Review of the application of organic materials to land

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Executive summary

Introduction

1. This report reviews the impacts of organic material spreading to land, using data collected from waste operators (2007 – 2010) and SEPA's own sampling (2007 – 2012).

2. The aim of the report is to review the benefits and risks associated with spreading organic materials to land. It makes recommendations for SEPA's future approach to monitoring of organic material spreading to land.

3. The report provides information on our current knowledge on the total amounts, distribution of and trends in organic materials spread to land in Scotland, and the impact of these on soil conditions.

4. The report discusses a range of different types of organic material, including but not limited to:
   - agricultural slurries and manures, which make up 95% of the organic material spread;
   - sewage sludge (2%);
   - distillery production residues (1%); and
   - paper crumble.

Key results of the review

Impacts upon soil

5. Soil quality indicator data available to SEPA has not identified any major benefits, to or adverse impacts upon, soil resulting from the application of organic material to agricultural land under a paragraph 7 exemption (Waste Management Licensing Regulations 2011; the 2011 Regulations) or the Sludge (Use in Agriculture) Regulations 1989 (the 1989 Regulations).

Wider environmental impacts

6. Excessive application of organic materials to land, especially those that contain large quantities of available nutrients (e.g. manures and slurries), wrong timing of application, or unsuitable application technique contribute to loss of nutrients from soil resulting in water pollution.

7. There are relatively few environmental incidents caused by the application of organic material to land. Over the period from 2008 to 2011 SEPA investigated over 20,000 incidents. Only a small percentage (113 incidents; 0.57%) were associated with organic material to land and most of these were not categorised as significant: only 6 incidents (0.03%) were categorised as significant.

Monitoring and Standards

8. Limitations in the data available to SEPA impose constraints on the conclusions which can be reached about how the environment is affected by the application of organic materials to land.

9. There are a number of areas where our understanding needs to be improved:
   - possible impacts on soil quality associated with the application of slurries, and manures, PAS100 compost and PAS110 anaerobic digestate;
   - contribution of different organic materials applied to land to nutrient pollution of waters;
   - a wider range of potential contaminants need to be assessed;
   - emission to air of greenhouse gasses and substances which can exacerbate air pollution;
   - possible impacts of high application rates on non-agricultural land.

10. The absence of soil standards makes it difficult to assess the impacts upon soil of potential contaminants introduced by the application of organic material applied to land.

11. The regulatory limits set out for PTE in the 1989 Regulations help SEPA regulate the application of sewage sludge. It is recommended that similar limits be developed for all types of organic material applied to land that are covered by the 2011 Regulations.

Conclusions

11. This review has collected together data from a range of different sources. Despite some limitations in this data, the results are reassuring.

12. The most important environmental risk identified was the well recognised problem of nutrient loss from soil resulting in water pollution. No new environmentally significant problems were identified, for example, associated with the potentially toxic elements associated with some types of material applied to land.

13. We consider that the regulatory regime has successfully protected agricultural soils from the potential harm which could have resulted from the application of controlled wastes and sewage sludge.

14. There is scope for changes to both existing monitoring and regulatory regimes to improve knowledge of the impact of all organic material application to land on soils and the wider environment and to simplify and improve regulation to offer both increased protection to the environment and reduced regulatory burdens on operators.

1. Purpose of this report

1.1. This report reviews the information collected by SEPA as part of its responsibility to regulate the application of organic material to land.

1.2. This report reviews the benefits and risks associated with the application of organic materials to land. The intention is to identify whether the existing approach delivers an appropriate level of environmental protection and to provide the basis of a review of SEPA's approach to monitoring.

2. Application of organic materials to land

Introduction

2.1. Soil is one of Scotland's key natural resources. It is self-evident that soil supports food production, but it also provides a range of other important "services" for society as detailed in the State of Scotland's Soil report (Dobbie et al. 2011).

2.2. Part of SEPA's role is to contribute to the Scottish Government's objective of delivering a sustainable future, one aspect of which is promoting sustainable land and soil management.

2.3. A key concept of sustainability is to reduce the demand upon the planet's non-renewable resources by reusing materials which would otherwise be discarded. The application of organic material to land is a practical example of how we can support this objective.

2.4. Applying organic materials to land should reduce the need for inorganic fertilisers which are either mined from natural resources or manufactured in energy intensive processes. By replacing these with organic materials we will reduce the need for these materials, which in turn will reduce greenhouse gas emissions. Another possible energy benefit that can result from organic materials use is improved workability of heavy soils which will result in lower fuel use in land preparation.

2.5. Well managed use of materials on land for agricultural benefit or ecological improvement can be the Best Practical Environmental Option (BPEO) in many circumstances. Potential benefits include the supply of nutrients and organic matter to the soil. However the use of organic materials must be managed properly to meet the specific requirements of the site, soil and its land use to avoid harming human health or the environment, including the soil itself. For existing regimes regulating spreading of organic material to land see Annex I.

2.6. There are clear incentives to increase responsible and sustainable organic material spreading to land, driven by a number of instruments that are designed to increase the recycling of materials e.g. the Waste Framework Directive and the targets associated with the Landfill Directive. There is a need to ensure that an appropriate balance is struck between these needs and the requirement to ensure that Scotland's soil resource and its wider environment are adequately protected.

3. Materials spread to land

Overview

3.1. Around 22 million tonnes (wet weight) of materials are spread on land in Scotland each year. Almost three quarters of these materials are organic in nature and just over one quarter is non-organic. This figure excludes peat and forest residues which have not been quantified for this report.

3.2. 95% of the organic materials discussed here are manures and slurries from agriculture. The remaining 5% is derived from residues from food and drink production, sewage sludge from the water industry and small amounts of organic materials derived from other industrial processes.

3.3. The non-organic materials primarily include soils, gravel, ash, bricks, concrete and bitumen which are typically used in construction activities. In addition, an estimated 225,000 tonnes of agricultural lime and one million tonnes of inorganic fertilisers are spread on agricultural land annually.

3.4. A breakdown of the amounts of materials spread by source (economic sector) is given in Annex II and the relative proportions (based on wet weight) are illustrated in Figure 3.1.

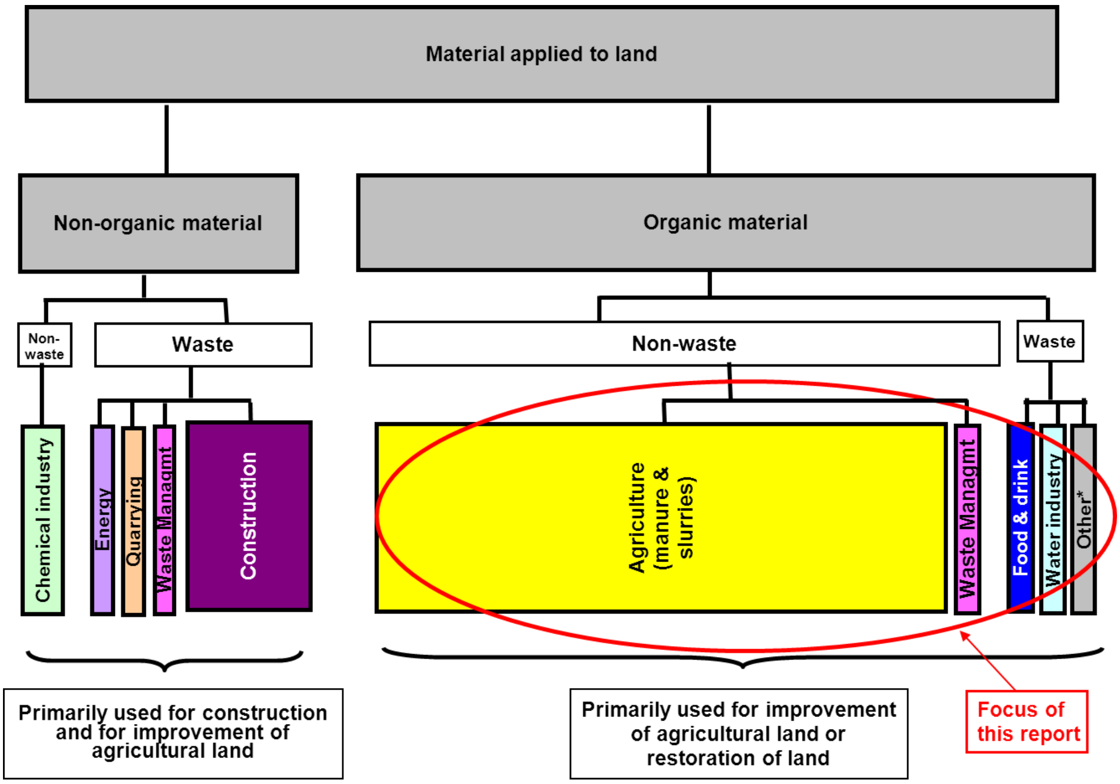

Figure 3.1. Source of materials spread on land
* Other includes agriculture, households, waste management, wood & paper processing

3.5. Agricultural activities generate the majority of materials spread on land, followed by the construction and chemical industries. The food and drink, quarrying, energy, water and waste management industries produce relatively small amounts of materials in comparison.

3.6. Two major pieces of legislation currently govern the spreading to agricultural land of most organic materials other than farmyard manures and slurries: The Sludge (Use in Agriculture) Regulations 1989 (the 1989 Regulations), which control the spreading of sewage sludge; and the Waste Management Licensing Regulations 2011 (the 2011 Regulations) which control the spreading of most other waste types.

Organic materials spread to land under the 1989 Regulations and the 2011 Regulations

3.7. The next section focuses upon organic materials spread to land, excluding manures/slurries, peat and forest residues.

3.8. Figure 3.2 shows the average percentage of organic materials (wet weight) spread on land under the 1989 Regulations and the 2011 Regulations over the four year period 2007-2010 classified by the economic sector producing the material. Drinks manufacturing and the water industry produce almost three quarters of the material that is spread. Distillery production residues make up almost all of the drinks industry derived material spread to land in Scotland, whilst materials produced by the water industry come mainly from sewage treatment, with a small amount from water purification.

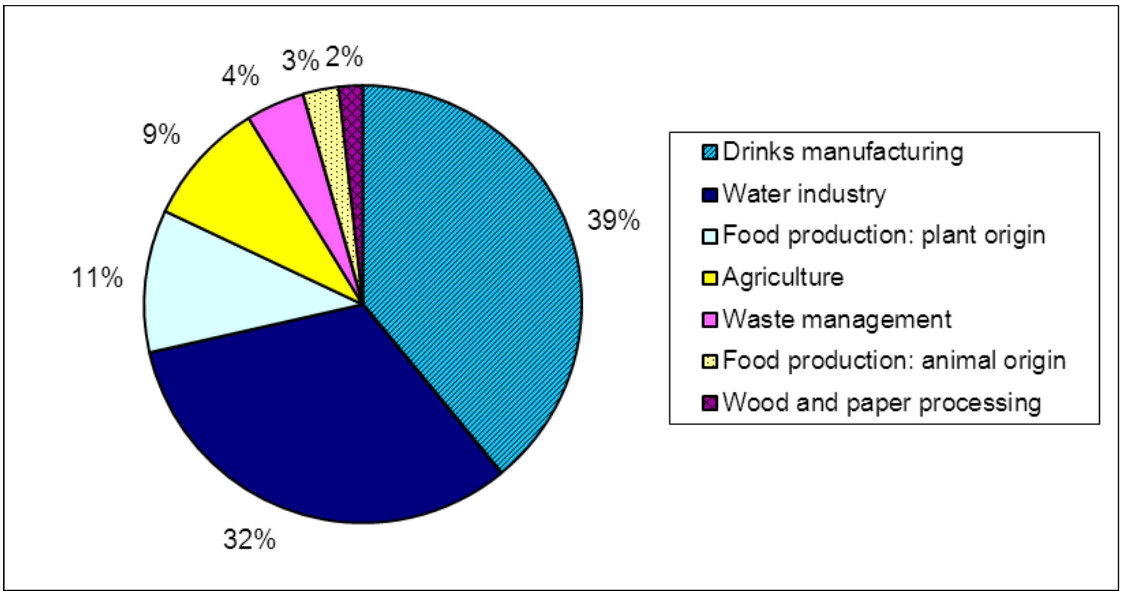

Figure 3.2. Organic materials spread on land under the 1989 Regulations or the 2011 Regulations by economic sector as a percentage of total wet weight 2007-2010 (four year average). Materials from 'agriculture' in this figure represent regulated wastes, not manures and slurries.

3.9. There are five exemptions from the 2011 Regulations[1] that regulate the spreading of waste on land – paragraphs 7, 8(2), 9, 19 and 50 (for more detail see Annex I). With the exception of paragraph 50, all of these exemptions have a requirement for exemption holders to provide data to SEPA annually on the amounts of waste that are spread on land.

3.10. Figure 3.3 shows the average[2] amount of organic material spread on land under the 2011 Regulations and the 1989 Regulations over the period 2007-2010 by economic sector. As can be seen the majority of organic material that is spread on land is under a paragraph 7 exemption (the 2011 Regulations) and the 1989 Regulations.

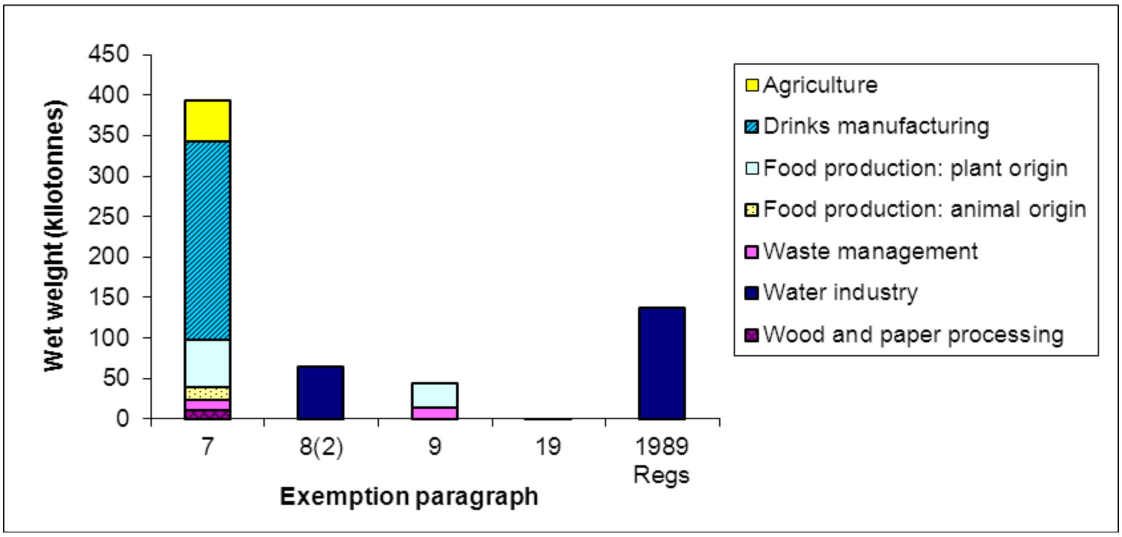

Figure 3.3. Organic materials spread on land under the 2011 Regulations and the 1989 Regulations by economic sector 2007-2010 (four year average). Materials from ‘agriculture’ in this figure represent regulated wastes, not manures and slurries.

3.11. Trends in the amount of organic materials spread on land under the 2011 Regulations and the 1989 Regulations over the period 2007-2010 are shown in Figure 3.4. Since 2008 there has been an overall decrease in the amount of organic materials spread on land. The water industry and drinks manufacturing produced a large proportion of the organic materials spread under these controls.

