Code of Practice

for the use of sludge, compost and other organic materials for land reclamation.

TECHNICAL DOCUMENT

This document has been produced concurrently with and relates to the information provided in SNIFFER report ER11 'Code of practice for the use of sludge, compost and other organic material in land reclamation.

SNIFFER
SCOTLAND & NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH

Introduction to the Technical Document

This technical document is intended as a supporting publication to the SNIFFER Report 'Code of practice for the use of recycled organic materials in land reclamation'. At each comparable stage it provides additional detail to augment the information within the code of practice itself. Unlike the code of practice this technical document is fully referenced.

The goal of the code of practice is intended to provide useful, reliable, and consistent guidance for use by practitioners. The technical document is intended to provide the supporting evidence underpinning the code, giving background to explain why a particular action, or actions have been recommended, as well as some discussion of the underlying issues related to the production, use and regulation of recycled organic materials. The technical document should be seen as a reference source, in comparison with the code, which should be seen as a field manual.

The remainder of this document is divided into the same chapters and paragraph numbers as the code of practice. Where additional information is available, it can be found at the same paragraph number for easy cross referencing. If there is no additional information to that contained in the paragraph of the code this is also marked.

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1 Introduction

Para	Comments

1. No additional comments.

2. The nature of organic matter and its contribution to soil functionality is discussed in section 2.

3. The code is intended to apply to land that has been significantly altered from its original state through degradation (e.g. compaction, contamination, acidification, loss of nutrients, loss of organic matter) disturbance or removal (through quarrying or opencast coal mining for example). This may have occurred through industrial activity, mineral extraction or construction activity, or a combination of these. It is also possible that several different activities may have occurred on the same piece of land over time. With industrial expansion, several neighbouring sites may adjoin one another over time, each exhibiting different forms of disturbance, degradation and, perhaps, contamination. It is also possible that reclamation or improvement activities may encompass woodland or semi-natural land as part of a larger renovation project.

Degraded land may be found wherever industrial activity has taken place in the past; it may vary significantly in size from less than 2 hectares to several hundred hectares; it may or may not contain buildings or other structures which may be intact or derelict. Contamination may or may not be present; guidance is available on the definition of contaminated land and the requirements for treating contaminated land under part 2A of the Environmental Protection Act, 1990 (Defra 2008).

In recent years there has been a notable increase in the area of disturbed land across Europe, a trend that is likely to continue (European Environment Agency 2007). Its restoration is becoming an increasing priority for many EU Member States. The end goal of improvement will vary depending on the size of the site, its location and local and regional planning policy, as well as the goals of the organisation undertaking the restoration. Typical examples of end goals include recreational uses (public open space and community woodland), ecology (establishment of new wildlife habitats), biomass production, housing, industry and mixed use.

By definition the soils on degraded land are likely to be of poor quality as a result of sealing, compaction and, possibly, contamination. It is also possible that topsoil is effectively not present due to previous activity (e.g. industry or landfill). In either case the replacement or improvement of soil will almost certainly require the addition of organic matter to improve its structure and quality.

Reliable estimates of the extent of disturbed land in the UK are difficult to obtain. Several surveys have been undertaken but they use different definitions and interpretations of the land that is included in the surveys. For example a report for the Department of Communities and Local Government (DCLG 2006) stated that there were 63,500 hectares of previously developed land in England. This quantity was subdivided into five categories (vacant land, vacant buildings, derelict land/buildings, land in use with potential for redevelopment and land in use with permission for redevelopment). It is not clear how much of this land would have a need for improvement through organic matter application, but 22% of the total was classified as vacant land, which would equate to nearly 14,000 hectares of land. Another survey of long term derelict land in England (Roger Tym and Partners 2002, cited in Cameron et al. 2008) suggested that there were approximately 17,000 hectares of land with an individual site size of over two hectares that had lain vacant or derelict for nearly a decade. A summary document from English Partnerships (2006) estimated the stock of disturbed land in England in 2004 to be 64,130 hectares, of which the greatest quantity was in North West England. A survey of derelict, underused and neglected land (DUN) in this region revealed 3,800 sites of greater than one hectare that fell into the category. Of these, approximately 1,600 were classed as brownfield land. Other surveys include the Scottish Vacant and Derelict Land survey (Scottish Government 2009), for which the latest reported data come from 2008. In total there were 10,832 hectares of vacant (i.e. not used and suitable for development) and derelict (i.e. not used and in need of remediation prior to development) land across Scotland, the majority being in the former industrial heartlands. This land was distributed over 3,930 sites, the three largest of which each covered an area greater than 600 hectares (Scottish Government 2009).

