating the benefits and reducing the volume to be transported. Stabilisation of the sludge can also minimise potential odour issues, as well as improving the benefits when applied to land.

The water fraction of the sludge can be divided into the following three categories:

- free water
- capillary and boundary layer water retained by surface forces
- intracellular and chemically bound water

Effluent sludges tend to have a high affinity for water and hence require artificial flocculation (or conditioning) to remove free water, prior to any further pre-treatment in the form of thickening or dewatering. Chemical and thermal conditioning and elutriation can be applied to the sludge to improve its dewatering characteristics. Chemical conditioners can include trivalent salts or aluminium and iron, as well as organic polyelectrolyte, which can be added to break down the natural barriers to particle flocculation. Thermal conditioning may consist of either heating or freezing, with elutriation involving the washing of sludge to remove fines and lower its alkalinity

(Casey 2006). The capillary and surface held water present within the sludge can only be removed by the application of pressure gradients that exceed the counter-gradients generated by the holding forces on the water (Casey 2006).

Sludge thickening involves the use of either sedimentation (gravitational thickening) or flotation to concentrate the solid phase of the sludge by removing readily separated water. This process produces a slurry or concentrated sludge. In contrast, sludge dewatering removes sufficient water so that the remaining sludge residue effectively acts like a solid, improving its handling characteristics. Dewatering can be achieved by spreading on open air beds, vacuum or pressure filtration and centrifugation (Casey 2006).

Sludge can be stabilised by biological methods to convert the organic fraction to a more stable end product. The aim of the stabilisation is not the degradation of the organic matter, but to place the micro-organisms in specific conditions that inhibit their metabolism (Lepeuple et al. 2004). This can stop any potential fermentation of the sludge and minimise the potential release of odours (WRc and European Commission 2001). This can be carried out using aerobic or anaerobic digestion processes or by chemically inhibiting microbial activity in the sludge mass, though the latter can result in an increase in the pH due to the addition of lime (Casey 2006).

Land application

Depending on the level of pre-treatment and separation, the sludge can be in liquid, semi-solid or solid form when applied to land. Liquid sludge is generally delivered to the farm or site in a closed tanker, while more solid material can be delivered in a covered skip or trailer (DELG 1999).

According to Sukumar (2011), consideration should be given to the method of treatment, storage, transportation and final application to:

- improve the management of the sludge for landspreading
- ensure the biodegradation process in the sludge is complete prior to landspreading

Table 4.2 lists typical methods for the handling and application of sludge to land.

Table 4.2 Methods for the handling and application of sludge to land

	Liquid form	Semi-solid form	Solid form
Solids content	1–10%	8–30%	25–80%
Methods of handling	Gravity flow	Conveyor	Conveyor
	Pump	Auger	Bucket
	Tanker transport		Box truck transport
Surface application method	Irrigation sprinkler spray	Irrigation spray	Spreading using a muck spreader or fertiliser spreader (if sludge has a very high dry solids content)
	Ridge and furrow irrigation	Ridge and furrow irrigation	
		Overland flow	
	Tank truck	Tank truck	Piles or windrows
	Band spreader	Farm tank wagon	Re-slurry and handle
	Farm tractor	and tractor	

	Liquid form	Semi-solid form	Solid form
Subsurface application method			Muck spreader
	Tank truck with plough furrow	Flexible irrigation hose with plough furrow/disc cover	Plough furrow cover
	Farm tractor and tank wagon with plough furrow cover		Piles and windrow plus plough cover

Notes: Crop irrigation and surface application to grassland is not recommended for brewery and soft drink industry sludge.
Source: Sukumar (2011) and DELG (1999)

The application of sludge can be restricted to particular times of the year – generally between March and October. It is also constrained by weather and site conditions. Hence, there may be the requirement for the sludge to be stored at a site. For example, the application of sludge is not permitted when the site soils are already waterlogged or flooded, the ground is frozen or snow covered, and/or heavy rain is forecast (Sukumar 2011, DELG 1999, Alloberganova 2006). Under such conditions, the infiltration of essential nutrients is likely to be minimal, with a high potential for pollutants to migrate off-site via overland flow.