3.12. The amount of sewage sludge spread on land for the period 2007-2010 is shown in Figure 3.5. Between 70-80% of sludge is applied to agricultural land each year with the remainder going to non-agricultural land for restoration purposes. Overall the amount of sludge spread on land remains fairly constant ranging between approximately 170 kilotonnes and 180 kilotonnes annually.

[1] The predecessor of the 2011 Regulations was the Waste Management Licensing Amendment Regulations 2003 (2003 Regulations), which were in force between 1st April 2003 and 27th March 2011. Data collection for this report was mainly done under the similar 2003 Regulations.
[2] Exemption paragraphs 7 and 8(2) data are based on a 4 year average, as are the 1989 Regulations data. Paragraphs 9 and 19 are based on data for 2010 only as no organic waste was reported as spread on land under these paragraphs in the other three years.

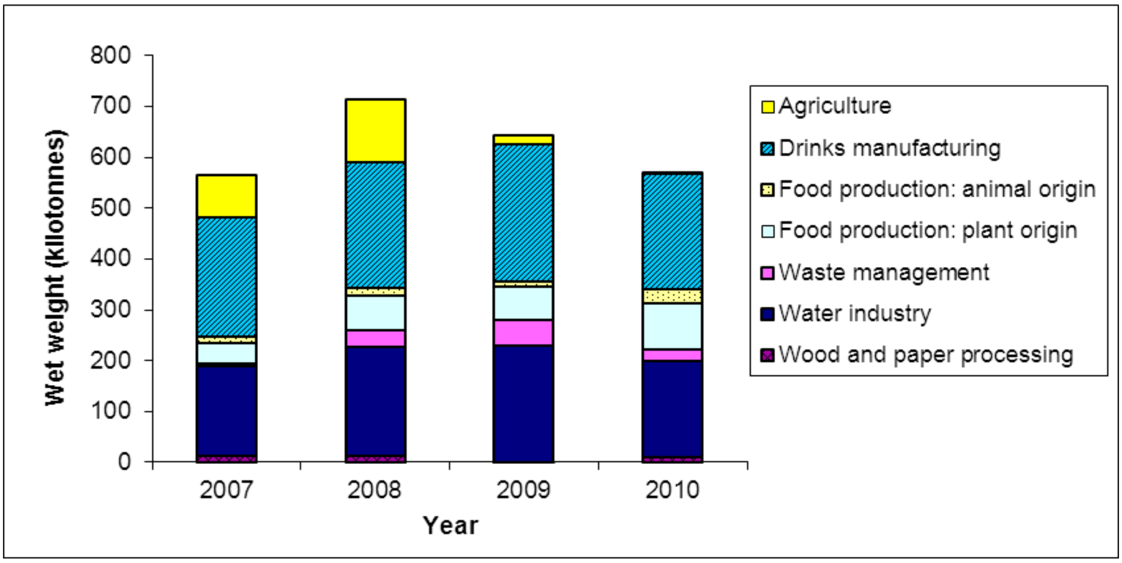

Figure 3.4. Economic sector producing organic materials spread on land under the 2011 Regulations or the 1989 Regulations 2007-2010. Materials from ‘agriculture’ in this figure represent regulated wastes, not manures and slurries.

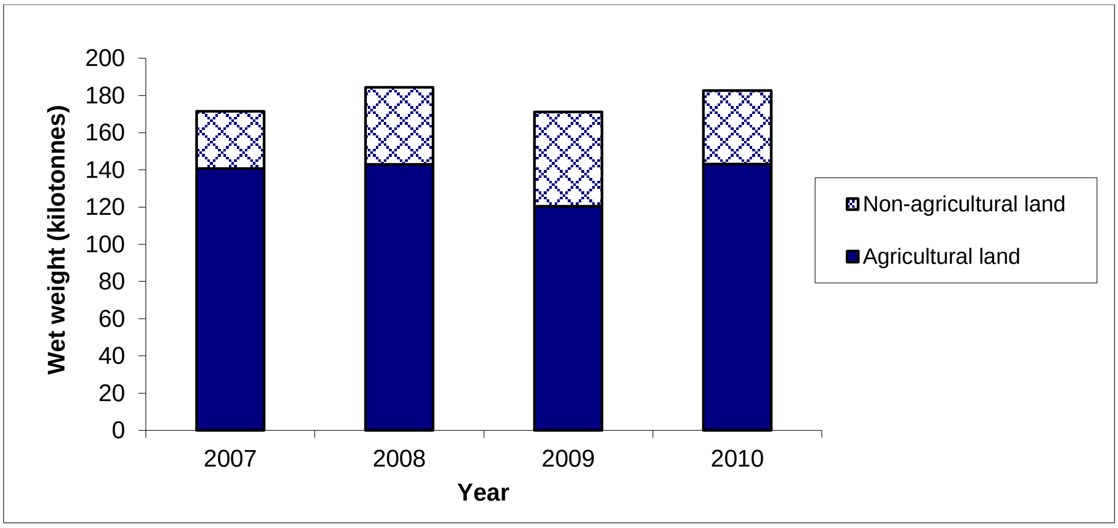

Figure 3.5. Sewage sludge spread on land 2007-2010. Sewage sludge spread to agricultural land is spread under the 1989 Regulations; sewage sludge spread to non-agricultural land is spread under exemption from the 2011 Regulations.

3.13. The geographical distribution of different types of organic material spread varies across Scotland. Figure 3.6 shows the relative amount and source of organic material spread to land for agricultural benefit under a paragraph 7 exemption (the 2011 Regulations) or the 1989 Regulations. It reflects the industries present in different parts of Scotland. For example areas with a high number of distilleries e.g. Speyside receive the highest proportion of material from drinks manufacturing applied to agricultural land.

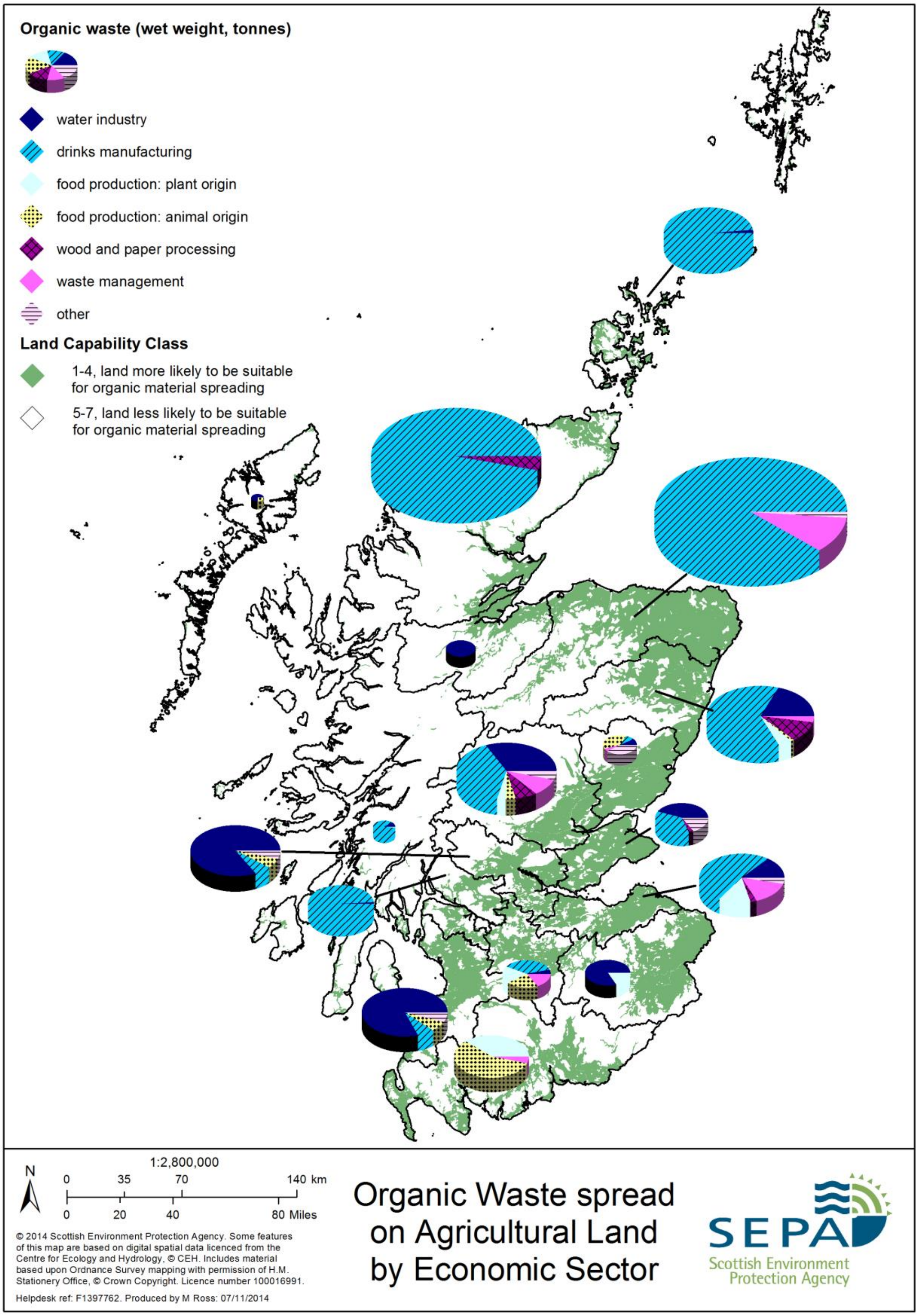

Figure 3.6. Distribution and relative amount of organic material by economic sector applied to agricultural land under a paragraph 7 exemption (the 2011 Regulations) or the 1989 Regulations in 2010. The size of the pie chart for each region of Scotland marked is proportional to the total amount of material spread in region. Data source: Returns to SEPA from paragraph 7 waste exemption applications and sludge register.

3.14. Although 66 % of all organic materials (wet weight) applied to agricultural land under a paragraph 7 exemption (the 2011 Regulations) or the 1989 Regulations is distillery production residue, when the average water content of this material in comparison with other organic materials is taken into account the amounts of other organic materials spread to land are often higher. This is because the water content of distillery production residue is generally very high (Fig 4.1).

4. Potential benefits and risks of applying organic materials to land

4.1. This section describes the potential benefits and risks of applying organic materials, including manures, slurries, PAS100 compost and materials regulated under the 2011 Regulations and the 1989 Regulations to land based on their properties. Identified benefits and risks of applying these materials to land, based on soil data, are discussed in chapter 5.

Sources of data of organic material properties

4.2. The potential benefits and risks of spreading organic material to land were assessed from analysis data that were available to SEPA and covered a wide range of organic material types.

4.3. Analytical data from all active paragraph 7 waste management licensing exemptions for 2010 were extracted, resulting in 61 data sets for drinks manufacturing, 12 for food production of plant origin, 8 for food production of animal origin, 10 for wood and paper processing, 17 for waste management, and 12 for other materials. Where the same material was spread at several locations only one analysis was used, in order not to bias the results towards larger companies. For water industry data, sludge registers submitted to SEPA for 2010 provided 78 sets of analyses in total. These contain multiple analyses from each company since the composition of the material varies between batches. Note, data are not always provided for all parameters in each analysis set.

4.4. SEPA does not collect data for agricultural manures and slurries, PAS 100 compost and PAS110 digestate and as a result data has been taken from published literature.

4.5. The properties of organic materials spread to land are highly variable, even for materials that are produced by the same economic sector and from similar processes. These properties may further be affected by treatment processes and the length and conditions of storage of the material. Therefore, where descriptions below highlight potential benefits or risks from applying a specific type of organic material to land, this should be regarded as a generalisation and it must be recognised that a specific batch of organic material spread to land may have properties that differ from the general properties of that type of material, resulting in different benefits and risks to those outlined below.

4.6. Details of the general properties of organic materials spread to land can be found in Annex III.

Potential benefits

4.7. Potential benefits to soil of spreading organic materials to land include soil conditioning, fertilising and liming. It is also recognised that wider environmental and social benefits may arise from choosing to apply these materials to land compared to alternative treatment or disposal options. These are not covered in detail here, but include:

- avoiding costly treatment requiring high levels of energy; and
- maintaining nutrients in circulation and thereby reducing the requirement to use inorganic fertilisers, saving energy, the use of non-renewable resources and the importation of potential contaminants in these products.

<u>Soil conditioner</u>

4.8. Certain organic materials can act as a soil conditioner by adding useful amounts of organic matter (as indicated by their carbon content; see Fig. 4.1) which can improve soil structure and increase water holding capacity. Such improvements to soil conditions will be maximised where regular and well managed dressings of bulky and highly organic materials are made to a low organic matter soil.

4.9. The types of materials which are most likely to have soil conditioning benefits are from:

- waste management – mostly composts (including PAS 100);
- wood and paper crumble;
- water industry – mostly solid sewage sludges;
- agricultural manures;
- food production from materials originating from plants.

<u>Fertiliser</u>

4.10. Some organic materials contain significant quantities of major plant nutrients, particularly nitrogen and phosphorus (Fig. 4.2), which encourage crop growth and can have long term benefits for soil fertility as nutrients are mainly present in organic forms which will be slowly released. The rate and timing of application of organic material must be matched to the nutrient requirements of the crop. To be of fertiliser value, at least part of the nutrient content should be available or become available for plant uptake within 3 years. Some organic materials contain other important nutrients (e.g. sulphur and magnesium) or a range of trace elements such as copper and zinc.

4.11. Organic material from the drinks, food production and paper industries tend to have low nutrient levels (Fig. 4.2); however there is a lot of variation in the nutrient data for materials produced by these sectors, which may represent real variations, or may be an artefact of sampling regime or handling.

4.12. The types of materials which are most likely to have fertiliser benefits are from:

- agricultural manures and slurries;
- waste management – mostly composts (including PAS 100);
- water industry – mostly sewage sludge.

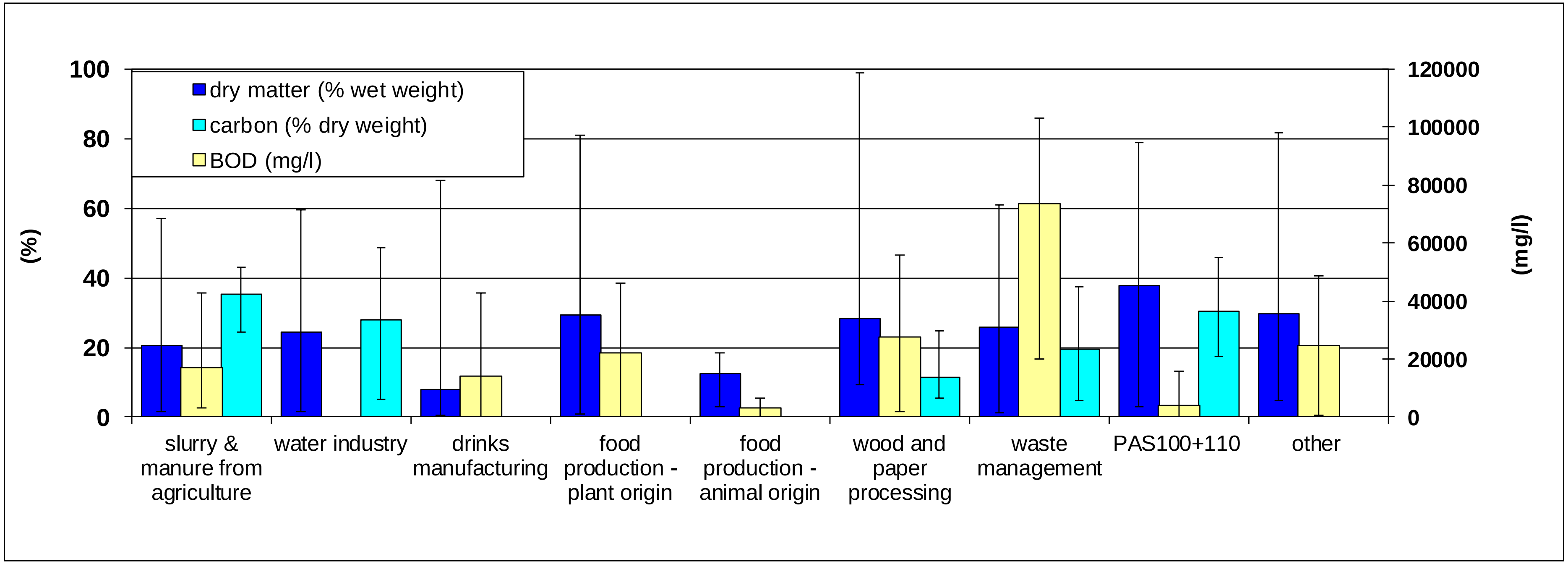

Figure 4.1. Dry matter content, biological oxygen demand (BOD) and carbon content of organic materials from different economic sectors[3]. Whiskers show maximum and minimum values. Where no bars are present no data are available.