The differences in definitions, the scale of the surveys undertaken and the scope of the surveys (i.e. they may not include all possible degraded land within the survey area) as well as the constantly changing quantity of disturbed land being created and reclaimed mean that an accurate estimate of the total area is not possible. However it can be stated that there is a large quantity of previously developed land suitable for reclamation available across the country at any one time and that recycled organic material is often a suitable amendment for revegetating such land.

4. Examples of the codes referred to include the code of good practice for agricultural use in sewage sludge (DoE 1996), the code of good practice for the use of sewage sludge in land reclamation (WRc 1999), the safe sludge matrix (ADAS 2001a, b), the United Utilities code of practice for the use of sewage sludge in land reclamation (United Utilities 2005), the Forest Research best practice guidance notes for land regeneration (Forest Research 2006a-f), the TWIRLS[1] good practice manual for using organic wastes and composts in land restoration (Nason et al. 2007), and work undertaken as part of SNIFFER project UKLQ09 (SNIFFER 2008a). While these documents provide good sources of information, none of them covers the use of a range of materials specifically for land reclamation, nor are any of them sufficiently up to date to consider the regulatory impact of Environmental Permitting in England and Wales.

5. No additional comments.

6. At present there is not a code of practice available that covers the use of any recycled inorganic materials in land reclamation projects although in some cases (e.g. steel slag) a Quality Protocol is in development, which will provide helpful advice and guidance on its use within England, Wales and Northern Ireland. Although the Quality Protocols are not a regulatory requirement in Scotland they still contain pertinent information. Quality Protocols are discussed further in section 6, Paragraph 38. Information specifically related to the steel slag QP can be found at:

http://www.environment-agency.gov.uk/business/topics/waste/95432.aspx

Inorganic materials provide benefit to soil largely by improving its physical qualities, such as increasing aeration and workability in heavy soils and giving stability, structure and improved moisture retention in sandy soils. They may also have beneficial chemical properties depending on the type of inorganic material used. For further advice on inorganic materials look at the relevant information on the Environment Agency Quality Protocols homepage:

http://www.environment-agency.gov.uk/business/topics/waste/32154.aspx

[1] Treating wastes for restoring life sustainability (TWIRLS) was a project funded through the European Commission LIFE fund

Livestock manures are actually the largest source of organic matter applied to land in the UK (Chambers et al. 2001a b). As stated in the code, these are largely used where they are produced, and are therefore of limited relevance to land reclamation.

Although the materials listed in this paragraph have not been included in the code, the general information provided by the code and this document may be of use and relevance in the application of these materials. If the information provided is applied to inorganic materials, it is the responsibility of the user to exercise due caution in interpreting the available information.

Box 1 The materials listed are discussed in more detail in section 2 of this document.

7. The codes of practice for agricultural land referred to are the Defra code of good agricultural practice (Defra 2009a), the code of good practice for the prevention of environmental pollution from agricultural activity, known by the acronym PEPFAA (Scottish Executive 2005), and the DARD NI code of good agricultural practice (DARD 2008). At present the Defra code is applicable in Wales, although this may change in the future.

Box 2 Other activities that are not included in this list may make use of the materials included in this code. Civil engineering projects, such as road and railway construction, or the development of major infrastructure such as airports where landscaped sound barriers may be required are some possible examples. These are not land reclamation projects and have therefore not been considered in the code. However the advice provided within the code may be valid for certain civil engineering applications in the absence of alternatives.

8. No additional comments.

9. No additional comments.

2 Types of organic matter

Para	Comments

10. A typical soil is composed of inorganic material, such as clay, sand and silt, which forms 45% of the soil, while the remainder is made up of air, water and organic matter, which make up 25%, 25% and 5% of the soil respectively (Brady 1990). These three components are dynamic features within the soil, so these percentages vary considerably. Water and air are predominantly found in the pore space of the soil, although small fractions of water and air may be found within or on the surface of the inorganic particles and organic material. The proportion of air and water is variable, depending on the prevailing conditions, such as drought or heavy rain. Although it is by far the smallest constituent of a soil, organic matter is a vital component; it is made up of partially decomposed plant and animal residues, which are broken down further within the soil profile by microorganisms (for which it is a source of energy) into its component parts, providing a source of nitrogen, phosphorus, potassium, carbon, sulphur and trace nutrients. It helps to bind the mineral particles of the soil together, contributing to the stability and structure of the soil. As organic matter is continually recycled within the soil profile, it needs to be replaced in order for the soil to maintain its structure and fertility. Sources from within the profile include animals such as earthworms, as well as root material from vegetation growing on the surface, which also provides a source of organic material from above ground. Animals which live on the soil surface may also provide a source of organic material. External sources may be applied deliberately and include the list of materials shown in section 2 of the code as well as alternatives such as manures. Animal manures are by far the most significant source of organic material applied to land (approximately 90 million tonnes per year in the UK). The vast majority is applied to agricultural land (Chambers et al. 2008) and is therefore not a major concern to this code.