Depending on the characteristics of the sludge, further restrictions on the type of crops and stage of growth that the sludge can be applied to, and restrictions on when livestock can be returned to the site, may also need to be considered at the deployment stage (DELG 1999).

A typical application rate for brewing and soft drink sludge is around 50 m³/ha, although the application rate should be adjusted to take into account crop requirements and the composition of the waste (Sukumar 2011). A survey of wastes spread to land conducted for the European Commission refers to sludge spreading rates (assumed to be per hectare) of 35–60m³ for liquid sludge, 25 tonnes for viscous sludge and 20 tonnes for solid sludge from the food and drinks industry (WRc and European Commission 2001).

The target rate of application should be limited to that corresponding to the **lowest** of the following (DELG 1999):

- the maximum permissible rate of application of nutrients
- the maximum permission rate of application of metals
- the maximum permissible hydraulic loading

No information was found to indicate the typical frequency for applications in the UK. The Environment Agency guidance (TGN EPR 8.01) on spreading waste to land notes that care should be taken not to over apply sludge to land, as over application can result in anoxic soil conditions which can have a negative impact on plant growth (Environment Agency 2013).

UK producers

No UK producers of soft drinks were identified other than Coca-Cola UK. No UK producers were contacted as part of this REA.

4.2.2 Chemical hazards

Little published information on the chemical composition of effluent sludge from the soft drinks industry was identified during this REA. What was found is discussed below, together with information on to contaminants typically found in the associated wastewater. The latter provides an insight into the contaminants that may be present in the effluent sludge following wastewater treatment.

Wastewater composition

The wastewater from the soft drinks industry can contain high levels of soluble sugars or carbohydrates, which can be transferred to the sludges through the wastewater treatment process. The degradation of this 'sweet water' can result in the production of organic acids, which can generally be easily neutralised but can still have a dramatic effect on the pH of the solution or material (Environment Agency 2013).

Some effluents can contain a high level of citric acid, which can also have a substantial impact on the pH of the wastewater and resultant sludge (WRAP 2013, Munter 2011). Sukumar (2011) noted that waste from waste code 02 07 00 can be highly acidic, with a mean of pH 4.8. In contrast, Visvanathan and Asano (2007, p. 10) stated that wastewater associated with soft drink production tends to have a high pH, in addition to the presence of suspended solids and biological oxygen demand (BOD) and Singh et al. (2013) found the pH of a mixed sludge from Coca-Cola in India to be pH 8.09.

Based on this evidence, there is the potential for sludge from the soft drinks industry to be acidic or alkaline in nature. However, this is likely to be dependent on the type of soft drinks being produced and the associated feedstock. The application of acidic sludge is of particular concern as this can have significant implications for crops and potentially soil biology, and should therefore be considered at the deployment stage. Acidic leachate from the sludge can also act as a mechanism for increased transport of metals in the sludge and the receiving soil, which can present a risk to groundwater and surface water.

An analysis from a sample of wastewater from a soft drink manufacturing plant in India is presented in Table 4.3. This wastewater had a fairly neutral pH, along with high concentrations of ammonia, electrical conductivity, chloride, BOD and COD, along with measurable concentrations of copper, zinc and chromium.

Table 4.3 Contaminant concentrations in wastewater from Indian soft drinks manufacturing plant

Contaminant	Concentration (mg/l)
Total solids	3,960
Total dissolved solids	3,864
Total suspended solids	96
Calcium (Ca)	320
Magnesium (Mg)	101
Sodium (Na)	690
Potassium (K)	20
Iron (Fe)	2.91
Manganese (Mn)	Nil

Contaminant	Concentration (mg/l)
Free ammonia (NH ₃)	21.28
Nitrite (NO ₂)	Nil
Nitrate (NO ₃)	21
Chloride (Cl)	792
Fluoride (F)	1.08
Sulphate (SO ₄)	288
Phosphate (PO ₄)	8.05
BOD	360
COD	998
Total Kjeldahl nitrogen	22.4
Copper (Cu)	0.000321
Zinc (Zn)	0.148
Chromium (Cr)	0.00236

Notes: Other properties of the wastewater included an electrical conductivity of 5,496 µmho/cm and a pH of 7.21.
Source: Sivasubramanian et al. (2012)

According to a survey on wastes spread to land carried out for the European Commission, very few trace organic compounds or heavy metals are found in wastewater from the food and beverage industry (WRc and European Commission 2001). This is apparent in Table 4.3 with regard to copper and chromium, with very low concentrations being recorded. However, the concentration of zinc is substantially higher than the other two metals.