[3] Data source: all paragraph 7 waste exemption applications in Scotland for 2010, all sludge registers for 2010, WRAP(2011) report for slurry & manure from agriculture, PAS100 compost and PAS110 digestate.

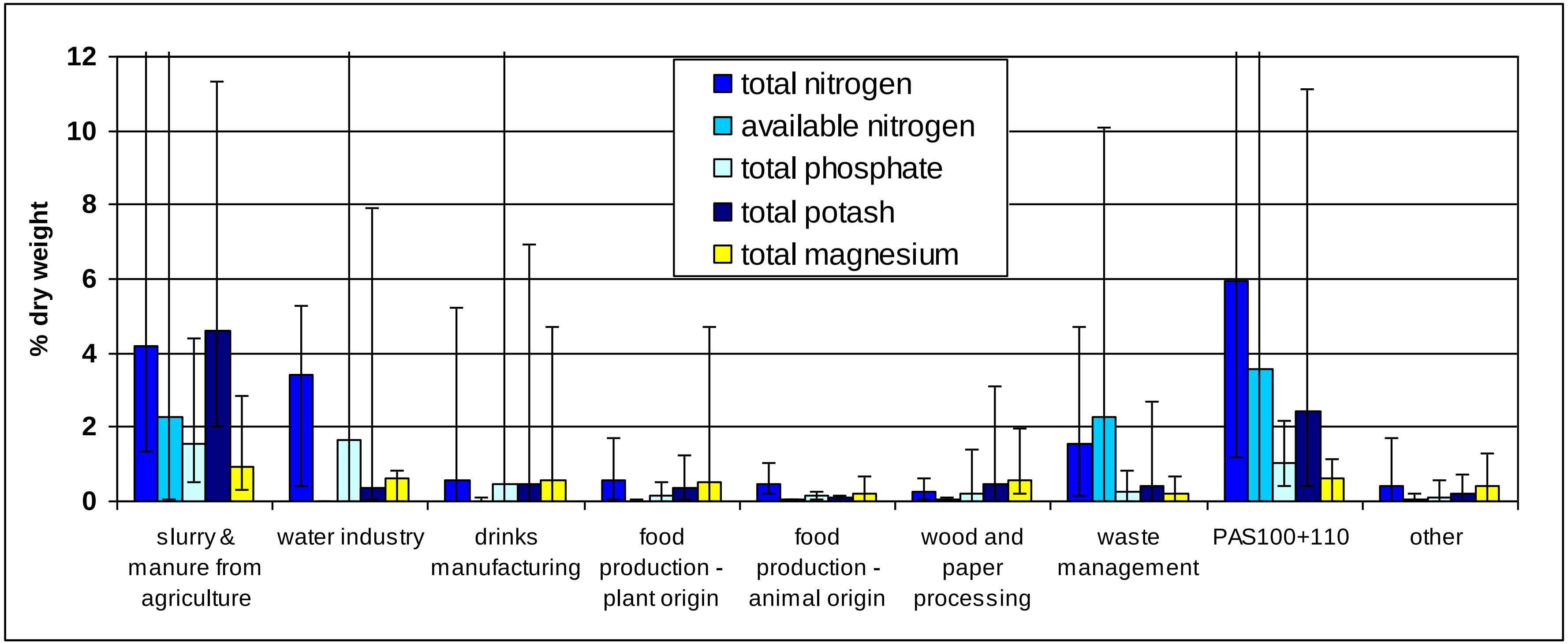

Figure 4.2. Nutrient concentrations of organic material from different economic sectors[4]. Whiskers show maximum and minimum values. Where no bars are present no data are available.

[4] Data source: all paragraph 7 waste exemption applications in Scotland for 2010, all sludge registers for 2010, WRAP(2011) report for slurry & manure from agriculture, PAS100 compost and PAS110 digestate.

Liming value and pH

4.13. Materials such as lime-treated sewage sludge can have a high neutralising value which makes them useful liming material for increasing or maintaining soil pH. Liming acidic agricultural soils can provide multiple benefits, including increasing crop yields and reducing the rate at which some contaminants such as Potentially Toxic Elements (PTE) are leached to watercourses.

Summary

4.14. Table 4.1 summarises the potential benefits to soil from applying organic materials. The greatest benefits are likely to come from:

- agricultural manures and slurries;
- water industry sludge;
- waste management industry composts.

Table 4.1. Summary of the potential benefits associated with spreading organic materials to land (++ major potential benefit; + minor benefit; ( ) refers only to some material types)

	Agricultural manures & slurries	Water industry sludge	Drinks manu-facturing	Waste manage-ment	Food production	Wood and paper processing
Soil conditioner	++	++	(+)	(++)	(+)	++
Adds major nutrients	++	++		++	(+)	
Adds trace nutrients	(+)	(+)	(+)	(+)		(+)
Liming		(++)				(++)
Climate change mitigation	(++)	+	(+)	(++)	(+)	++

Potential risks of applying organic materials to land

4.15. There are a range of potential risks posed to the environment by the application of organic materials to land.

4.16. The severity of risk posed by organic material application to land depends to a large extent on the time scale over which the risk occurs. Risk duration may be roughly classified as follows:

- Persistent (over decades): Potentially toxic elements (PTE); some organic contaminants
- Long-term (over years): Some organic contaminants; over-application of nutrients; acidification (if left unmanaged)
- Medium-term (over months/years): pathogens; some organic contaminants; lock-up of nutrients; some air quality impacts; greenhouse gas emissions; acidification (if managed) and salinisation
- Short-term (over days/weeks): odour; oxygen depletion

4.17. Risks are considered below in approximate order of the time scale over which they operate, with longer duration risks considered first.

Potentially toxic elements (PTE)

4.18. Regular application of organic materials containing high PTE concentrations to land will result in accumulation of PTE in soils over time, since PTE are not biodegradable and are only slowly taken up by plants. Even in the absence of further additions, PTE contamination of soils declines very slowly and becomes near-permanent in some circumstances. Organic materials are not the only potential source of PTE: For example, some phosphate fertilisers contain cadmium and PTE are also deposited on land through atmospheric deposition.

4.19. Some PTE (e.g. cadmium, mercury) are toxic at very low levels, whereas others, such as copper and zinc, are essential plant and animal trace nutrients, causing harm only when excess concentrations are present.

4.20. PTE availability is influenced by soil factors, particularly pH. The majority of soils in Scotland which may receive organic material have a strong or very strong metal binding capacity, thus posing little risk of PTE leaching and plant uptake if suitable soil pH is maintained (Towers and Paterson, 1997). Pollution resulting from surface runoff is however a potentially more serious problem.

4.21. Despite being bound strongly in most Scottish soils, at high concentrations PTE have a range of known impacts on soil quality and ecosystem services. For example, zinc advisory limits for soils have been revised downward due to impacts on rhizobium bacteria (EA 2008), which are responsible for nitrogen fixation in soils. Ongoing UK research suggests that further downward revisions in zinc advisory limits may be needed to protect rhizobium bacteria.

4.22. As PTE concentrations in sewage sludge tend to be high (Fig. 4.3), spreading this material has the potential to increase soil concentrations, possibly with wider environmental impacts. For example, increased soil cadmium (Cd) concentrations following sewage sludge application may lead to increased cadmium in the grains of growing cereal crops, especially in acidic soils (Chaudri et al. 2007), which are common in Scotland. Very little is known about the impact on soil quality and the wider environment of certain PTE, e.g. platinum and palladium, which have gained in importance in recent decades due to new technologies and are found in sewage sludge.

4.23. Some materials contain a wide range of PTE in higher concentrations such as those from water industry, wood and paper industry and waste management, whereas others contain only one or two PTE(s) but those may be in relatively high concentrations (e.g. from drinks manufacturing or slurries) (Fig. 4.3).

Organic contaminants

4.24. Some organic substances are persistent in soil, however in contrast to PTE most are biodegradable, although the breakdown products can be more toxic and persistent than the original substance. For most organic contaminants, little is known about their behaviour and breakdown rates in soil or their effects on soil organisms and almost nothing is known about their cumulative effects. Human health impacts are also poorly known and understood.

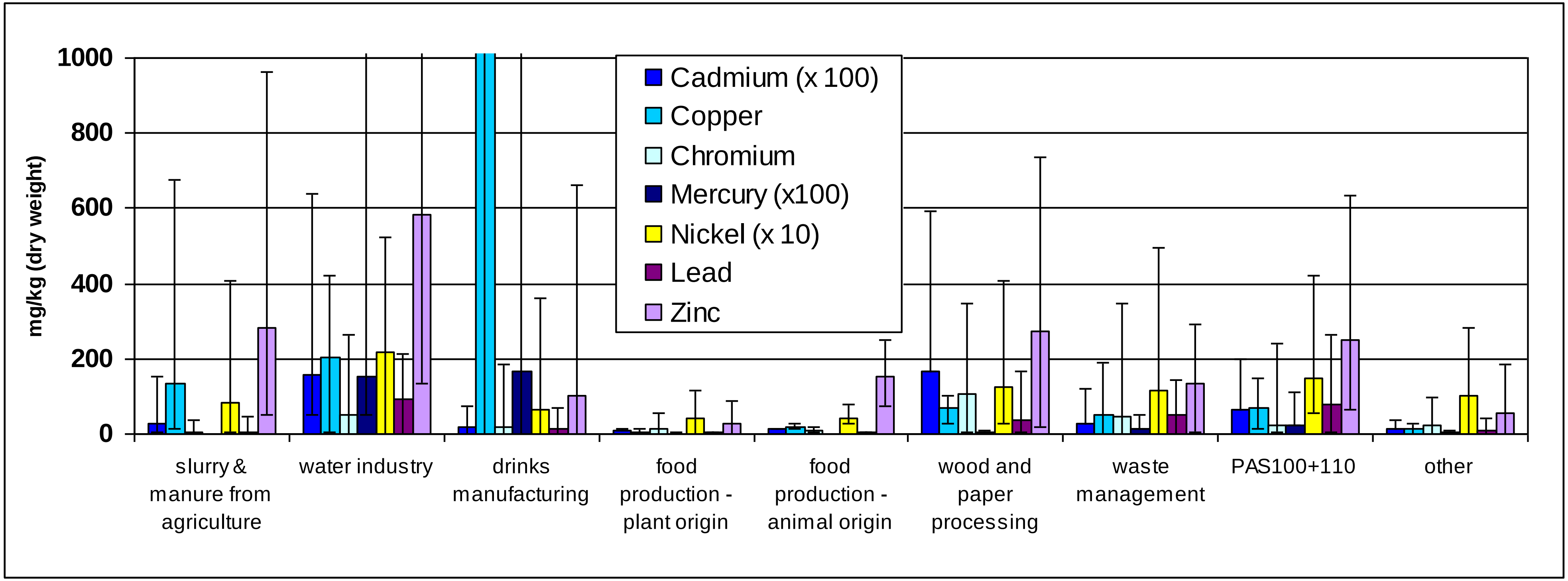

Figure 4.3. PTE concentrations of organic materials from different economic sectors[5]. Whiskers show maximum and minimum values. Where no bars are present no data are available.

[5] Data source: all paragraph 7 waste exemption applications in Scotland for 2010, all sludge registers for 2010, WRAP(2011) report for slurry & manure from agriculture, PAS100 compost and PAS110 digestate.

4.25. Materials from some industrial processes may contain potentially toxic organic substances including chloroform, toluenes, phenols, polyaromatic hydrocarbons, endocrine disrupting chemicals, surfactants from detergents, pharmaceuticals or pesticides. Fungicides and bactericides are likely to be present in paper wastes, whereas manures and slurries are likely to contain veterinary medicines, such as antibiotics.

4.26. SEPA research project EP1302 ‘Assessment of Soil Quality and Human Health from Organic Contaminants in Materials Commonly Spread on Land’ used a modelling approach to estimate the relative risks to the environment and human health from organic substances in materials spread to land in Scotland. The study found that veterinary medicines represent the greatest general risk to the environment. Their application load is high as their concentrations are highest in manures and slurries, which are the organic materials spread to land in greatest amounts. Modelled results from a preliminary human health assessment found that the risk from dioxins in organic materials spread to land is likely to be minimal as amounts of substances that contain significant amounts of dioxins that are spread to land is small. However caution must be exercised in interpreting results such as these, which are based on modelled concentrations and literature values, rather than direct measurement of organic contaminants in materials spread to land.

<u>Acidification and salinisation</u>

4.27. Spreading organic materials which have a high level of salinity or acidity can affect soil structure and nutrient and pollutant retention in soils. Some organic materials can have pH values of 4 and below. The resulting acid conditions can potentially impact on agricultural productivity through restricting the availability of major nutrients to plants, with possible side effects including increasing the potential for nutrient and PTE leaching and crop scorching.

4.28. The extent of impact and the timescale over which acidification impacts on soil quality can be reduced by management practises such as liming.

<u>Over-application of nutrients (especially nitrogen and phosphorous)</u>.

4.29. The application rate of nutrients in organic materials seldom matches the nutrient needs of the growing crop. In addition, perceived lack of control over the amount spread and the spread pattern achieved, as well as lack of awareness of the nutrient value, reduce the confidence of farmers in the use of organic materials and can lead to insufficient allowance being made for the contribution of organic materials to crop fertiliser requirements. This poses a risk of over-application of one or more nutrients.

4.30. Excess nutrients can reach watercourses through surface run-off, transfer via field drains or leaching. In particular, excess phosphorous in surface waters can lead to the formation of algal blooms, which in severe cases can be toxic to humans, livestock and fish. In addition, nitrogen can also be lost to the atmosphere (see sections 4.36 – 4.39).

4.31. This risk is likely to be higher where large amounts of material are spread, which is more often the case for ecological improvement of non-agricultural land then for agriculture benefit of agricultural land. However, good practise in managing the spreading of organic materials can reduce this risk and the threat to the wider environment that this poses.

Lock-up of nutrients

4.32. Spreading organic materials with a high carbon to nitrogen (C:N) ratio may impair crop growth because soil microbial biomass growth will be stimulated by the carbon addition, and with limited extra nitrogen, this will lock-up (immobilise) nitrogen that is already in the soil. Plants are less effective at competing for nitrogen than soil microbes, and therefore crop growth will be reduced.

4.33. Spreading organic materials with high pH on a soil where pH is already high can lead to trace nutrients being locked-up, which will impair crop growth and/or the productivity of animals grazing or consuming fodder or silage crops grown on that land.

Pathogens

4.34. Blood or faecal-containing materials such as manure, abattoir waste or sewage sludge can contain high levels of pathogens posing potential risk to animal and human health. Requirements for treatment and some cropping restrictions reduce pathogen risks associated with abattoir waste and sewage sludge (see The Animal By-Products (Enforcement) (Scotland) Regulations 2011 for abattoir waste treatment requirements; see the 1989 Regulations for sewage sludge requirements. However, slurry and manures are normally applied to land in even larger quantities and without any treatment or land use restriction, although the PEPFAA code should be followed.