Green waste and food waste composts

11. To be classed as green waste compost the feedstock used in the process must be source segregated material collected independently from other waste streams, from sources such as domestic gardens, municipal parks and recreational areas, and may be treated using a composting process. Certain types of food waste, from commercial kitchens for example, may also be composted. Material from mixed waste feedstock is considered in paragraph 18.

Composting is the term used to describe the aerobic biodegradation of organic material by a range of microorganisms under controlled conditions of temperature and moisture. The end result of the composting process is a stable organic residue with valuable organic matter and nutrient content; it should not be odorous, attractive to vermin, or contain an excess of pathogens (Bardos 2005). The content of organic matter will vary with the maturation time: fully biostabilised, mature composts will have a relatively low organic matter content of around 8% or less, while immature composts will have a far higher organic matter content of around 40%; immature materials are usually used for mulches and top dressings. The composting process may be undertaken in a variety of ways, from basic open air or indoor turned windrows (long piles of composting material turned periodically to ensure even decomposition), forced air systems designed to speed up the process, and in-vessel systems which contain the composting material during the initial processing stage, either in a large diameter (near) horizontal or vertical tube or a large rectangular sealable shed.. In-vessel systems are the only acceptable form of composting process for food waste in the UK and must be compliant with the Animal By-Products Regulations (ABPR). The current ABPR date from 2005; the regulations were amended in 2009 to include the Isle of Wight as a designated remote area. Further information on ABPR requirements can be found at the following weblinks:

- **ABPR (2005):** http://www.opsi.gov.uk/si/si2005/20052347.htm
- **ABPR amendment (2009):** http://www.opsi.gov.uk/si/si2009/uksi_20091119_en_1

The composting process has three distinct stages; a mesophilic stage, a thermophilic stage and a maturation stage. The mesophilic stage is achieved in the early stages of the composting process as biological activity degrades the feedstock and temperatures begin to rise to an ambient temperature of around 40°C (Bardos 2005). At this stage the majority of the organic material is broken down. The subsequent thermophilic stage is reached as biological activity reaches its maximum, during which the majority of the most significant pathogens are effectively destroyed by the high temperatures generated, which must exceed >50°C. Once these initial composting processes have been completed, the resulting material should be allowed to mature for a period of several weeks, during which time the biodegradation of more persistent materials within the feedstock takes place. As this activity takes place over a longer period than the earlier stages, temperatures are correspondingly lower. At all stages in the composting process appropriate conditions of air and moisture must be maintained. Biological activity will cease at moisture contents below 12-15% and composting material must be aerated regularly to ensure an even supply of air to all areas and consistent biodegradation. The time taken to produce mature compost varies with the method taken to produce it, ranging from several months with open air windrows to a few weeks with in-vessel and forced air systems.

Green waste composts can be assessed to comply with the Publically Available Specification PAS100 (BSI 2005a) for quality compost; they may also be of an appropriate standard to pass the Quality Protocol for compost (WRAP and Environment Agency 2007), which applies in England and Wales.

According to the latest composting industry survey undertaken by AfOR (2009), 4.5 million tonnes of organic waste were composted in the period 2007-2008; it is likely that this level of production has since increased in line with current policy goals. The figure of 2.7 million tonnes of compost produced is equivalent to 60% of the original volume of feedstock, which is a typical reduction in volume over the composting process. Most of the feedstock in the survey (88%) was collected either from the kerbside or from civic amenity sites, with a small proportion from parks and gardens. The main use of the resulting compost is as a soil improver (78%), while soil manufacture accounts for 7% of the output and mulch 4% (AfOR 2009). Very little of the waste processed is food waste. Less than 1% of the total feedstock is source separated food waste, while approximately 10% of the feedstock is food waste co-collected with source separated green waste (AfOR 2009). Although food waste composts could be used in land reclamation it is unlikely at present that a significant source would be available locally. However, recent initiatives by Defra to improve food waste collection will mean that the availability of food waste composts increases in the future.

Compost-like outputs

12. Compost-like output is the most widely used term to describe organic-rich material produced from feedstock that has not been source-segregated (Cameron et al. 2008). Other terms used to describe similar types of material include waste-derived organic matter (WDOM), MBT organic matter (MBT-OM), mixed-waste compost, and low-grade compost. Although they describe similar materials they are not synonymous and the term CLO is used within the code and this technical document.