The survey report also indicated that the wastewater tends to be heavily loaded with potassium, with elements that are beneficial to plant growth being in solution in the liquid phase (WRc and European Commission 2001). This suggests that the transfer of potassium and nutrients, other than organic matter, may be constrained to the water fraction of the sludge.

Given that the wastewater originated primarily from the washing of containers, equipment and so on, there is the potential for it to contain chloride and sodium and other disinfectants (for example, calcium hypochlorite), which can result from any cleaning agents used (WRc and European Commission 2001).

Excessive sodium can present a risk to groundwater and nearby surface watercourses. Sodium can also have a negative impact on soil structure via the swelling of clay particles and soil dispersion. The sodium induced dispersion can eventually result in reduced infiltration, reduced hydraulic conductivity and surface crusting, with all these factors impacting on soil quality (that is, the soil's structure, form and its ability to act as a habitat) and crops grown at the site. High concentrations of chloride present a risk to groundwater and nearby surface watercourses. They can also result in leaf and root scorch, and hence could present a risk to crops at the receiving site. Note that high concentrations of sodium and chloride can result in a high electrical conductivity, which can present a potential hazard to crops and groundwater.

Residual pesticides can be present in the wastewater as a result of the washing of fruit and vegetables during juice production, and these pesticides could end up in the

residual sludge (Allobergenova 2006). This is likely to depend on the type of soft drinks being produced. In the event that pesticides are present in the sludge, these are likely to be at very low concentrations, with substantial dilution both in the wastewater and sludge itself. However, even at very low concentrations, pesticides can present an adverse risk to a number of sensitive receptors such as soil biology and surface water.

The primary and secondary treatment processes can remove some organic pollutants from the wastewater, particularly those that are oxygen-demanding and solids (Munter 2011). Other contaminants such as those that are resistant to degradation, for example, persistent organic pollutants such as organochlorides, inorganic salts, and heavy metals, are not removed efficiently by treatment processes and hence may remain in the wastewater rather than being transferred to the residual sludge material.

Summary: Implications for effluent sludge

- Has the potential to be acidic, although this depends on the type of soft drinks being produced.
- Likely to have a high ammonia, BOD and COD content.
- May contain metals, although dissolved phase metals may mostly remain in the wastewater, post treatment.
- May contain residual pesticides (as will the wastewater), if fruit juices are being produced.
- May contain chloride, sodium and other disinfectants associated with the cleaning of the treatment system. This may result in a high electrical conductivity.

Composition of effluent sludge

As discussed above, the chemical composition of the sludge from the effluent treatment plant can vary depending on:

- the stage of the wastewater treatment process
- whether any pre-treatment has occurred
- the type of soft drinks being produced and associated feedstock

In general, the sludges have a high level of organic matter and phosphorus, and varying amounts of nitrogen and have a low carbon to nitrogen ratio (WRc and European Commission 2001, Environment Agency 2013). The nutrients present in the sludge, particularly phosphorus, present a risk to surface waters, although this risk can be managed through the application of sludge in accordance with the SR2010 conditions.

Based on the information presented above, high concentrations of metals are not likely in the effluent sludge. However, effluent sludges from the Coca-Cola factory in the Palakkad district in Kerala, India, were found in 2003 to be contaminated with high concentrations of cadmium and lead. Analysis of the sludge from the plant, undertaken by the Kerala State Pollution Control Board, University of Exeter and Central Pollution Control Board found concentrations of cadmium of 201.8 mg/kg, 100 mg/kg and 333.8 mg/kg, respectively. Concentrations of lead of 1,100 mg/kg and 3,471 mg/kg were also reported by the University of Exeter and the Central Pollution Control Board, respectively. The presence of cadmium and lead in the sludge was assumed to be due

to the company's failure to install reverse osmosis in the wastewater treatment system (KSGD 2005).