4.35. Potential impacts on plant health may result from spreading plant diseases via materials of plant origin; even commercial composting at high temperatures may not kill all plant diseases, especially those caused by fungi. Potato cyst nematode survives certain sewage treatment processes and can pass through animal guts, which poses a risk to crops where sewage sludge is applied to land or animals are fed on contaminated materials.

Gaseous emissions

4.36. Spreading organic materials on land may result in the release of various gases, including ammonia, methane and nitrous oxide to the atmosphere. The extent of release depends on the type of organic material and the timing and method of application; emissions may also occur during handling and storage.

4.37. Air emissions from the spreading of organic waste on land do not have significant direct effects on human health. There are, however, significant concerns about the indirect effects associated with the formation of secondary air pollutants, such as ground-level ozone and secondary particulate matter.

4.38. In terms of air quality, the most environmentally significant emission from organic materials applied to land is ammonia. Ammonia emissions are mainly derived from spreading manures and slurries but also from sewage sludge with low dry matter content. Impacts of its deposition on the environment include

- soil acidification;
- nitrogen deposition and resulting eutrophication in nearby N- sensitive habitats; and
- creation of particulates through chemical reactions in the atmosphere.

4.39. Methane and nitrous oxide are potent greenhouse gases, 25 and 300 times more potent than carbon dioxide, respectively. Nitrous oxide arises from bacterial nitrification, or denitrification of nitrogen applied to the soil in excess of plant requirements. Denitrification in heavy textured soils during wet conditions is the main source of nitrous oxide emissions, but nitrification in lighter textured soils in drier conditions can also produce nitrous oxide.

<u>Oxygen depletion caused by high biochemical or chemical oxygen demand</u>

4.40. Organic materials with a high biological oxygen demand (BOD) or chemical oxygen demand (COD), such as slurries and materials from some sectors of the food and drink industry (Fig. 4.1), can give rise to temporary anaerobic conditions within soils leading to poor plant growth and increased nitrous oxide emission. In addition, if such materials enter watercourses their breakdown by micro-organisms depletes available oxygen in the water, which will result in the death of aquatic animals, including fish and fish eggs.

<u>Odour</u>

4.41. Several organic materials are associated with odour problems; in particular abattoir stomach content, molasses waste, anaerobic paper crumble, liquid sewage sludge and pig slurry. These materials contain high levels of odorous volatile substances that are released to the atmosphere during and shortly after application to land. Although typically a short-lived problem, odour can travel long distances, cause nuisance and distress to the public and may be associated with impacts on human health.

Table 4.2. A summary of the potential risks associated with spreading organic materials to land (++ significant potential risk; + risk; ( ) refers only to some material types)

	Duration of risk	Manures and slurries from agriculture	Water industry	Drinks manu-facturing	Waste manage-ment	Food production	Wood and paper processing
Accumulation of PTE	persistent	+ (Cu, Zn)	++ (potentially all PTE)	(++) (Cu)	+ (potentially all PTE)	(+) (potentially Zn)	+ (most PTE)
Organic contaminants	mid-term to persistent	+	++				+
Climate change	Long-term	(+)	(++)				
Nutrient over-application	long-term	++	++		+		
Nutrient lock-up	mid-term		(+)				+
Pathogens	mid-term	++	(++) (varies with treatment)		++	++ (mainly plant related)	
Air quality	mid-term	(++)	(++)	(++)	(++)		
Odour	short-term	++	++		++	++	(+)
Anaerobic conditions	short-term	(++)	+	(+)	(+)	+	
Acidification	long-term but can be managed			(++)		+	+

Summary

4.42. Risks from applying organic materials to soils are listed in Table 4.2. The greatest risks posed by applying organic materials to soils are likely to come from the same materials that potentially provide the highest benefits:

- water industry sludge; and
- agricultural manures and slurries.

5. Evidence of impacts on soil

5.1. This section considers the actual impact of organic material application to agricultural soils only under the 1989 Regulations and the 2011 Regulations, and is based on analysis of soil data provided by operators and results from SEPA's own soil compliance monitoring. No soil data is available for farm manures and slurries. Information on reported pollution incidents and impacts upon the water environment is also included.

5.2. This section only includes evidence of impacts of organic material spreading on soils. It is recognised that organic material spreading may benefit crop growth through other means, however these are not included in this report as the relevant data were not considered as part of this review.

5.3. Annex IV provides more details of the sampling regimes. Some additional data showing impacts on soil parameters from organic material spreading are shown in Annex V.

Data source and analysis

Operator data

5.4. Soil analysis data from sewage sludge registers provided by waste water treatment works operators and paragraph 7 exemption submissions from major waste operators between 2007 and 2010 were analysed.

5.5. Sufficient data to allow a reasonable overall assessment of the impact of organic material spreading on soil quality indicators is available for distillery production residues, paper crumble and sewage sludge. The analysis is based on 310 fields where distillery production residues had been spread, 25 fields where paper crumble had been spread and 76 fields where sewage sludge had been spread across Scotland.

5.6. For the operator data, it was only possible to compare a limited range of soil properties (see Table 5.1) as the analytical data supplied is tailored to meet the requirements of the 1989 Regulations and the 2011 Regulations.

Table 5.1: Data available for different organic materials

	Distillery production residue	Paper crumble	Sewage sludge
PTE	✓		✓
pH	✓	✓	✓
Phosphorus	✓	✓	

SEPA soil compliance monitoring data

5.7. Since 2007 SEPA has carried out risk-based soil compliance monitoring to allow the effects of organic material application on soil quality indicators to be monitored, and compliance with the soil limit values set out in the 1989 Regulations to be audited. For further details see Annex IV.

5.8. Over the period 2007 to 2011 SEPA sampled a total of 287 fields subject to applications of organic material under exemptions (the 2011 Regulations or the 2003 Regulations) or the 1989 Regulations and 86 reference fields. To put the scale of SEPA sampling into context, for sewage sludge approximately 2% of fields to which Scottish Water applied sludge over the five years were sampled.

5.9. The SEPA monitoring programme includes the following chemical soil quality indicators for all soil samples:

- pH;
- extractable nutrients (phosphorus, potassium and magnesium);
- total carbon and nitrogen
- total PTE (cadmium, chromium, copper, mercury, nickel, lead, zinc).

Data analysis

5.10. Operators must carry out soil analyses for land where they wish to spread organic material under either a paragraph 7 exemption (the 2011 Regulations) or the 1989 Regulations. These analyses are repeated, typically at intervals of around 3 – 5 years, if the material spreading activity continues at the same location. The data analysis within in this report is based on the results for those fields where at least two separate soil analyses were available. The previous soil analysis was regarded as “before spreading” and the more recent soil analysis as “after spreading”. This allows assessment of the change in soil properties in a given field over time, however the “before spreading” data set might contain fields that had been spread with waste in the past.

5.11. SEPA’s sampling programme compares reference fields where no waste has been spread in recent years with fields where waste has been spread under a paragraph 7 exemption (the 2011 Regulations) or the 1989 Regulations. This does not allow for a direct comparison but ensures reference fields were not spread with waste.

5.12. The student t-test was used to establish whether differences between before and after spreading for operator data and between spread and reference fields for SEPA data were significant.

5.13. The 1989 Regulations require that sewage sludge is not spread on fields with soil pH below 5 and also specify the maximum allowable soil concentrations for certain PTE (Table 5.2), which have been developed taking human, farm animal and crop health into account. These standards have also been used by SEPA to assess soil condition at sites where other wastes are to be applied although under these circumstances they are not legally enforceable.

Table 5.2. Regulatory limits for PTE concentrations in soils receiving sewage sludge applications (taken from the 1989 Regulations).

PTE	Limit according to soil pH			
	5.0<5.5	5.5<6.0	6.0<7.0	>7.0
Zinc (mg/kg)	200	250	300	450
Copper (mg/kg)	80	100	135	200
Nickel (mg/kg)	50	60	75	110
	At pH 5.0 and above			
Lead (mg/kg)	300			
Cadmium (mg/kg)	3			
Mercury (mg/kg)	1			

Changes in soil chemical properties

Potentially toxic elements (PTE).

5.14. For sewage sludge, analysis of both SEPA and operator data showed no evidence of a general increase in soil PTE concentrations as a result of spreading (Annex V, Fig. A5.1). A very small proportion of soils containing PTE concentrations close to or in excess of the 1989 Regulations limits were identified in both operator and SEPA datasets (Annex V; Tables A5.1 and A5.2). The reference fields that contain soil PTE concentrations close to or in excess of the 1989 Regulations limits demonstrate that background concentrations in soil may be high due to either natural factors or land management practises that are not associated with sewage sludge spreading. In particular, soils formed from a basaltic parent material may naturally contain nickel concentrations close to or in excess of the 1989 Regulations limit.

5.15. Copper (Cu) and zinc (Zn) concentrations in soil were slightly but statistically significantly higher after distillery production residue spreading than before spreading (Operator data; see Fig. 5.1a). This suggests that distillery production residue spreading may lead to increases in Cu and Zn concentrations in soil. In areas where background Cu and Zn concentrations in soils are low, this may benefit agricultural production by contributing to a reduction in trace nutrient deficiencies.

5.16. SEPA data (Fig. 5.1b) show that Cu concentrations were slightly higher in fields spread with distillery production residue than reference fields, although this difference was not statistically significant. Concentrations of Zn were slightly lower in spread fields than reference fields, although the difference was not significant. These results are based on a much smaller dataset (45 spread fields and 17 reference fields) than the ‘before’ and ‘after’ data supplied by operators (308 fields).

5.17. The 1989 Regulations do not apply in the case of distillery production residue spreading, so the maximum limits for Cu and Zn from those regulations (Table 5.1) are not relevant as mandatory standards, however, they provide SEPA with useful guideline values. No reference soils contained Cu or Zn close to or in excess of these guideline values, nor did any fields prior to spreading. Less than 5 % of sites to which distillery production residue were spread did contain Cu or Zn close to or in excess of these guideline values (Annex V, Tables A5.3 and A5.4).

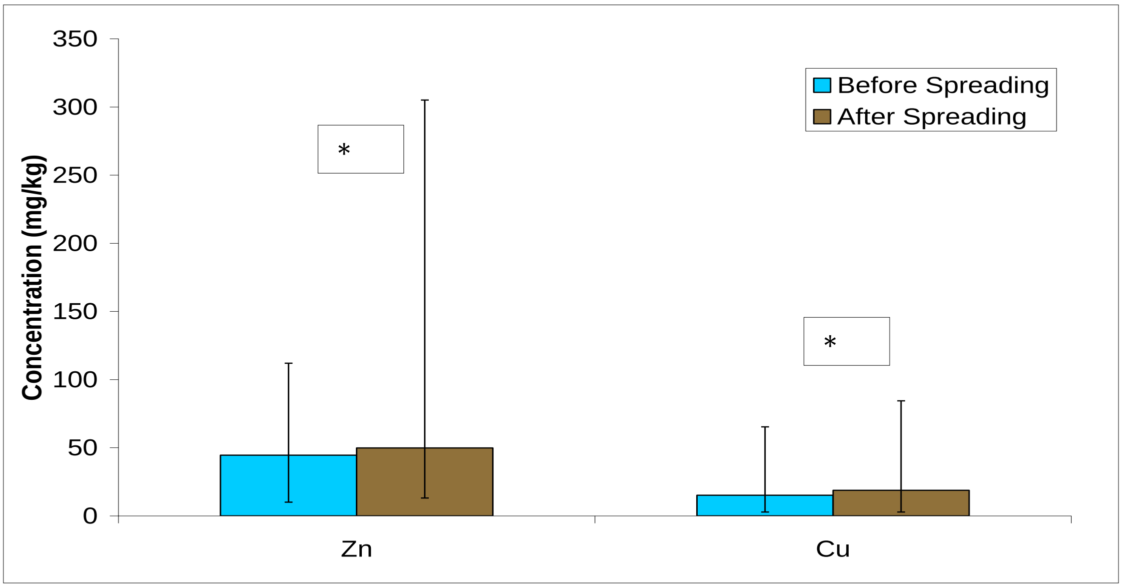

Figure 5.1a. Average zinc and copper concentrations in fields receiving distillery production residue, before and after spreading (operator data). The whiskers show maximum and minimum concentration. Where "*" is shown the concentration is significantly different at p < 0.005 level. Number of fields = 308.

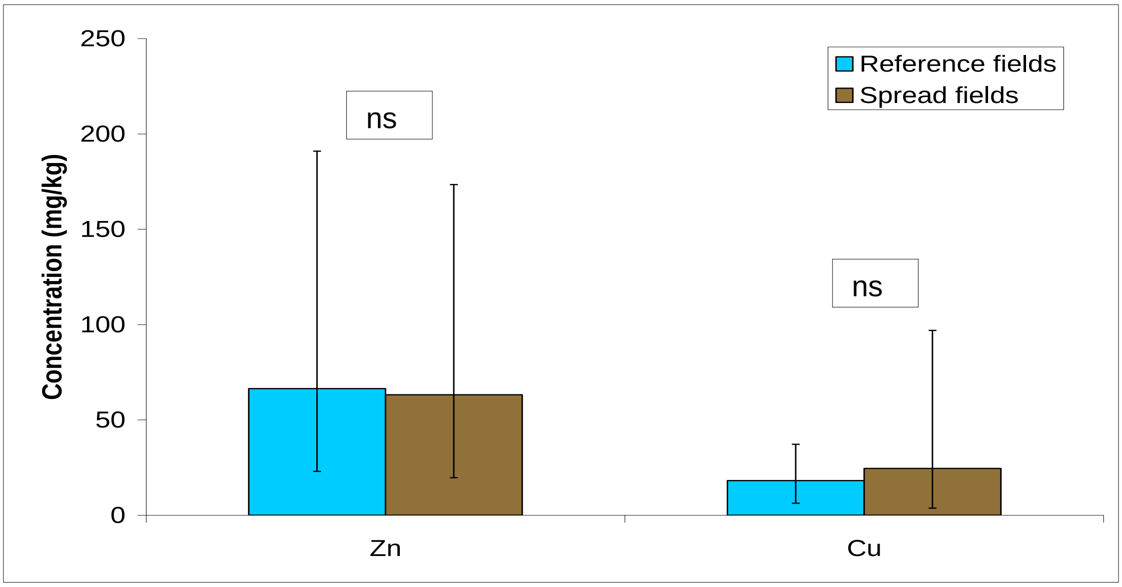

Figure 5.1b. Average zinc and copper concentrations in fields receiving distillery production residue in comparison with reference fields (SEPA data). The whiskers show maximum and minimum concentration. Where "ns" is shown the concentration is not significantly different at p < 0.005 level. Number of spread fields sampled = 45, number of reference fields sampled = 17.

5.18. Numbers of fields spread with paper crumble that have been sampled as part of the SEPA soil compliance monitoring campaign to date have been small. None were found to contain PTE concentrations near to or in excess of the 1989 Regulations limits.

Acidity

5.19. Fields spread with sewage sludge had higher average soil pH and fewer instances of pH close to the 1989 Regulations limits than the same fields prior to spreading (operator data; Annex V, Table A5.1) or the corresponding reference fields (SEPA data; Annex V, Table A5.2). This is possibly because much of the sewage sludge spread to agricultural land in Scotland is lime stabilised, with a pH generally ranging between 9 and 11, and therefore increases soil pH after spreading.