MBT is another generic term encompassing many processes, or more accurately combinations of processes; the only common factor between them is that they include some form of biological treatment process to biostabilise the material, and some form of mechanical separation process. Typically the mechanical processing comes before the biological processing but the two are sometimes reversed (Bardos 2005). Possible biological treatments of the feedstock include windrow or in-vessel composting, anaerobic digestion and autoclaving. Some of these processes are described independently within this document; in these cases the feedstock is source separated. Mechanical processing is partly undertaken to remove residual material of value, in particular metals, and partly to remove fragments of material such as metal, glass and plastics from the CLO produced at the end of the process in order to reduce contamination from inert materials. Typical mechanical processes found at MBT plant include magnetic and ballistic or air separation, washing, sieving, milling or shredding. At any one plant it is likely that only some of these processes will be used.

Not all MBT plants are configured to produce CLO, or significant quantities of CLO; they may be configured to produce Refuse-Derived Fuel (RDF) to be used in power generation plant. In this case the advantage of the pre-treatment process is to increase the calorific value of the output material by removing non-combustible elements of the feedstock and reducing the moisture content of the output material.

13. The variability in quality between different materials described as CLO, and between CLO from the same MBT plant through the year, is one of the major concerns over the use of CLO on land (Environment Agency 2010), although it can be applied to non-agricultural land under a paragraph 9 exemption or an Environmental Permit (section 6, paragraph 40). Ongoing trials of CLO applications to agricultural land are also being undertaken, but the position regarding their use in this capacity is unclear (Environment Agency 2008b). As a result of the uncertainty over reliable markets for CLO to land, some MBT plant have been reconfigured to produce a refuse-derived fuel as a more reliable output from the treatment process (Bardos and Chapman 2008). Much material that is processed at MBT plant is destined to be landfilled because it is not of appropriate quality or there is no market available at the time of production.

14. This estimate of production is derived from Cameron et al. (2008). It assumes that 35% of the input material is processed by composting or an equivalent biological treatment and that this process results in a 40% reduction in volume; in total this means that approximately 21% of the original feedstock ends up as CLO. The exact scale of CLO production in the UK is difficult to estimate due to differences between processes at different sites, the fact that not all MBT plant focus on CLO production, differences in feedstock composition, and the ongoing development of new MBT plant. A further source of data comes from the AfOR annual survey of the composting industry (AfOR 2009). They report that 583,500 tonnes of mixed waste feedstock was treated via an MBT process. It is unclear from the report text whether this figure is the amount of CLO produced, which would be close to the estimate of Cameron et al (2008), or whether it is the amount of feedstock processed. If it is the latter the same percentage of output CLO to input material is used as for the Cameron et al. (2008) estimate, which would suggest that the approximate output of CLO in 2007-8 was 122,500 tonnes. The actual figure may be larger, as there may be CLO producers who did not respond to the survey.

Anaerobic digestate

15. Anaerobic digestion is a technology that has been used in sewage treatment processes for many years but it has only been applied to other waste feedstocks in the UK relatively recently. Of the outputs from the process the emphasis at most plants is on biogas production, as this is the most readily usable and saleable output. The development of a specification (BSI 2008a) and Quality Protocol for anaerobic digestate (WRAP and Environment Agency 2009) as described in section 4, paragraph 33 means that opportunities for the use of anaerobic digestate are increasing.

Anaerobic digestion is a process whereby organic material is broken down by bacteria in a sealed environment without oxygen (Friends of the Earth 2007, BSI 2008). The material to be processed can be shredded to increase the surface area available to microbes in the digesters and hence increase the speed of digestion, which is a four-stage process (Friends of the Earth 2007). The first stage is hydrolysis, where complex organic molecules are broken down into simple sugars, amino acids, and fatty acids with the addition of hydroxyl groups. This is followed by three biological processes: acidogenesis, where the hydrolysed material is further broken down into simpler molecules, producing ammonia, carbon dioxide and hydrogen sulphide as by-products; acetogenesis, where the molecules produced via acidogenesis are further digested to produce carbon dioxide, hydrogen and mainly acetic acid; methanogenesis, where methane, carbon dioxide and water are produced by bacteria known as methanogens. During the process pH should be kept between 5.5-8.5 and the temperature between 30-60°C in order to maximise digestion rates. The end products of digestion are biogas (approximately 60% methane, 40% carbon dioxide; Friends of the Earth 2007), which is subsequently used to generate electricity, for heating, fuel and fuel cells, and anaerobic digestate, a nutrient-rich liquor that can be applied to land. Digestate comes in three forms: separated fibre, separated liquor and whole digestate, which is a combination of the two. The proportion of biogas and digestate produced depends on the nature of the feedstock; more putrescible material produces a greater quantity of biogas, while sewage and manure produce less biogas (Friends of the Earth 2007).

Green waste, food waste and mixed waste can be treated using anaerobic digestion; anaerobic digestion may also form part of a mechanical biological treatment process for mixed waste feedstock. However, for the purposes of this code we will only consider digestate that has been produced from source segregated material.