This sludge had been provided to farmers around the plant as a 'free fertiliser' and had consequently been spread to land. Further investigation of the area led to the discovery of consistently higher concentrations of cadmium and lead in well waters, along with samples of soil, fodder, milk, meat and eggs collected from the area. These findings demonstrated the cumulative effect of the discharge of lead and cadmium into the local environment (KSGD 2005).

Further analysis and investigation of the Coca-Cola sludge was made by Singh et al. (2013). They noted that three main types of sludge (water treatment sludge, effluent treatment plant sludge and filter cake sludge) are produced by Coca-Cola during the treatment of wastewater and clarification of sugar syrup. These sludges are often mixed before being spread to land. The chemical properties of this mixed sludge are presented in Table 4.4.

Table 4.4 Chemical properties of mixed sludge from Coca-Cola soft-drink production plant in India

Contaminant	Concentration
pH	8.09
Electrical conductivity (dSm ⁻¹)	6.32
Nitrogen (%)	1.12
Phosphorus (%)	0.96
Potassium (%)	0.23
Sulphur (%)	0.51
Zinc (mg/kg)	142
Copper (mg/kg)	34
Iron (mg/kg)	6820
Manganese (mg/kg)	223
Cadmium (mg/kg)	20
Lead (mg/kg)	288
Nickel (mg/kg)	68
Chromium (mg/kg)	159

Notes Mixed sludge at a ratio of 1:2:4 for filter cake sludge: water treatment sludge: effluent treatment plant sludge
Concentrations presented are the mean of three samples.
Source: Singh et al. (2013)

Table 4.4 shows substantially lower concentrations of cadmium and lead in the mixed sludge from the Coca-Cola factory, although the concentration of cadmium is still considered to be of potential concern, with respect to risks to livestock and human health.

During the study by Singh et al. (2013), it was noted that cadmium appeared to have a greater mobility and bioavailability than the other metals present in the mixed sludge, resulting in greater cadmium uptake by rice grains compared with other metals and a

control sample. In contrast, the direct application of mixed sludge to wheat fields resulted in a greater uptake of chromium compared with the control, with insignificant cadmium and lead uptake, and lower nickel uptake. This demonstrates that the uptake by plants from sludge applications is not only influenced by the contaminant concentrations in the sludge, but also the type of crops grown at the site.

Singh et al. (2013) also noted that, although the concentrations of non-essential heavy metals in rice and wheat grains with mixed sludge applications increased in comparison to the control sample, the concentrations were comparably less than the normal range for these heavy metals in plants (0.1–5.0 mg/kg for cadmium and nickel and 0.1–12 mg/kg for lead). They further noted that the study supported previous assumptions that heavy metals are capable of forming insoluble complexes with soil organic matter, resulting in a restricted heavy metal uptake from soil.

Sukumar (2011) also identified copper (maximum of 43 mg/kg), zinc (247 mg/kg) and lead (maximum 7.6 mg/kg) in on-site effluent sludge from the treatment of beverage waste. However, the concentrations were fairly low compared with other waste sludge, such as paper sludge. These concentrations are fairly comparable to those given in Table 4.4, particularly for copper. It was further noted that the concentrations of toxic elements from residual sludge waste from anaerobic digestion were almost insignificant.

Sukumar (2011) indicated that compost waste and water clarification sludge contained organic contaminants, such as PAHs (chrysene, anthracene and naphthalene), total petroleum hydrocarbons (TPH) and antimony, although the potential source of these contaminants was not discussed. It was further noted that concentrations of PAHs in these sludges of 0.018–10 mg/kg (dry matter) had been reported in the literature for European Union Member States.

The Quality Protocol for anaerobic digestate (applicable in England, Wales and Northern Ireland) sets out the criteria for the production of quality outputs from anaerobic digestion of material that is biodegradable, including several types of sludge. However, waste code 02 07 05 is not an acceptable biowaste type to be covered by the Quality Protocol (WRAP and Environment Agency 2014, Appendix).