5.20. Many fields spread with distillery production residue have low soil pH with over 30% being in the range 5.0 - 5.5 in both the SEPA and operator data. However, there is no evidence from the operator data (Annex V, Table A5.3) or SEPA data (Annex V, Table A5.4) that these low soil pH values are a result of distillery production residue spreading since before and after spreading as well as reference and spread soils show no difference. It is more likely that this reflects the general low pH of soils in Scotland, particularly areas where distillery production residue spreading takes place, which are often upland areas with acidic soils.

5.21. Operator data clearly demonstrates that soil pH in fields after paper crumble spreading is significantly higher than before spreading (Annex V, Fig. A5.6), providing evidence that paper crumble spreading is having a liming effect on soil.

Nutrients - phosphorus

5.22. For distillery production residues, SEPA data suggests that spreading may increase soil extractable phosphorus concentration, at least in the short term. Figure 5.2 shows that a greater proportion of fields spread with distillery production residues had soil with ‘high’ phosphorus index, and a smaller proportion ‘low’ or ‘very low’ phosphorus index than reference fields.

5.23. However, SEPA analysis of the operator data showed that average extractable phosphorous concentration in soil after spreading was statistically significantly lower than before. This probably reflects a general downward trend in extractable phosphorus concentration in Scottish soils that was noted by Sinclair et al. (2011) since the operator data are based on results from different years. General trends in phosphorus concentration in Scottish soils over time does not affect SEPA data since samples are taken on the same day from reference fields and fields on which organic material was spread.

5.24. For sewage sludge no difference in extractable phosphorus concentrations between reference fields and spread fields could be detected from SEPA data; and no comparison could be made for extractable phosphorus in soils before and after sewage sludge spreading as no data was available for this (Table 5.1).

5.25. Figure 5.2 indicates that up to 15% of fields to which sewage sludge is applied and 10% of fields to which distillery production residues are applied already contain high or very high levels of soil phosphorous.

5.26. No significant changes in soil phosphate concentrations could be detected as a result of spreading with paper crumble.

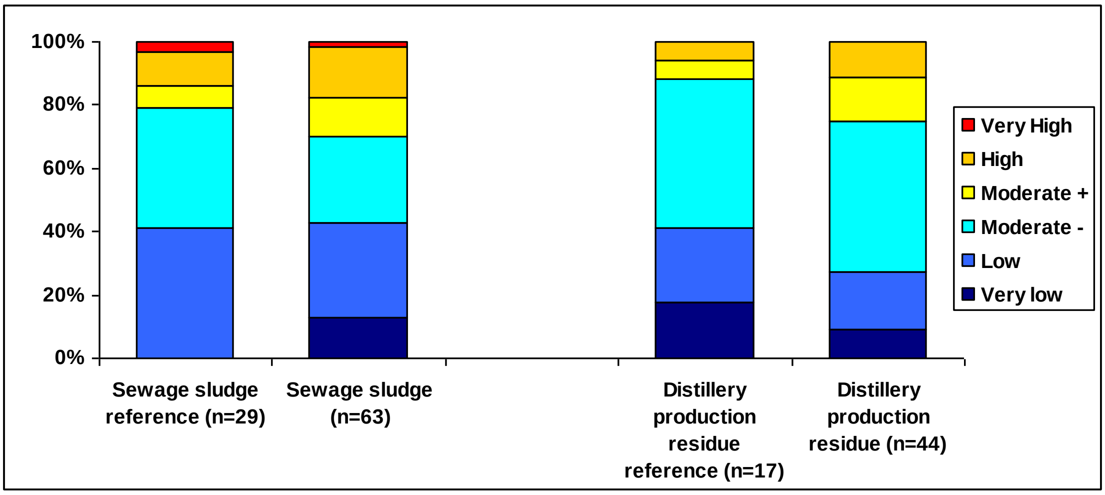

Figure 5.2. Comparison of percentage of fields with different SAC extractable soil phosphorus indices in all fields sampled as part of SEPA's soil compliance monitoring, fields spread with sewage sludge and distillery production residue and reference fields at the same farms (n = number of fields sampled).

Changes in soil biology

Sources of data

5.27. SEPA's soil compliance monitoring includes an assessment of microbial biomass and earthworm abundance and biomass on reference fields and fields to which sewage sludge and distillery production residue are applied.

5.28. In general microbial biomass and earthworm abundance and biomass would be expected to increase as a result of spreading organic materials because the added organic matter provides food for soil organisms. Soil organic matter content is highly dependent on land use, therefore the analysis is performed separately for three land use categories: arable; rotational grassland; and permanent grassland.

5.29. Samples for microbial biomass carbon have been taken from a total of 72 reference fields and 187 fields to which sewage sludge or distillery production residues were applied. Samples for earthworms have been taken from a total of 41 reference fields and 85 fields to which sewage sludge or distillery production residues were applied.

Microbial biomass

5.30. There is a clear land use effect regarding microbial biomass concentrations in soils, which is much greater than any effect from waste application. No statistical significant differences were found between reference field and fields receiving sewage sludge or distillery production residue (Fig. 5.3, Annex V Figures A5.2 and A5.4).

Earthworm abundance and biomass

5.31. As with microbial biomass, earthworm abundance and biomass are affected by land use. The spreading sewage sludge or distillery production residue does not result in significant changes (Fig. 5.4, Annex V Figures A5.3 and A5.5) indicating neither positive nor negative overall impact.

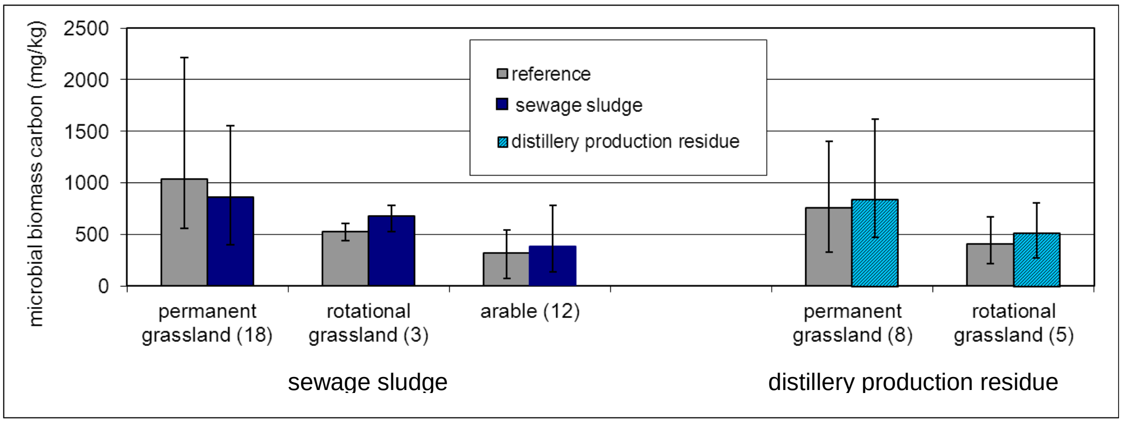

Figure 5.3. Average microbial biomass carbon in fields receiving sewage sludge or distillery production residue and reference fields under the same land use. The whiskers show maximum and minimum concentration. The number in brackets is the number of farms sampled.

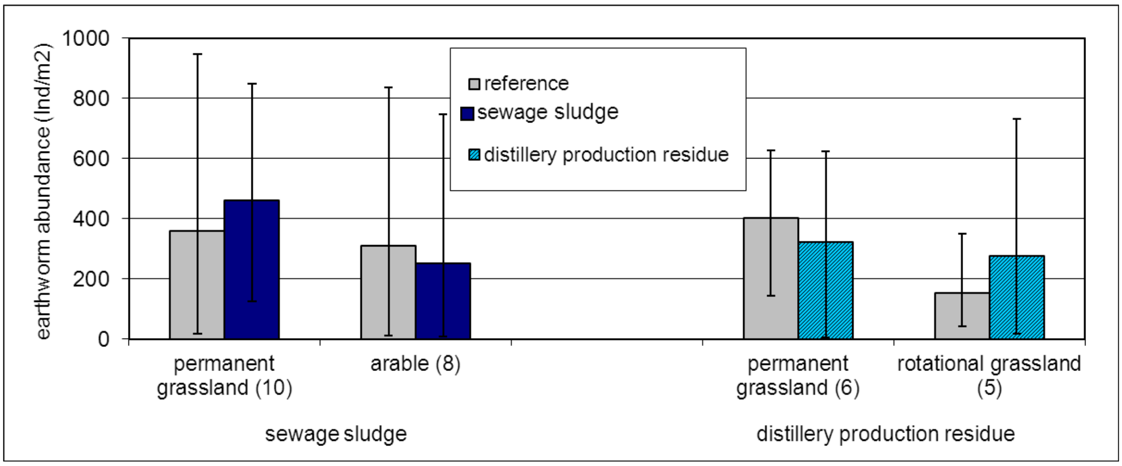

Figure 5.4. Average earthworm abundance of fields receiving sewage sludge and reference fields under the same land use. The whiskers show maximum and minimum abundance. The number in brackets is the number of farms sampled.

6. Evidence of wider environmental impacts

Impacts upon water

6.1. SEPA monitors the condition of groundwater and surface water. The single largest cause of pollution is agricultural diffuse pollution. This is associated with contamination of water with nutrients, pesticides and sediments. Nutrient loss from soils where nutrient application is in excess of plant requirement is one of the most serious problems affecting the water environment with impacts upon:

- 15% of groundwater;
- 13% of rivers;
- 10% of lochs; and
- 5% of estuaries.

6.2. The consequence of nutrient pollution of the water environment is degraded ecology status, reduced fisheries, damage to the recreation potential of rivers and additional costs for industrial and drinking water treatment.

6.3. The application of inorganic fertilisers and slurries and manures in excess of crop requirements is the primary cause of diffuse pollution. Other organic materials may contribute to the problem if they are applied to fields where nutrient levels are already high. Figure 5.2 indicates that up to 15% of fields to which sewage sludge is applied already contain high or very high levels of soil phosphorous.

Impacts upon climate and air

6.4. SEPA has not been able to collect evidence of the impacts of organic material spreading on air pollution or the production of greenhouse gasses in Scotland.

Impacts upon climate

6.5. It is recognised that organic material application to land may result in emissions of greenhouse gases (nitrous oxide and methane), however these emissions are difficult to quantify and vary over time and space. SEPA currently do not have any data on this.

6.6. Application of organic materials to land has the potential to increase the carbon stock of Scottish soils at a time when there is evidence that soils may be losing carbon at rates hitherto unforeseen. As a general objective, the principles of this approach are sound, but this effect is highly dependent on land use and land management, and therefore is difficult to quantify.

Impacts upon air quality

6.7. Air emissions from the spreading of organic materials on land probably have limited direct effects on human health. However, indirect effects associated with the formation of secondary air pollutants, such as ground-level ozone and secondary particulate matter, may require further consideration in this respect.

Ammonia

6.8. The main source of ammonia emissions in the UK is livestock slurry and manure management, which was estimated to represent 68% of total ammonia emissions in Scotland in 2010 (NAEI, 2011). Slurry, manure and other organic material spreading to land may have the potential to impact locally upon designated nature conservation sites, but data on precise impacts is limited.

6.9. The amount of ammonia emitted depends on the type of organic material, as well as the timing and method of application (SEPA, 1998). Following application to land, the rate of emissions of ammonia may be high for a few hours, but then rapidly declines to lower levels, which may then continue for several days (Pain, 1998).

Particulate matter

6.10. Due to reactions with other molecules in the atmosphere, for example sulphur dioxide, oxides of nitrogen and organic aerosols, ammonia acts as a precursor to particulate matter (PM) emissions and therefore indirectly contributes to related health impacts. According to the World Health

Organisation (WHO), PM emissions affect more people than any other pollutant (WHO, 2012).

Ground-level / tropospheric ozone

6.11. Ground-level ozone is formed in the atmosphere through reactions of pollutant precursors including oxides of nitrogen and methane, which may be emitted during organic material spreading. Several European studies have reported impacts on human health associated with an increase in ground-level ozone exposure. Ground-level ozone also causes harm to habitats and is a significant greenhouse gas. The impact of organic material spreading in Scotland on ground-level ozone concentrations is unknown.

Environmental incidents

6.12. SEPA records the number and type of incidents which are investigated each year. Over the four years from 2008 to 2011, SEPA investigated some 20,000 events.

6.13. Local authorities also receive complaints from the public (especially associated with nuisance: smell, noise, visual impacts). The Local Authority figures for complaints associated with materials applied to land are not currently available.

Organic materials spread to land

6.14. A total of 113 incidents reported to SEPA were associated with the spreading of organic material onto land across Scotland between 2008 and 2011. Six of these incidents were described as "significant". The largest number of reported incidents were associated with the spreading of agricultural slurries and manures (Fig. 6.1; 82 complaints were recorded of which 5 were recorded as significant).

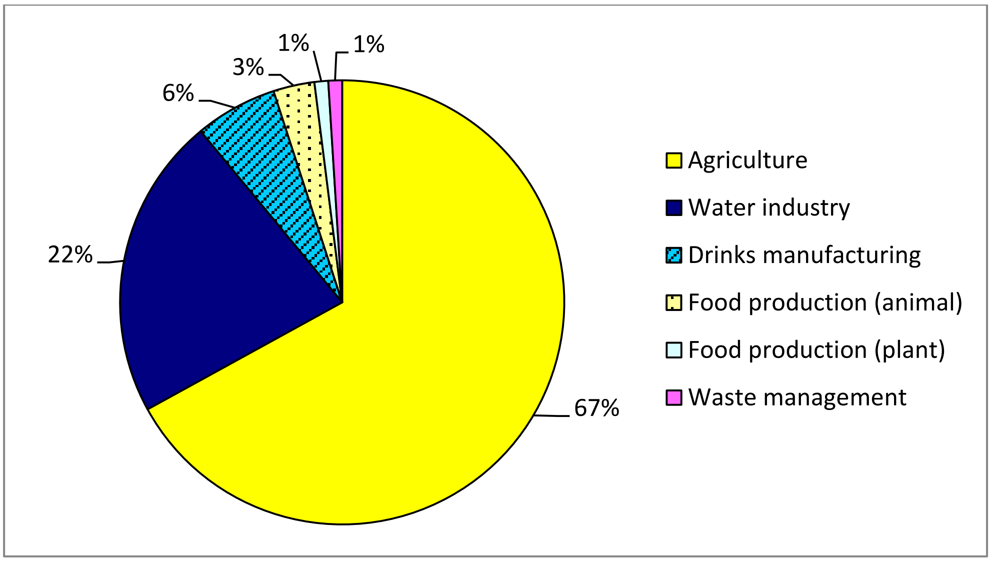

Figure 6.1. Proportion of complaints connected with different organic materials spread to land, organised by economic sector (total number 113).

Organic material spread to land under the 1989 or the 2011 Regulations only

6.15. If only looking at materials applied to land under the1989 Regulations or the 2011 Regulations, thus excluding agricultural slurries and manures and PAS100 compost, a total of 38 incidents recorded were associated with the spreading of organic material onto land. Only one of these incidents was described as “significant”. The largest number of reported incidents was associated with the spreading of sewage sludge (26) generated by the Water Industry (Fig. 6.2).