16. The data for 2006-7 were taken from the AFOR survey of that year (AfOR 2008). However, in the latest survey (AfOR 2009) no respondents indicated that they produced anaerobic digestate. This is not to say that no anaerobic digestion took place; merely that it was not reported. The availability of anaerobic digestate for land reclamation is therefore likely to be limited in the immediate future both by the limited supply available and also by the small number of anaerobic digestion plant around the country. However, more facilities are being planned or are in construction (for example Shanks have recently opened an anaerobic digestion plant in Scotland), therefore this figure is likely to increase in future.

Biosolids

17. Raw sewage derived largely from human wastes undergoes sedimentation and treatment at wastewater treatments plants; the end products of the process are an effluent, which may be discharged to receiving waters, and a liquid sludge. This sludge is subsequently treated by a range of processes that may include dewatering, anaerobic digestion, composting, drying and lime treatment. These processes are undertaken to reduce water content, to stabilise organic matter and to reduce the content of bacteria and viruses (WRc 1999). The different treatment processes produce material that has different characteristics. The main difference between sludge types is their dry matter content. Liquid sludge has a dry matter content of 2-5%. Further water is often removed mechanically (by centrifuging or compression between filters) to produce dewatered sludge cake, which has a dry matter content of 25-30%. Untreated but dewatered sludge can also be treated by composting with a bulking agent such as cereal straw, or by the addition of lime or limy wastes (WRc 1999). Sludge compost and limed sludge cake have a dry matter content of around 30-40%. A further alternative treatment method is for moisture to be driven off thermally to produce thermally dried granules or biopellets, which have a typical dry matter content of 90-95% (WRc 1999, SNIFFER 2008b).

The different biosolids products can be designated as ‘conventionally treated’ and ‘enhanced treated’ products depending on the level of pathogen destruction as a result of the treatment process. In conventionally treated biosolids 99% or more of the pathogens must be destroyed (ADAS 2001a, b). Most sludge cakes meet this criterion. To be classified as enhanced treated biosolids 99.9999% of pathogens must be destroyed (ADAS 2001a, b) Products such as limed cake, biopellets and cakes produced using thermal or enzyme hydrolysis normally meet this criterion. The additional treatment processes increase the cost of production but produce products that are safe to use on land producing food crops as well as for land reclamation.

Most biosolids have an organic matter content of more than 50% by dry weight. Levels of nitrogen and phosphorus are variable. In a comparison between digested and undigested liquid sludge and cake (WRc 1999) total nitrogen varied between 3% and 5% dry solids and total phosphorus varied between 1.1% and 1.7% dry solids. Similar data reported in SNIFFER (2008b) showed that the total nitrogen concentration in liquid sludge varied between 1% and 7% dry matter, while total phosphorus varied between 0.9% and 5.2%. Availability of nitrogen in sludge varies with treatment, with up to 60% nitrogen available in liquid digested sludge and as little as 15% available in digested sludge cake (WRc 1999). Availability of phosphorus does not vary between treatments, being constant at 50% availability according to data from WRc (1999). Phosphorus content of sludge remains constant over time, whereas the nitrogen content has been recorded as falling during storage by as much as 30% in four months (SNIFFER 2008b).

Dewatered sludge cake is the most common form of biosolid used for land restoration in the UK, but sludge compost is important in some regions. Although granules are the easiest form of sludge to transport and apply, they break down less quickly in the soil profile and are currently not widely used in land reclamation, mainly because they are expensive to produce.

Figures 4.1 and 4.2 show the scale of sewage sludge produced by the water industry and its use on land. In total around 1.4 million tonnes of sludge are produced per year of which most is used in agriculture. Use in land reclamation is more variable; 52,500 tonnes (4%) were used in 2007, whereas 34,300 tonnes (3%) were used in 2008. It is possible that uses on industrial crops may have taken place on reclaimed land, but this is not specified in the available data.