Further quantitative data are available in the WRc and European Commission report, although these data are generic for the food and drink industry as a whole and are based on information from Denmark, France, Germany and the UK.

Table 4.5 presents a range of contaminant concentrations for sludge from the food and drink industry.

Table 4.5 Average composition of food and drink industry sludge

Contaminant	Concentration (mg/kg dry solids)		
	Minimum	Maximum	Mean
Dry solids (%)	1.3	91	12
Carbon to nitrogen ratio	3.6	43	7
pH	2.3	13	7
Organic matter (%)	25	93	58
Total Kjeldahl nitrogen (N-TK)	0.7	12	3.5
Ammonical nitrogen (N-NH ₄)	0.03	4	0.5
Phosphorus pentoxide (P ₂ O ₅)	0.1	16	2.4

Contaminant	Concentration (mg/kg dry solids)		
	Minimum	Maximum	Mean
Potassium oxide (K ₂ O)	0.1	16	1.4
Calcium oxide (CaO)	1.3	56	10
Magnesium oxide (MgO)	0.04	4	0.6
Sulphur trioxide (SO ₃)	0.4	1.6	1.5
Sodium oxide (Na ₂ O)	0.4	1.9	1
Iron (Fe)	780	1305	1042
Manganese (Mn)	20	45	32
Molybdenum (Mo)	7.9	23	15
Boron (B)	11	42	23
Cobalt (Co)	0.1	0.8	0.4
Cadmium (Cd)	0.01	10	0.8
Chromium (Cr)	0.05	240	28
Copper (Cu)	0.10	379	57
Mercury (Hg)	<0.01	8	0.2
Nickel (Ni)	0.10	154	14
Lead (Pb)	0.10	250	10
Zinc (Zn)	0.10	1815	199
Selenium (Se)	0.35	6	3.7
Fluoranthene	0.01	0.3	0.2
Benzo(b)fluoranthene	0.01	0.05	0.04
Benzo(a)pyrene	0.01	0.06	0.04
Sum of 7 polychlorinated biphenyls (PCBs)	0.02	0.21	0.07

Notes: Taken from WRc and European Commission (2001)

Food industry effluent and associated sludge can be quite variable in composition, depending on the type of industry and period of year (WRc and European Commission 2001). This is evident in the results presented in Table 4.5, with a wide range in reported concentrations for all contaminants. However, the table still provides a useful guide to which contaminants may be present in sludges from soft drink manufacturers.

Summary of findings

- Sludges have a high level of organic matter and nitrogen and have a low carbon to nitrogen ratio.
- Sludge may contain high concentrations of metals, particularly cadmium and lead, and particularly if pre-treatment prior to landspreading was inappropriate or insufficient.
- There is a suggestion that sludge could contain PAHs (chrysene, anthracene, and naphthalene), TPH and antimony.

4.2.3 Plant and animal pathogens

Animal pathogens in sludges mostly come from the human population, companion animals and livestock (Lepeuple et al. 2004). Given that the on-site effluent sludge in question will have originated from wastewater associated with the production of soft drinks, this is unlikely to contain any sanitary or animal related waste materials (Lepeuple et al. 2004, Fiss et al. 2013). As such, it is considered unlikely that animal pathogens will be a viable hazard for this sludge type.

Plant pathogens may be present initially within the sludge, although this is highly dependent on the type of soft drinks being produced. The potential will be greater where fruit and/or vegetable juices and pulp are present in the wastewater and subsequent sludge. For example, bacteria such as *Cornebacterium michiganense* and *Alternaria porri* can be found in tomatoes and carrots, respectively. Furthermore, fungi in the form of *Didymella lycopersici* can also be found in tomato waste. Further types of fungi can also be present should the organic matter in the sludge be transformed by moulds such as *Aspergillus fumigatus* (Lepeuple et al. 2004). As a result, there is the risk that pathogenic species could develop in the sludge itself. The presence of plant pathogens in the waste is a risk to crops at the receiving site and in adjacent areas.