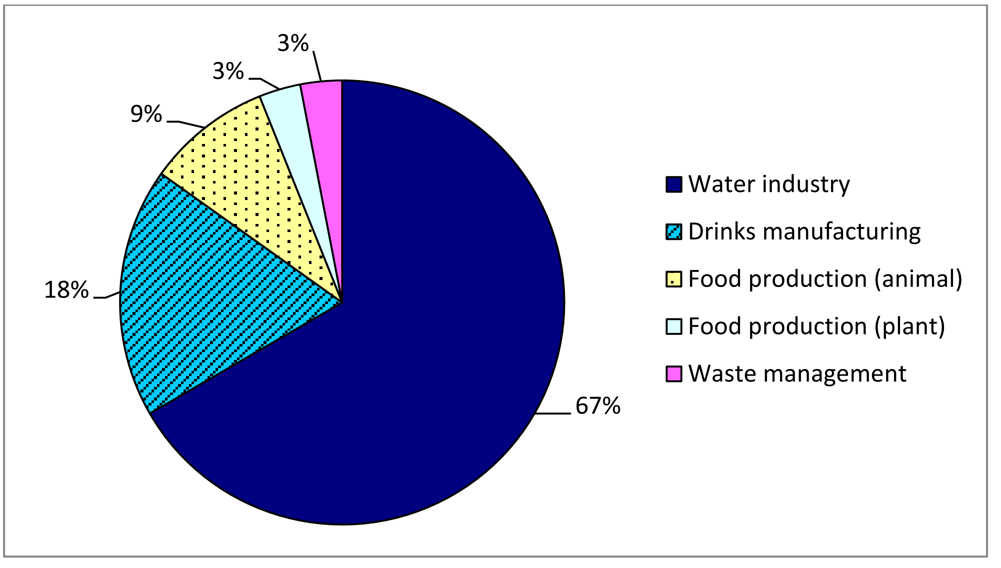

Figure 6.2. Proportion of complaints connected with different organic materials spread to land under the 1989 Regulations or the 2011 Regulations, organised by economic sector (total number 38).

7. Key findings and conclusions

7.1 The key conclusions from the assessment of the impacts of organic materials spread to land in chapters 5 and 6 are outlined below.

Key Findings

Impacts upon soil

Key finding 1

7.2 Soil quality indicator data available to SEPA has not identified any major benefits to, or adverse impacts upon, soil resulting from the application of organic material spread to agricultural land under the 1989 Regulations or the 2011 Regulations.

7.3 Data have been collected on soil quality indicators at sites where organic materials have been applied to land under the 2011 Regulations or the 1989 Regulations. These data have been obtained through SEPA’s own soil sampling and from operator soil analysis. No major overall impacts on soil quality have been determined from either dataset for agricultural land. However it is recognised that organic material spreading may benefit crop growth through other means, which were not considered in this report as they are not directly monitored or measured by SEPA.

7.4 No analysis was possible for non-agricultural land because SEPA has little data on non-agricultural soils. However, there is published research demonstrating that there can be significant benefits, particularly on sites with heavily degraded soils resulting from previous industrial use. Despite the accepted benefits, the quantities applied need to be carefully controlled as there are environmental risks associated with high levels of application.

Wider environmental impacts

Key finding 2

7.5 Excessive application of organic materials to land, especially those that contain large quantities of available nutrients (e.g. manures and slurries), wrong timing of application, or unsuitable application technique contribute to loss of nutrients from soil resulting in water pollution.

7.6 The pollution of water, and greenhouse gas emissions caused by nutrients lost from land has serious environmental and socio-economic consequences. The bulk of nutrients added to soil come from the agricultural application of inorganic fertilisers, slurry and manures. The application of regulated organic materials to land may contribute to this problem if they are applied to soils which already have nutrient concentrations in excess of crop requirements, or are applied in such large quantities that crop requirements are exceeded. On the other hand, good practise in the management of fertilisers and organic materials can greatly reduce this threat and its impacts.

Key finding 3

7.7 A relatively small number of environmental incidents are caused by the application of organic material to land.

7.8 There were only 113 pollution incidents over the period from 2008-2011 where adverse consequences from applying organic materials (including manure and slurry) to land led to public complaint or were identified by SEPA as a pollution incident. Only six of these incidents were recorded as “significant”. This represents only 0.03% of the overall total of 20,000 pollution incidents recorded by SEPA over this period. It is also a small number of complaints in comparison to the total number of occurrences of organic material spreading to land.

Monitoring and standards

Key finding 4

7.9 Limitations in the data available to SEPA impose constraints on the conclusions which can be reached about how the environment is affected by the application of organic materials to land.

7.10 Manures and slurries are the organic materials that are most frequently spread to land in Scotland; however, there is no requirement for impacts on soil associated with spreading these materials to be monitored. The same applies to PAS100 compost and PAS110 anaerobic digestate.

7.11 The risk of loss of nutrients from soils resulting in the pollution of surface and ground water has been identified by this report as being a more important environmental impact than previously recognised. However, good management of organic material spreading to land minimises this risk. SEPA do not monitor nutrient concentrations in any organic material applied to land, although data supplied by operators typically contains analyses for total nitrogen and total phosphorus.

7.12 Monitoring of contaminants in material applied to land has focused on potential toxic elements (metals). However, there is a need to increase understanding of other contaminants such as pesticides and pharmaceutical products.

7.13 There is currently no required monitoring of greenhouse gas emissions associated with organic material applied to land nor is their potential to contribute to air pollution assessed.

7.14 Possible impacts from application of organic material to non-agricultural land should be investigated further as application rates are generally thought to be much higher than those for agricultural land.

Key finding 5

7.15 The absence of soil standards makes it difficult to assess the impacts upon soil of potential contaminants introduced by the application of organic material applied to land.

7.16 In order to develop appropriate soil standards, it will first be necessary to define what constitutes ‘good quality soil’. It should be noted that whether or not a soil is ‘good quality’ is likely to be dependent on the function(s) that should be performed or ecosystem service(s) that should be provided by the soil in question. A soil that is good quality for agriculture will not necessarily be good quality for nature conservation, for example.

Key finding 6

7.17 The regulatory limits set out for PTE in the 1989 Regulations help SEPA regulate the application of sewage sludge. It is recommended that similar limits be developed for all types of organic material applied to land that are covered by the 2011 Regulations.

Conclusions

7.18 This review has collected together data from a range of different sources. Despite some limitations in this data, the results are reassuring.

7.19 The most important environmental risk identified was the well recognised problem of nutrient loss from soil resulting in water pollution. No new environmentally significant problems were identified, for example, associated with the potentially toxic elements associated with some types of material applied to land.

7.20 We consider that the regulatory regime has successfully protected agricultural soils from the potential harm which could have resulted from the application of controlled wastes and sewage sludge.

7.21 There is scope for change to both existing monitoring and regulatory regimes to improve knowledge of the impact of all organic material application to land on soils and the wider environment and to simplify and improve regulation to offer both increased protection to the environment and reduce regulatory burdens on operators.

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Annex I. Controls over the application of organic materials to land

A regulatory regime has been created to manage the process of applying organic material to land, to prevent environmental harm and to ensure the material is only applied where there is either agricultural benefit or ecological improvement. This includes the use of organic material as part of the process of restoring soils (e.g. after quarrying or open-cast mining).

The approach taken to control organic materials which are to be spread onto land is determined by whether it is classified as waste. The definition of waste is a complex issue which is covered under the definition of waste page of the SEPA website.

<u>Organic materials which are not waste</u>

The application to land of organic materials that are not defined as waste is covered by General Binding Rules[6](GBR) and codes of good practice. Regulatory action can be taken if the GBR or codes are not followed and environmental harm results.

Agricultural animal slurry and manure are the most common materials applied to soil. These are not defined as waste, as long as they are spread to agricultural land for benefit of agriculture, the spreading is carried in compliance with the PEPFAA code and the 4 Point Plan, and the material does not leave the farm it was produced at.

As outlined in the PEPFAA code, every livestock farm should draw up a Manure Management Plan (also known as a Farm Waste Management Plan) to establish the quantities of animal manures produced and the available nutrient content. This should be used to demonstrate that the application of inorganic fertilisers, livestock manures and slurries and non-agricultural wastes matches the nutrient requirements of the rotation and crops being grown.

The PLANET software and the Fertiliser Series Technical Notes, provide detailed information on the nutrient requirements of crops and grass, as well as the fertilising value of different types of manures and slurries and inorganic fertilisers.

Waste materials can cease to be waste if they become a product with a value. An example is compost, which, if it meets the PAS100 criteria, is no longer regarded as waste in Scotland. The PAS 100 criteria ensure that if codes of good practise are followed in spreading the material, this will lead to soil quality benefit and not result in contamination from the most common potentially toxic elements in compost source materials.

<u>Controls over application of waste materials to land (excluding sewage sludge to agricultural land)</u>

The main legislative mechanism for controlling the application of organic materials to land is the Waste Management Licensing (Scotland) Regulations 2011 (the 2011 Regulations). There is a hierarchy of decisions which determine how these regulations are applied.

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[6] Defined under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 which require, amongst other rules, that fertilisers (including slurries and manures) must not be applied to land in excess of the nutrient needs of the crop.

The 2011 Regulations allow for certain activities to be exempt from licensing provided that the spreading is carried out in accordance with the criteria stipulated in the relevant exemption paragraph and no pollution or harm results from the activity. In order to qualify for an exemption, a person must demonstrate that the application of the waste will deliver a benefit. This requires the submission of a certificate describing how the treatment will result in benefit to agriculture or ecological improvement prepared by or based on advice from a person with appropriate technical or professional expertise. This certificate must be supported by an analysis of the waste and the soil to which the waste is to be applied.

The 2011 Regulations cover most wastes applied to land, including organic material from paper mills, food and drinks industry. Sewage sludge applied to non-agricultural land and excess peat and forest residue that result from a development can also fall within their scope. The objective of the Regulations are to prevent the application of organic materials to land in unsuitable circumstances and so prevent the activity giving rise to water pollution, offensive odours or contamination of the soil.

A licence to apply waste to land is required if the material is to be added in excess of the thresholds for each exemption, as defined in the 2011 Regulations. There are very few examples of licence applications for the application of waste to land.

Controls over application of sewage sludge to agricultural land

Use of sewage sludge on agricultural land is controlled by the 1989 Regulations, which control the addition to soil of potentially toxic elements (PTE) and restrict the planting, grazing and harvesting of certain crops following the application of sludge. The statutory controls on the application of sewage sludge to agricultural land must be complied with in order to be eligible for the Single Farm Payment. Before spreading to agricultural land, sludge producers (in Scotland this generally means Scottish Water and PFI operators or their contractors) are required to analyse both sludge and soils. Sludge must subsequently be re-analysed at least once every 6 months or after any event which causes a change in the characteristics of the wastewater being treated. Soils must be reanalysed within 20 years of them having first been tested as specified in the 1989 Regulations. Sludge producers are also required to maintain detailed records of applications of all sludge to agricultural land, including accurate information on the location spread, the amount spread and the date on which it was spread. These records must be submitted to SEPA on an annual basis.

The Safe Sludge Matrix (an agreement between the UK water industry and the British Retail Consortium on sludge use) should also be followed. The Matrix does not allow raw or untreated sewage sludge to be used on agricultural land for food production. Undigested sludge or septic tank sludge should therefore not be used on land used for food crops.

Additional controls

The spreading of waste derived from imported agricultural or horticultural produce on to arable land is controlled by the Plant Health (Great Britain) Order 1993 and The Potatoes Originating in Egypt (Scotland) Regulations 2001. These regulations control the risk of introducing pests and diseases, such as potato brown rot, potato ring rot and potato cyst nematode. Guidance on methods to minimise plant health risks by the management of waste from the commercial handling of certain types of plant produce is provided in the Code of Practice for the Management of Agricultural and Horticultural Waste.

The application of animal by-products to land is controlled under the TSE (Scotland) Regulations 2002 (TSE = Transmissible Spongiform Encephalopathies). These regulations ban the use of fertilisers containing mammalian meat and bone meal. The Animal By-Products (Scotland) Regulations 2011 prohibit the land-spreading of unprocessed abattoir waste, including blood.

There are mandatory measures in Nitrate Vulnerable Zones (NVZs) to control the application of nitrogen, which must be followed by all farmers as a Cross Compliance requirement. The rate and timing of the application of nitrogen in both organic materials and inorganic fertilisers must be matched to the nutrient requirements of the crop. If this is exceeded then the operation will be classed as waste disposal rather than fertilisation.

A summary of the legislative requirements is provided in Table A1.1. Further advice can be found on the Net Regs site.

Table A1.1. Summary of the legislative requirements for land-spreading

Landspreading activity	Control
Landspreading agricultural manures and slurries	Agricultural manures and slurries spread to agricultural land for benefit are not considered to be waste providing the spreading is carried in compliance with the PEPFAA code and the 4 Point Plan
Landspreading sewage sludge on agricultural land	Comply with the Sludge (Use in Agriculture) Regulations 1989 as amended
Landspreading sewage sludge on non-agricultural land	Paragraph 8 exemption see Paragraph 8 under Individual paragraph details SEPA Technical Guidance Note
Spreading waste on agricultural land for agricultural benefit or ecological improvement	Paragraph 7 exemption see Paragraph 7 under Individual paragraph details SEPA Technical Guidance Note
Spreading waste on non-agricultural land for ecological improvement	Paragraph 7 exemption see Paragraph 7 under Individual paragraph details SEPA Technical Guidance Note
Spreading waste for reclamation or improvement of land	Paragraph 9 exemption see Paragraph 9 under Individual paragraph details SEPA Technical Guidance Note
Spreading waste on land for “relevant work”	Paragraph 19 exemption see Paragraph 19 under Individual paragraph details SEPA Technical Guidance Note
Spreading pig or poultry ash for agricultural benefit or ecological improvement	Paragraph 50 exemption see Paragraph 50 under Individual paragraph details
Spreading compost	Compost meeting the PAS100 criteria is not regarded as waste and may be spread to land providing it is done for a benefit and no harm or pollution occurs as a result. Compost not meeting PAS100 criteria can be spread under paragraph 7, 9 or 19 exemptions as indicated above. Compost may be created under a Waste Management Licence, a PPC permit or a Paragraph 12 exemption
Spreading any waste in an NVZ	Any spreading in a NVZ must comply with the Nitrate Vulnerable Zones (Scotland) Regulations 2008 (as amended). Guidance covering compliance with the NVZ regulations can be found on the Scottish Government website

Annex II. Tables of quantities of materials applied to land

Organic materials spread on land 2007-2010 (four year average)

Economic sector	Waste	Non-waste	Total
	wet weight (tonnes)		
Agriculture	57,815	15,000,000	15,000,000
Food & drink industry	326,875	0	326,875
Waste management	26,982	167,109	194,092
Water industry	202,692	0	202,692
Other*	12,391	0	12,391
Grand Total	**626.756**	**15,167,109**	**15,793,865**

* Other includes households, wood & paper processing

Non-organic materials spread on land 2007-2010 (four year average[7])

Economic sector	Waste	Non-waste	Total
	wet weight (tonnes)		
Chemical industry	0	1,266,647	1,266,647
Construction	4,506,317	0	4,506,317
Energy industry	359,745	0	359,745
Quarrying	310,558	0	310,558
Waste management	167,338	0	167,338
Grand Total	**5,343,958**	**1,041,647**	**6,385,605**

[7] Data for all sectors is based on a four year average (2007-2010) with the exception of the chemical industry which is based on 2010 data only.

Annex III. Properties of different types of organic materials

This Annex provides further information on the attributes of different types of organic materials which are applied to land.

Slurries and manures from agriculture

Common forms of organic material derived from livestock husbandry are farmyard manure (FYM) and farm slurry (liquid manure). FYM contains plant material (often straw), which has been used as bedding for animals and has absorbed faeces and urine. Slurry is a liquid mixture of manure and water.

There are no systematic surveys of the quality of these materials. Composition and properties are likely to be highly variable, depending on factors such as livestock species, breed and age, diet, production methods and handling systems. Dry matter content and nutrient content can vary considerably between batches (Fig. 4.2).

Manures have high organic matter content and the nutrients are often not readily available, although there are some exceptions to this, e.g. poultry manure typically contains a high proportion of available nitrogen, phosphorus and potassium. Slurries on the other hand contain a high amount of volatile ammonia and readily decomposable organic matter. Both can often contain significant amounts of copper and zinc (Fig. 4.3).