Figure 4.1 Pie chart showing the use of sewage sludge in the UK in 2007

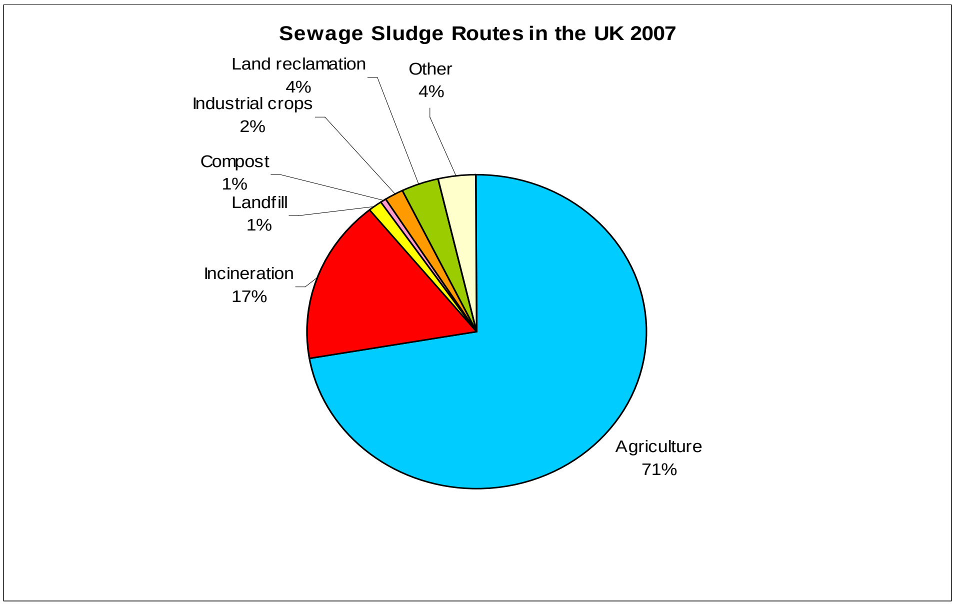
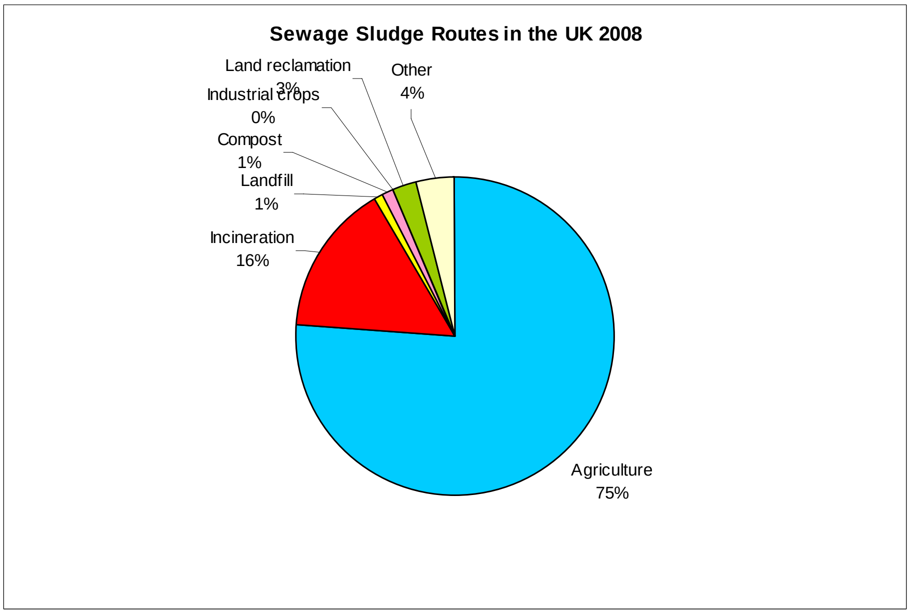


Figure 4.2 Pie chart showing the use of sewage sludge in the UK in 2008



Water treatment cake

18. Unlike biosolids, which are the processed residue from wastewater treatment processes, water treatment sludges are the by-product of the production of potable water in water treatment works. Typical processes include centrifuging, coagulation (using iron hydroxide or aluminium sulphate), filtration, dewatering and thickening, the end product of which is sludge. Sludges of this type typically have a small content of major plant nutrients (nitrogen, phosphorus and potassium) a higher content of the minor nutrient than other comparable organic materials, sulphur, and some trace nutrients. However, the main benefits to soils are physical rather than chemical. The concentration of potential contaminants such as heavy metals largely reflects the background content in the soils of the catchment and is not elevated by the treatment process (Davis and Rudd 1998).

Approximately 71% of sludge from freshwater treatment was recycled in the UK in 2003-2004; separate data on the quantity of water treatment sludges produced in the UK are not available as they are usually combined with data for sewage sludge. Around half of the water treatment works sludge produced in the UK is passed into the sewage system where it is processed along with wastewater sludge into biosolids. Alternatively it may be processed separately into a sludge that can be applied to land.

Paper Crumble

19. Paper crumble consists mostly of short wood fibres such as cellulose, lignin and hemicellulose (Nason et al. 2007, Shipitalo and Bonta 2008). It may also be produced in a cake or sludge form but contains essentially the same material. It is a by-product of processing both new and recycled papers and has a long history of being used on both agricultural land and in land reclamation. The Lambton cokeworks case study cited in the code (section 5, paragraph 40) used paper mill crumb in conjunction with PAS100 standard compost (WRAP 2008a, b).