4.2.4 Invasive weeds

Invasive weeds are not considered to be a viable hazard for this waste type.

4.2.5 Physical contaminants

Physical contaminants are likely to be removed from the wastewater during the preliminary phase of treatment and hence are unlikely to be present in the residual sludge material. As such, physical contaminants are not considered to be a hazard for this waste type.

4.2.6 Nuisance

The sludge can be extremely odorous due to it being rich in poorly stabilised organic matter (with a low carbon to nitrogen ratio) (Casey 2006, WRc and European Commission 2001). However, stabilisation of the sludge prior to landspreading can minimise the potential for odours to be released (Environment Agency 2013). An odour management plan may be needed to mitigate these risks.

In the event that the sludge spread to land has not been sufficiently stabilised and biodegradation is still occurring, there is the potential for this material to attract flies and scavenging animals, resulting in nuisance to adjacent residents or site users (Allobergenova 2006).

There is little risk of dust release if the sludge is applied to land in a liquid or semi-solid form. Following dewatering, the sludge can act like a solid and be applied as such. However, this material will still contain some water (the solid form can contain 25–80% solids; Table 4.2) and hence is unlikely to release sufficient quantities of dust to present a hazard.

4.2.7 Other environmental hazards

No other environmental hazards, other than those discussed above, were identified.

4.3 Hazard evaluation and screening

4.3.1 Master List of hazards

The information given above was used to produce a Master List of hazards (Table 4.6).

Table 4.6 Master List of hazards for on-site effluent treatment sludge from soft drinks production applied to agricultural land

Hazards	Relevant receptor
Chemical hazards	
Metals and metalloids	Soil quality, human, livestock/ecology, crops, surface water and groundwater
Low pH (that is, <pH 5)	Soil quality, crops, groundwater and surface water
PAHs	Soil quality, humans and livestock/ecology
TPH	Soil quality, humans and livestock/ecology
Phosphorus	Surface waters
Sodium	Crops and groundwater
Chloride (and potentially other disinfectants)	Crops and surface water and groundwater
Electrical conductivity	Crops and groundwater
Pesticide residues	Soil quality, humans, livestock/ecology, surface water and groundwater
Plant and animal pathogens	
Plant pathogens	Crops
Nuisance	
Odour	Humans
Attraction of pests and scavenging animals	Humans

Notes: In the context of the application of on-site effluent treatment sludge from the production of soft drinks to agricultural land.

4.3.2 Principal List of hazards

In the absence of sufficient information relating to the Master List of hazards, it was not possible to identify a list of priority hazards for consideration at the deployment stage.

4.4 Refined generic conceptual model

The findings of the hazard assessment and evaluation were used to refine the generic conceptual model for landspreading for on-site effluent sludge from soft drink production. The refined generic conceptual model, which takes account of the hazards identified on the Master List of hazards, is presented as Table 4.7.

Table 4.7 Refined generic conceptual model for the landspreading of on-site effluent sludge from soft drinks production to agricultural land

Source	Pathway	Receptor	Potential effect
Chemical contamination:	Direct contact, ingestion and inhalation (dust and vapour)	Livestock	Toxic, hazardous to health
• Metals and metalloids, including sodium	Uptake via plants and ingestion		
	Direct contact, ingestion and inhalation (dust and vapour)	Humans (operator)	Toxic, carcinogenic, hazardous to health
• Low pH	Inhalation (dust and vapours)	Humans (bystanders)	
• PAHs			
• TPH	Uptake via plants and ingestion of produce	Humans (consumers)	
• Phosphorus	Uptake via livestock and ingestion of produce		
• Electrical conductivity	Plant uptake	Crops	Reduction in crop yield and productivity due to phytotoxicity, plant die-back, detrimental conditions to plant growth and so on
• Chloride and other disinfectants	Leaching from soil to groundwater and vertical migration through the unsaturated zone	Groundwater	Groundwater contamination – deterioration of quality, impact on potable water resource requiring treatment or closure of source of supply (borehole, well or spring)
	Surface run-off and lateral migration in groundwater	Surface water	Surface water contamination – deterioration of water quality, sediment loading
	Direct application to land	Soils	Deterioration of soil quality, damage to soil structure, toxicity and other adverse changes to soil micro-organisms impacting soil functions, or increased contaminant loading in site soils affecting amenity and use.