Sewage sludge from water industry

Depending on waste water source and treatment method, sewage sludge composition varies widely. Most sewage sludge has a high nutrient content, especially nitrogen and phosphorous (Fig. 4.2). Some sludges are lime-stabilised: these typically have high pH and liming value. The sludge treatment influences the availability of the nutrients, with the more liquid sludge containing generally more volatile substances and readily available nutrients.

Sewage sludge often has high organic matter content. Concentrations of potentially toxic elements (PTE), especially copper, zinc and lead are often high in sewage sludge (Fig. 4.3). Enhanced sludge treatment usually increases organic matter content but reduces the nutrient, PTE and volatile matter content.

In addition to PTE, more than 300 different persistent organic pollutants (such as polycyclic aromatic hydrocarbons, pharmaceuticals and hormones) have been detected in sewage sludge (EC 2001). Sewage sludge is not routinely analysed for organic pollutants.

Raw sewage sludge contains very high numbers of pathogenic organisms. However sludge spread to agricultural land must be pre-treated to reduce pathogen numbers to safe levels, in accordance with the 1989 Regulations. The 1989 Regulations also place additional restrictions on growing certain crops in fields treated with sewage sludge, in order to further reduce risks associated with pathogens.

Organic residues from drinks manufacturing

In Scotland, this is almost exclusively distillery production residue. Historically, most distillery production residues spread to land originated from malt whisky distillation, which is a batch process and is carried out in copper pot stills. There are three main residues from malt whisky production, draff, pot ale and spent lees, which differ notably in their properties. Draff, the remains of the fermented grain, has a high dry matter and nutrient content, but is generally low in PTE. It is not normally spread to land, as it is a valuable by-product used as cattle feed. Pot ale and spent lees, which are the undistilled component of the fermented mash remaining in stills following a distillation, have a low dry matter and nutrient content, but can contain significant copper and zinc concentrations. These are more frequently spread to land.

Grain whisky production involves continuous distillation in column stills. The residues produced from grain whisky production differ from those produced from malt whisky distillation in both physical and chemical properties, for example they do not contain high copper concentrations as they are not produced in copper pot stills. They are frequently treated by lime-stabilisation. Over the last few years, increasing amounts of these materials have been spread to land.

Distillery production residues are increasingly used in energy recovery via combustion or anaerobic digestion, so the frequency with which 'raw' forms are spread to land in Scotland is likely to decline in the future. Instead, ash or anaerobic digestate may be spread to land. These are likely to have different chemical and physical properties to the 'raw' distillery production residues, resulting in different impacts on soil quality. SEPA will need to investigate these impacts in more detail in the future.

Organic residues from food production

With the exception of plant residues, organic residues from food production have low dry matter content. For example, about 90% of the milk used for cheese-making ends up as whey, a watery residue containing proteins and lactose. Residues from vegetable preparation will consist of plant and soil material diluted by wash waters.

Nutrient and PTE concentrations in food production residue are generally low (Fig 4.2 and Fig 4.3). However some materials have high biological oxygen demand (e.g. treated blood and gut content from abattoirs or residue from potato processing, which has high starch content) (Fig. 4.1) and may contain pests and disease.

Organic residues from wood and paper processing

Organic matter in residues from producing and processing pulp paper consists mainly of short cellulose fibres and lignin wood fibres which are relatively stable substances. These residues often have a high pH and therefore a liming value. However, the nutrient concentrations in these residues are low (Fig 4.2). These materials may contain high concentrations of PTE, especially cadmium, chromium and zinc but also copper and lead (Fig 4.3), and other organic contaminants. Levels of PTE and organic contaminants may be especially high in residues from recycled paper processing.

Organic residues from waste management activities

Organic residues from waste management mainly derive from two treatment streams: aerobic digestion, also called composting, and anaerobic digestion. Although the composition is dependent on the source of the waste stream, some general observations can be made: Anaerobic digestion results generally in more liquid residues whereas composts are always high in dry solids. Both materials usually contain relative high nitrogen contents (Fig. 4.2), with nitrogen in anaerobic digestate being more plant available. PTE concentrations are generally higher in composts than anaerobic digestates.

Annex IV. Source of soil data used for analysis in this paper

Operator data

Soil analysis data from sludge registers provided by waste water treatment works operators and paragraph 7 exemption submissions from major waste operators were analysed. Operators with only one or two exemptions were not included in the analysis, which is why only distillery production residues and paper crumble were analysed in addition to sewage sludge.

Individual fields for which at least two separate soil analyses were available were identified, and it was then determined whether the exempt waste or sewage sludge had been spread between the two analysis dates. Where records showed that spreading had occurred, PTE, pH and nutrient concentration results from before and after spreading were compared in order to determine possible impacts of the spreading on soil concentrations. It was not possible to compare a wider range of soil properties using the operator data as the analytical data supplied is tailored to meet the requirements of the 1989 Regulations and the 2011 Regulations and the analysis performed varies with material type. For locations spread with sewage sludge, data for PTE and pH was available, for locations spread with paper crumble pH and nutrient concentrations were provided and for locations spread with distillery production residues, data for pH, copper, zinc and in some cases total nitrogen was supplied. The student t-test was used to establish whether differences between results before and after spreading where significant.

Overall, suitable results were identified for 310 fields where distillery production residues had been spread, 25 fields where paper crumble had been spread and 76 fields where sewage sludge had been spread across Scotland.

SEPA’s soil compliance monitoring

In 2007, SEPA established a risk-based soil compliance monitoring strategy for SEPA regulated activities[8] to allow the effects of organic material application on soil to be monitored and to audit compliance with the soil limit values set out in the 1989 Regulations for the relevant sites. Sites most at risk of exceeding the 1989 Regulations limits are selected for monitoring each year.

Soil compliance monitoring has been undertaken since 2007, with a gradual expansion in numbers of farms and fields sampled during that period. A further expansion has occurred in 2012 (Table A4.1), however this report only uses data collected up to the end of 2011. To put the scale of SEPA sampling into context, approximately 2 % of fields to which Scottish Water applied sludge over the five years (2007 – 2011) were sampled.

Individual annual soil compliance monitoring reports were published for the years 2007 – 2010. These reports can be accessed from SEPA’s website. A summary of results from 2011 and 2012 are presented in Tables A4.2 – A4.5.

[8] SEPA regulated activities that impact on soil initially considered include the spreading of sewage sludge to agricultural land under the 1989 Regulations and the spreading of exempt waste to agricultural land under the 2011 Regulations.

Table A4.1. Numbers of farms and fields sampled for SEPA's soil compliance monitoring.

	Number of farms sampled			Number of fields sampled			
Year	2011 Regulations	1989 Regulations	Total	2011 Regulations	1989 Regulations	Reference	Total
2007	9	6	15	29	17	14	60
2008	10	6	16	39	21	11	71
2009	11	8	19	34	22	19	75
2010	12	10	22	32	26	21	80
2011	9	13	22	30	37	21	88
2012	14	11	25	44	31	24	99

SEPA's soil compliance monitoring covers all of Scotland. The locations of farms sampled and processes the applied materials derived from are shown in Figure A4.1.

Figure A.4.1. Farms sampled 2007-2012. a) farms receiving sewage sludge b) farms receiving material under paragraph 7 waste management licensing exemptions, from the following processes: ■ Distilling; ⬟ Food processing; ▲ Composting (off-spec); ⍰ Wood/paper processing; ⬢ Anaerobic digestion.

In each field, one representative soil sample[9] is taken and analysed for pH; soil carbon; total nitrogen; extractable phosphorous, potassium and magnesium; total cadmium, chromium, copper, lead, nickel, zinc and mercury; and microbial biomass carbon. In addition, earthworms are sampled in a subset of fields. More details of sampling methods used may be found in SEPA (2008). Results from fields spread with waste materials are usually compared and contrasted with reference fields, which are nearby fields that have similar soil types and management histories, but have not been spread with waste. The SEPA dataset is smaller than the operator datasets, but covers a wider range of soil chemical and biological properties than the operator data.

[9] A representative soil sample is taken by collecting 25 sub-samples across the whole field to be sampled, mixing these together and then sub-sampling to produce a final sample for analysis.

Table A4.2 Mean, median and ranges for each parameter measured (except earthworms)

Parameter	Unit	Mean	Median	Minimum	Maximum	N
pH		6.0	5.9	4.5	7.8	89
P*	mg/l	8.2	5.8	0.5	37.9	89
K*	mg/l	126	109	35	411	89
Mg*	mg/l	186	148	51	1118	89
$C_{org}^{\$}$	%	4.4	3.6	1.3	19.9	89
$N^{\dagger}$	%	0.33	0.29	0.09	1.44	89
C:N		13.3	12.5	8.7	27.9	89
$Cd^{\dagger}$	mg/kg	0.21	0.17	0.05	1.35	89
$Cr^{\dagger}$	mg/kg	33.3	29.0	4.2	98.1	89
$Cu^{\dagger}$	mg/kg	23.7	15.0	3.2	251.7	89
$Hg^{\dagger}$	mg/kg	0.12^	0.09	<0.03	1.03	89
$Ni^{\dagger}$	mg/kg	24.1	19.9	2.3	131.3	89
$Pb^{\dagger}$	mg/kg	35.5	21.9	6.6	533.9	89
$Zn^{\dagger}$	mg/kg	62.1	49.7	8.5	519.4	89
$C_{mic}^{\sim}$	µg/g	628	535	153	2583	89
C_{mic}:C_{org}	%	1.6	1.4	0.1	4.8	89

* extractable, $^{\$}$ organic carbon, † total, $^{\sim}$ microbial biomass carbon, ^ The mean concentration is calculated using a value of half the detection limit for all data, where measured concentration is below the detection limit.

Table A4.3 Mean, median and ranges for earthworm parameters measured

Parameter	Unit	Mean	Median	Minimum	Maximum	N
Species number		5	5	1	8	27
Total abundance	Ind m^{-2}	192	173	8	700	27
Adult abundance	Ind m^{-2}	40	33	0	198	27
Total biomass	g m^{-2}	53.8	46.5	1.5	180.0	27
Adult biomass	g m^{-2}	20.9	17.1	0	81.1	27

SEPA's soil compliance monitoring: 2012 results

Table A4.4 Mean, median and ranges for each parameter measured (except earthworms)

Parameter	Unit	Mean	Median	Minimum	Maximum	N
pH		5.8	5.8	4.7	7.8	99
P*	mg/l	7.5	6.0	1.3	45.5	99
K*	mg/l	123	104	24	363	99
Mg*	mg/l	132	114	39	309	99
$C_{org}^{\$}$	%	4.3	3.6	1.6	30.3	98
$N^{\dagger}$	%	0.32	0.28	0.12	1.79	99
C:N		13.6	13.2	10.1	30.8	98
$Cd^{\dagger}$	mg/kg	0.23	0.20	0.07	1.30	99
$Cr^{\dagger}$	mg/kg	39.5	35.0	9.4	181.1	99
$Cu^{\dagger}$	mg/kg	18.8	14.5	6.8	171.0	98
$Hg^{\dagger}$	mg/kg	0.13^	0.10	<0.03	0.94	99
$Ni^{\dagger}$	mg/kg	25.3	21.0	4.7	178.3	99
$Pb^{\dagger}$	mg/kg	36.0	25.5	7.5	424.5	99
$Zn^{\dagger}$	mg/kg	75.7.1	64.6	25.7	425.2	99
$C_{mic}^{\sim}$	µg/g	678	626	184	3203	99
C_{mic}:C_{org}	%	1.9	1.6	0.6	4.0	98

* extractable, \$ organic carbon, † total, ~ microbial biomass carbon, ^ The mean concentration is calculated using a value of half the detection limit for all data, where measured concentration is below the detection limit.

Table A4.5 Mean, median and ranges for earthworm parameters measured

Parameter	Unit	Mean	Median	Minimum	Maximum	N
Species number		6	6	2	11	33
Total abundance	Ind m^{-2}	212	177	13	560	33
Adult abundance	Ind m^{-2}	53	43	2	173	33
Total biomass	g m^{-2}	66.4	52.1	5.6	337.4	33
Adult biomass	g m^{-2}	27.9	23.5	1.4	88.6	33

Annex V. Impact of different organic materials on soil quality indicators

Sewage sludge spreading

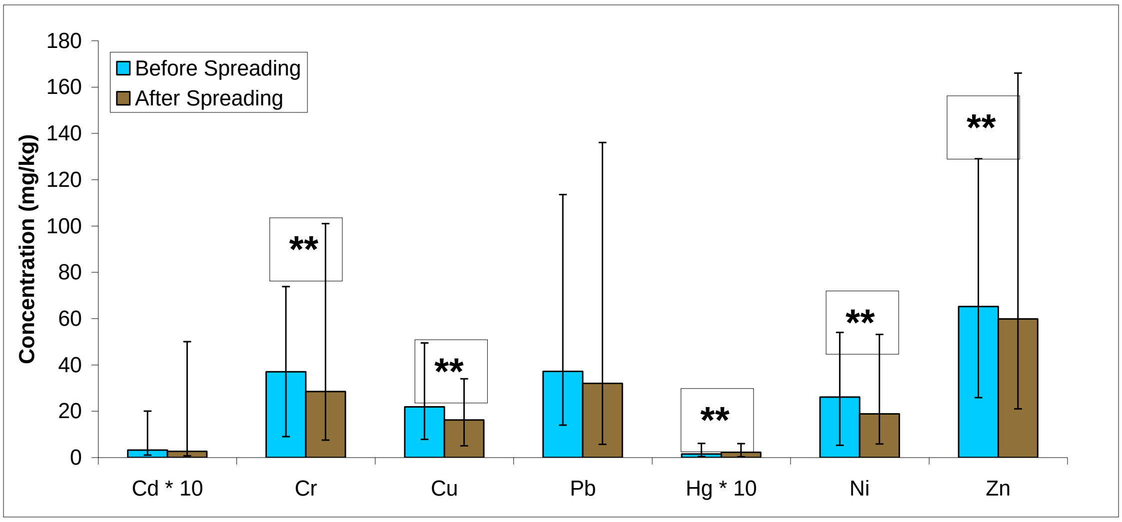

Figure A5.1. Average PTE concentrations in soil before and after sewage sludge spreading. The whiskers show maximum and minimum concentration. Where "**" is shown the PTE concentration is significantly different at $p < 0.05$ level.