A big advantage of paper crumble is its ability to hold moisture, the typical moisture content being around 60%. Organic matter content ranges from 30-70% on a dry solids basis (Environment Agency 2005). It also has a very high carbon content and a high carbon to nitrogen (C:N) ratio, potentially exceeding 150:1, although more typically 70:1 according to data from the Environment Agency (2005). As a result it can lead to N immobilisation if it is applied directly to land unless a nitrogen-rich source of material is applied at the same time, or it is combined with a material that fixes nitrogen, such as straw. Paper crumble can also be pre-treated prior to land application by composting, which reduces the C:N ratio as well as the volume and moisture content of the material. For example Tucker (2005) trialled a process of co-composting with fruit and vegetable waste in an in-vessel system, followed by vermicomposting to produce an enhanced organic amendment with a better C:N ratio. Paper crumble may also have a high copper content as well as potential contamination from inks, dyes and other chemicals (Tucker 2005). There is some liming capacity in paper crumble although it is relatively low at between 0.1 and 0.7 pH units per hundred tonnes per hectare (Environment Agency 2005). Nitrogen content ranges from <1 to 11 kg t^{-1} and phosphate content has been recorded between 0.2 and 3 kg t^{-1}. The mean values were 2.5 kg t^{-1} and 0.59 kg t^{-1} respectively. It is reported by the Environment Agency (2005) that the moisture content of paper crumble appears to have gone down in the last decade. Although there is no explanation given for why this should be the case, or whether or not it has been a conscious development, on the part of the paper industry it has resulted in sludge that is easier to transport and lighter in weight.

20. According to data from The Environment Agency (2005), 280,000 tonnes of paper crumble were applied to 10,500 hectares of agricultural land in 2003; this is the most common land application use for the material. Applications for land restoration were estimated at 85,000 tonnes (Environment Agency 2005). An alternative estimate of paper crumble production comes from Tucker (2005), who estimated that production of paper crumble from recycling operations in the UK was around one million tonnes per year in 2005; note that this figure, although notably higher, relates to the production of crumble and not its use. With increased rates of recycling this figure may increase in the future. Further sludge is produced from the processing of new paper but no estimate of the quantity produced is available.

Other recycled organic materials

21. It is not the purpose of the code to favour one form of organic material above another as a means of improving or manufacturing topsoil in land reclamation projects. The intention is to provide a balanced description of the benefits and disadvantages of each for the purposes that are covered in the code, as described in Section 1. The most commonly applied materials have been described in some detail above; other materials are available, or may become available in the future as a result of changes in manufacturing processes or waste policy. It may be that some alternative materials, such as seaweed and by-products from mushroom growing (Moffat 2006) may be appropriate for specialised use but may be available only in small quantities or from a local supplier rather than nationally. Others, such as wood residues or agricultural residues (e.g. straw) are widely available in large quantities; in these cases they are more likely to be treated in conjunction with other material via a process such as composting. However, users of such materials are advised to check whether such mixing of materials, even where they are source segregated, will affect and restrict the status of the resulting organic material. Details on waste streams that may be combined and treated by composting or anaerobic digestion can be found in the relevant publically available specifications, PAS100 and PAS110 respectively (BSI 2005a, BSI 2008a). Sources of additional advice include the Chartered Institution of Wastes Management (http://www.ciwm.co.uk) the Environment Agency (http://www.environment-agency.gov.uk/business/topics/waste/105375.aspx), the Association for Organics Recycling (http://www.organics-recycling.org.uk) and WRAP (http://www.wrap.org.uk).

The fact that materials have not been included in this code should be taken to signify that they are excluded from use in reclamation projects. If organic materials other than those described within the code are to be used in land reclamation, the general guidance in this code of practice will be appropriate as a source of information. If there are specific concerns or needs for clarification with regard to using the material (for example whether or not the material is classed as source segregated, application rates, use in conjunction with other materials, or the nutrient and contaminant concentration of material to be applied) it is recommended that consultation with the regulatory authority is undertaken at a local level, with reference to the relevant regulatory bodies at national level if necessary. A record of this consultation should be maintained as it may be used to inform good practice in the future. This may include more specific information in a revised code or technical document.

3 Benefits and risks

Para Comments

22. The benefits and risks associated with different types of organic material are well known and have been well documented (Chambers et al. 2002, Noble and Roberts 2003, Amlinger et al. 2004, Jobaggy and Jackson 2004, Bardos 2005, ADAS 2006, Defra, 2006, Zhang et al. 2006, Cameron et al. 2008, CL:AIRE 2008, Kinney et al. 2008). However, in a code of this nature it is important that the essential information related to benefits and risks is described. The code provides a very concise summary of this information. This section of the technical document provides more detail, but remains an introduction to the subject. If more information is required, we recommend the material referred to in the text at the appropriate points.