Source	Pathway	Receptor	Potential effect
	Direct application to land, direct contact and uptake via soil vertebrates and invertebrates followed by transmission through the ecological food web	Ecological designation/wildlife	Harm to protected site through toxic contamination or habitat interference (nutrient enrichment, loss, disturbance and so on)
	Migration of dusts and leachate to adjacent sites, direct contact and uptake via soil vertebrates and invertebrates followed by transmission through the ecological food web	Ecological designation/wildlife	Harm to protected sites and species through indirect contamination of sites adjacent to spreading area
Plant pathogens	Direct application to land	Crops on site	Reduced crop yield and productivity, deterioration of soil quality
	Windblown migration	Crops on adjacent land	Reduced crop yield and productivity, deterioration of soil quality
Release of odours	Airborne transport and inhalation (odours)	Humans (bystanders)	Nuisance, impact on quality of life and loss of amenity
Attraction of pests and scavenging animals	Airborne transport	Humans (bystanders)	Nuisance, impact on quality of life and loss of amenity

5 Conclusions and recommendations

5.1 Conclusions

This REA identified the potential hazards associated with on-site effluent sludge from the production of soft drinks and its application to agricultural land. The evidence collected was examined to establish a Master List of hazards (Table 4.6). In the absence of sufficient published information on the waste type under consideration, it was not considered possible to establish a priority list of Principal hazards for this waste. The Master List of hazards is summarised below:

Chemical hazards:

- Metals and metalloids – a negative risk to soil quality, livestock, ecology, humans, crops, surface waters and groundwater
- Low pH – a negative risk to crops and soil biology and also potentially increasing the mobilisation of metals in sludge and receiving soils, presenting a risk to groundwater and surface water
- PAHs and TPH - a negative risk to soil quality, humans, livestock and ecology
- Phosphorus – a negative risk to surface waters
- Sodium and electrical conductivity – a negative risk to crops and groundwater
- Chloride (and other disinfectants) – a negative risk to crops, surface water and groundwater

Plant and animal pathogens:

- Plant pathogens – potential negative impact on crops at the receiving site and adjacent areas

Nuisance:

- Odour and attraction of pests and its impact on amenity for adjacent human receptors. This is indirectly linked to the stability of the sludge, with unstabilised sludge presenting a greater odour risk.

In the absence of a range of typical concentrations for the above contaminants, it is unclear whether the risks from these hazards can be successfully mitigated by adherence to standard permit conditions and good practice in general during the storage, transport and application of this sludge to land.

To enable adequate assessment of these factors during the deployment process, the operator's application should be accompanied by representative analytical data for the sludge for the Master List of hazards and an assessment of the risks noted above. An odour management plan may be needed to deal with potential nuisance from odorous sludges.

5.2 Limitations and recommendations

Time constraints on the preparation of this REA meant it was not possible to liaise with UK producers of soft drinks and no data were available from deployments. This was a major limitation of the study. In the absence of published information for on-site effluent sludge from the soft drinks industry, the REA would have benefited greatly from obtaining specific information on the composition and characteristics of this waste, in addition to further information on the production processes, pre-treatment, typical application rates and methods of application for this waste type, specific to the UK.

It is recommended that liaison is undertaken with a selection of UK producers to obtain further information, particularly on the chemical composition of the waste. This should be used to update this REA, allowing a determination of a Principal List of hazards, which was not considered possible at this time.

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List of abbreviations

BOD	biological oxygen demand
COD	chemical oxygen demand
EPR	Environmental Permitting Regulations 2010
NPS	National Permitting Service
PAH	polycyclic aromatic hydrocarbon
REA	Rapid Evidence Assessment
SPZ	Groundwater Source Protection Zone
SR	Standard Rules [Permit]
TGN	Technical Guidance Note
TPH	total petroleum hydrocarbons

Appendix: Search strategy and evidence extracted

See Excel spreadsheet accompanying this report.

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