Table A5.1. Percentage of fields sampled by operators before and after sewage sludge spreading between 2005 and 2011 in breach of the 1989 Regulations limit at pH measured and close to the 1989 Regulations limit (in excess of 90% the 1989 Regulations limit for pH 5.0 – 5.5). Numbers in brackets are the number of fields.

		pH	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Before spreading (76)	Exceeding the 1989 Regs limit	0%	0%	0%	0%	0%	0%	0%	0%
	Close to the 1989 Regs limit	14.5% (11)	0%	0%	0%	0%	7.9% (6)	0%	0%
After spreading (76)	Exceeding the 1989 Regs limit	0%	1.3% (1)	0%	0%	0%	0%	0%	0%
	Close to the 1989 Regs limit	2.6% (2)	0%	0%	0%	0%	6.6% (5)	0%	0%

Table A5.2. Percentage of fields in breach of the 1989 Regulations limit at pH measured and close to the 1989 Regulations limit (in excess of 90% the 1989 Regulations limit for pH 5.0 – 5.5). Numbers in brackets are the number of fields. Comparison of fields spread with sewage sludge and reference fields sampled by SEPA between 2007 and 2012.

		pH	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Spread fields (124)	Exceeding the 1989 Regs limit	0%	0%	0%	0.8% (1)	0.8% (1)	4.0% (5)	0.8% (1)	1.6% (2)
	Close to the 1989 Regs limit	12.1% (15)	0%	0%	0.8% (1)	0%	8.1% (10)	0%	2.4% (3)
Reference fields (42)	Exceeding the 1989 Regs limit	0%	0%	0%	0%	0%	0%	0%	2.4% (1)
	Close to the 1989 Regs limit	31.0% (13)	0%	0%	2.4% (1)	0%	11.9% (5)	0%	0%

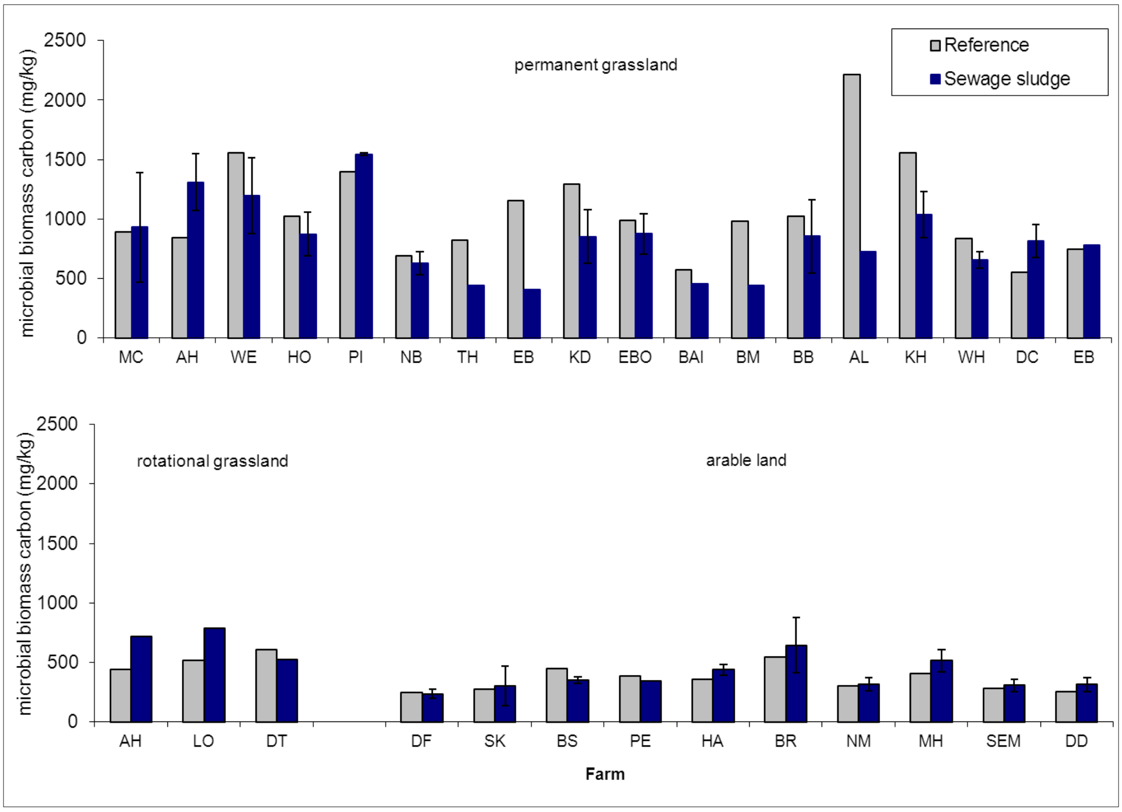

Figure A5.2. Mean ± standard deviation of microbial biomass carbon in fields receiving sewage sludge and reference fields under the same land use. The identifiers on the x-axis represent individual farms.

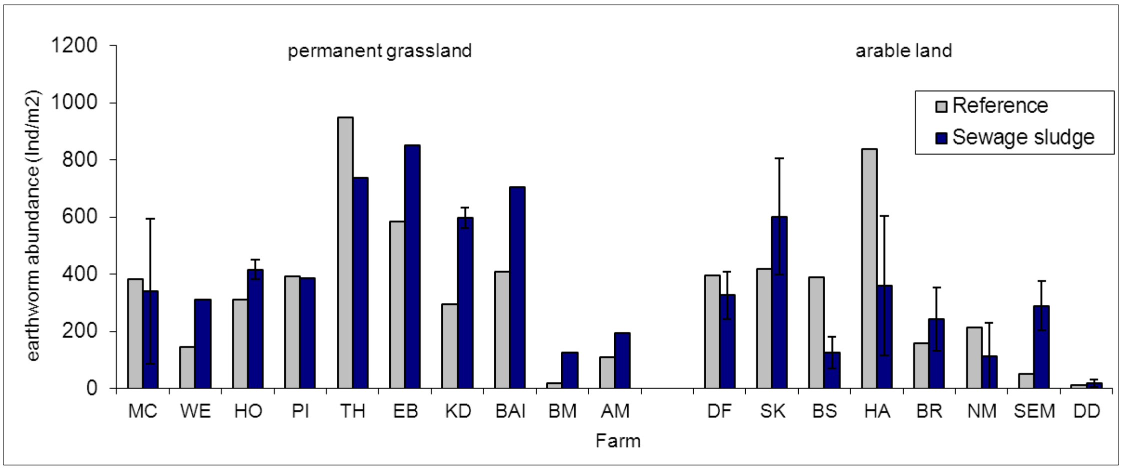

Figure A5.3. Mean ± standard deviation of earthworm abundance of fields receiving sewage sludge and reference fields under the same land use. The identifiers on the x-axis represent individual farms.

Distillery production residue spreading

Table A5.3. Percentage of fields with pH below 5 or with PTE concentration above the guideline values[10], and pH below 5.5 or PTE concentration close to guideline values, before and after distillery production residue spreading. Based on data supplied by operators for the years 2005 -2011, where 'close to guideline value' is defined as in excess of 90% of the PTE guideline value for pH 5.0 – 5.5. Numbers in brackets are the number of fields. [a]310 fields for pH only; 308 fields for copper (Cu) and zinc (Zn). [b]310 results for pH only; 304 results for Cu and Zn.

		pH	**Cu**	**Zn**
Before spreading (310[a])	pH below 5 or concentration exceeding guideline values	1.6% (5)	0%	0%
	pH below 5.5 or PTE concentration close to guideline values	31.6% (98)	0%	0%
After spreading (310[b])	pH below 5 or concentration exceeding guideline values	0.3% (1)	0.3% (1)	0.3% (1)
	pH below 5.5 or PTE concentration close to guideline values	32.0% (99)	1.0% (3)	0%

[10] SEPA has used the limits in the 1989 Regulations as guideline values. Please note these guideline values are not legally binding for spreading wastes other than sewage sludge, so values outlined in tables A5.3, A5.4 and A5.5 as exceeding these values do not represent a breach of legal requirements.

Table A5.4. Percentage of reference fields and fields spread with distillery production residue with pH below 5 or with PTE concentration above guideline values, and pH below 5.5 or PTE concentration close to guideline values. Based on soil analysis from fields sampled by SEPA, where 'close to threshold value' is defined as in excess of 90% of the PTE guideline value for pH 5.0 – 5.5. Numbers in brackets are the number of fields.

		pH	Cd	Cr	Cu	Hg	Ni	Pb	Zn
All fields spread with distillery production residue (82)	pH below 5 or concentration exceeding threshold values	3.7% (3)	0%	0%	3.7% (3)	1.2% (1)	0%	0%	0%
	pH below 5.5 or concentration close to threshold values	36.6 % (30)	0%	0%	1.2% (1)	0%	3.7% (3)	0%	0%
All distillery production residue reference fields (20)	pH below 5 or concentration exceeding threshold values	0%	0%	0%	0%	0%	5.0% (1)	0%	0%
	pH below 5.5 or concentration close to threshold values	30% (6)	0%	0%	0%	0%	5.0% (1)	0%	5.0% (1)

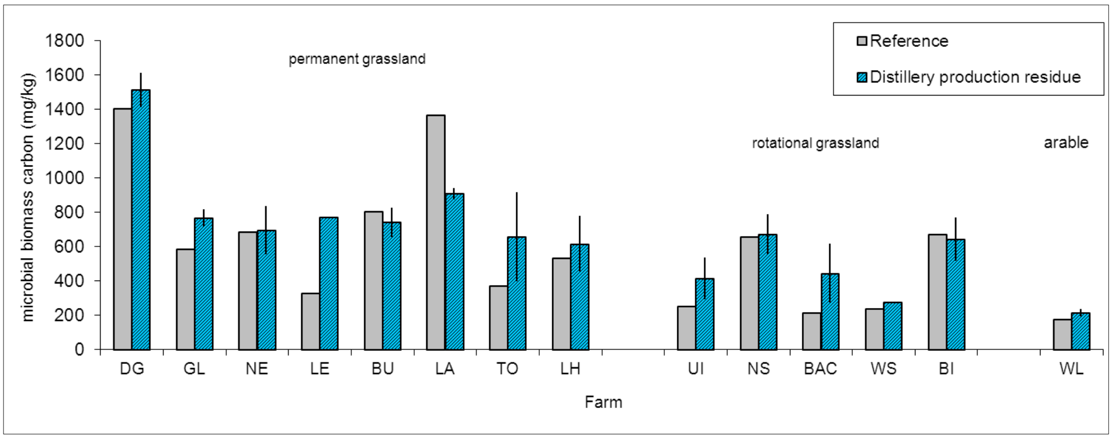

Figure A5.4. Mean and ± standard deviation of microbial biomass of fields receiving distillery production and reference fields under the same land use. The identifiers on the x-axis represent individual farms.

Figure A5.5. Mean and ± standard deviation of earthworm abundance of fields receiving distillery production residue and reference fields under the same land use. The identifiers on the x-axis represent individual farms.

Paper crumble spreading

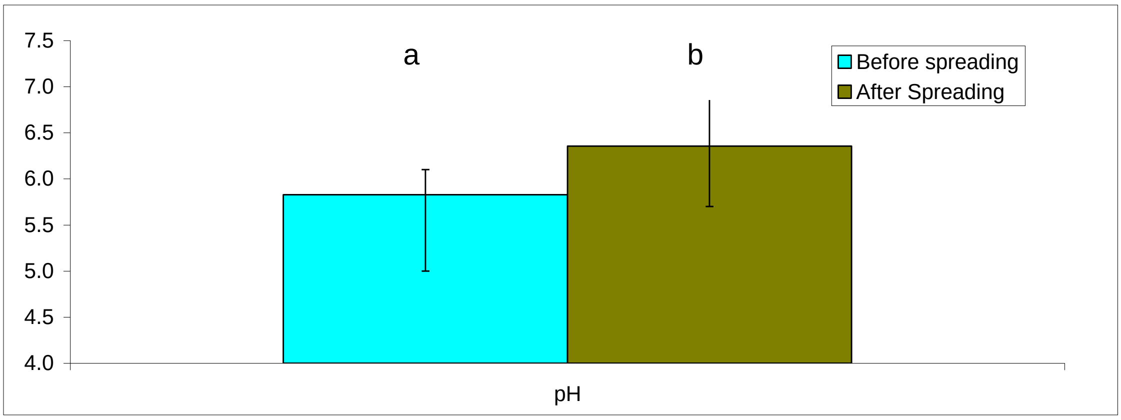

Figure A5.6. Average soil pH in fields where paper crumble has been spread, before and after spreading. The whiskers show maximum and minimum concentration. Different letters above the 'before' and 'after' bars indicate that the PTE concentration is significantly different at $p < 0.005$ level

Spreading of other organic materials under paragraph 7 exemption

Table A5.5. Percentage of fields spread with organic materials other than distillery production residue under a paragraph 7 exemption and reference fields with pH below 5 or with PTE concentration above guideline values[11], and pH below 5.5 or PTE concentration close to guideline values. Based on soil analysis from fields sampled by SEPA, where 'close to guideline value' is defined as in excess of 90% of PTE guideline value for pH 5.0 – 5.5. Numbers in brackets are the number of fields.

		pH	**Cd**	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
other waste spread fields (81)	pH below 5 or concentration exceeding guideline values	1.3% (1)	0%	0%	0%	0%	2.5% (2)	0%	0%
	pH below 5.5 or concentration close to guideline values	4.9% (4)	0%	0%	0%	0%	3.7% (3)	0%	0%
other waste reference fields (34)	pH below 5 or concentration exceeding guideline values	0%	0%	0%	0%	0%	0%	0%	0%
	pH below 5.5 or concentration close to guideline values	14.7% (5)	0%	0%	0%	0%	2.9% (1)	0%	0%

[11] SEPA has used the limits in the 1989 Regulations as guideline values. Please note these guideline values are not legally binding for spreading wastes other than sewage sludge, so values outlined in tables A5.3, A5.4 and A5.5 as exceeding limits do not represent a breach of legal requirements.

Annex VI. Development of soil indicators

Chemical indicators

Certain chemical determinations are required to form the basis of future monitoring since they provide essential background information needed to assess and understand other soil parameters, especially biological data. Monitoring campaigns require a measurement of the following soil chemical characteristics: organic matter content (or organic carbon); pH; nutrients (nitrogen, phosphorus, potassium, magnesium); potentially toxic elements (cadmium, copper, chromium, nickel, mercury, lead and zinc as a minimum). The reason for this is outlined below:

- Organic matter content and soil pH are vital parameters which play a major role in determining the ability of soils to carry out most functions. These parameters have various influences on soil processes, including the availability and uptake of nutrients and PTE, the composition and activity of soil microbial communities, and soil structure.
- Excess nutrient concentrations pose a risk to water, air and climate.
- Excess PTE concentrations pose a risk to soil, water and human health.
- Soil pH and PTE results are essential to check compliance with legislation.

Organic chemical pollutants

The number, concentration and potential impact of organic pollutants present in organic materials spread on land in Scotland were investigated as part of a SEPA research project that was completed in March 2014 (EP1302 ‘Assessment of Soil Quality and Human Health from Organic Contaminants in Materials Commonly Spread on Land’). Some of the outcomes from this research project are set out in section 4.24 of this report.

The research project did not involve any direct measurement of organic contaminants in materials spread to land. Instead a risk assessment was performed for a set of organic contaminants on the basis of data from literature and determination/estimate of the total amount of various organic materials spread to land in different parts of Scotland. This approach has established which organic contaminants may pose the greatest risk to the environment, suggesting that veterinary medicines in particular may be worthy of further investigation.

The consequences of the results from SEPA’s research project are still being evaluated, however it is possible that sampling and analysis of Scottish soils for organic contaminants will be required in the future.

Biological indicators

Biological indicators have the advantage of summarising the overall impact of organic material spreading. The development of new molecular techniques could provide a range of new options to explore soil organism communities and their function. New methods are currently being developed to utilise these techniques to assess soil quality, however these methods are not established or standardised and results are not yet understood to the point where their implications for soil quality can be accurately interpreted. Before employing any of these new methods, further confidence that these indicators can be used to help understand the impact of organic material spreading to land is required.

In the short term, SEPA should maintain a watching brief on the development of molecular soil analysis techniques.

In the longer term, once more is known about molecular soil analysis techniques and the results they produce, SEPA should consider how these could be used in soil monitoring campaigns.

Physical indicators

It is well established that the physical environment is very important for the behaviour of chemical substances and the presence and functioning of soil organisms. However physical indicators are infrequently measured as sampling is usually time-consuming and labour intensive. Nonetheless, an increasing number of soil monitoring schemes recognise that there is a lack of knowledge of soil physical status. The Countryside Survey for example included physical parameters in its last sampling (Emmett et al. 2010).

In the short- to mid-term, SEPA should investigate existing published methods for soil structure assessment, which were mainly developed for use in agricultural settings (e.g. Guimaraes et al. 2011). If a suitable method is found, this could be used in locations where organic material is spread to land to determine soil physical condition.