Benefits

23. All organic matter, regardless of the source, makes a significant contribution to the physical structure of the soil to which it is applied, despite being by far the smallest major constituent of a soil (Brady, 1990). Organic matter lowers soil density, which improves the circulation and availability of both air and water through the soil profile, and aids plant performance and animal life (Chambers et al. 2002). It also improves soil moisture retention and increases soil aggregate stability by binding the inorganic soil particles together making the soil less prone to erosion, particularly when combined with good vegetation cover. From a biological perspective the addition of organic material stimulates soil biological activity, which improves nutrient cycling and soil fertility by association (Atlas and Bartha 1997). Organic matter gradually biodegrades in the soil profile as it is recycled into its component parts; therefore if it is not replaced, the level of organic matter in a soil profile will reduce over time, particularly in soils that are cultivated intensively. Although there are sources of organic matter within the soil profile, such as the flora and fauna that live within and upon it, the most effective means of maintaining organic matter content in a soil is to add further material.

24. The nitrogen and phosphorus content of recycled organic material is variable but significant. Unlike conventional inorganic fertilisers, the nutrient content of most recycled organic materials are in a 'slow-release' form that provides a lower level of nutrients over an extended period of time (Bardos 2005). Levels of potassium may also be beneficial in some organic materials such as compost and sewage sludge. The average ecosystem in a temperate climate needs about 100 kg N ha^{-1} year^{-1} to maintain good growth. Assuming normal rates of mineralisation or organic nitrogen there needs to be a capital of at least 1,000 kg total N per hectare (Bradshaw 1983, Marrs 1989) and this requirement will normally determine application rates of organic materials to reclamation sites. Most recycled organic materials tend to have neutral or slightly alkaline pH (Cameron et al. 2008, Environment Agency 2010, SNIFFER 2008c) which benefits acidic soils in particular; this includes soils and soil forming material on most degraded sites. Increased pH improves the buffering capacity of the soil, which can reduce the mobility of certain contaminants (Brady 1990). Recycled organic matter may also contain useful levels of vital trace elements. It is made up of partially decomposed plant and animal residues, which are broken down further within the soil profile by microorganisms (for which it is a source of energy) into its component parts, providing a source of nitrogen, phosphorus, potassium, carbon, sulphur and trace nutrients.

Risks

25. It is possible for organic materials derived from waste feedstocks to cause undesirable impacts which may affect human health, the intended application, or the wider environment as a result of a range of potential contaminants that they might contain. This is the case regardless of whether or not the feedstock is source segregated, although the risk is typically lower if this is the case. The severity of any impact is related to the composition of the organic matter added, the way in which it is applied and site specific circumstances relating to topography, the soil, substrate and proximity to water (SNIFFER 2008b, c).

26. Chemical monitoring data for sewage sludges from numerous sources were reported in work by SNIFFER (SNIFFER 2008d). The most significant biological risks to human health included *E. coli*, *Salmonella*, and hepatitis; several other human pathogens were also identified (SNIFFER 2008d). However, even in these cases the risk to those not working in close proximity to sludge was only moderate to low and the assessment included data that were not from the UK. If the biological treatment process used was undertaken correctly, the risk of the presence of pathogens should be very low and should diminish to background levels within a few months of application, although some pathogens may persist (Noble and Roberts 2003, Defra 2006).

27. Although there are potentially a huge variety of contaminants that could be present in recycled organic matter, the source of most of them can be found in widely available domestic and commercial products, making it difficult, if not impossible to eliminate them entirely. There is abundant evidence of metal contamination in composts, CLO and biosolids (SNIFFER 2008 b, d, Amlinger et al. 2004, Cameron et al. 2008, Chambers et al. 2002, DCLG 2008, Environment Agency 2010). Paper crumble, in contrast, has relatively low metal contamination, with the exception of copper, lead and zinc which are found in many inks and dyes used in the production process (Environment Agency 2005, Tucker 2005). Although some trace elements may be beneficial in small quantities, the concentrations found in recycled organic matter often exceed these concentrations.

A review of studies on the impacts of metal contamination on soil organisms, plants, grazing animals and wildlife (SNIFFER 2008b) showed that the conclusions of these studies are inconsistent, with different studies showing wide variations in effect. However, recent research in the UK on sewage sludge applied to agricultural land has suggested that the risk may be more significant than previously thought (Gibbs et al. 2007, Environment Agency 2008).

More recent research has also highlighted the potential for other forms of contamination besides metals in recycled organic materials. These include PAHs, PCBs, dioxins, furans and pesticides (SNIFFER 2008 a, b, Environment Agency 2010). These contaminants may or be persistent and may bioaccumulate. Some of these substances, if present at sufficiently high levels, can affect the health of natural plants and animals, affect grazing animals through the ingestion of plant material, and adversely influence human health. The migration of contaminants, in particular to ground and surface water, is a particular environmental concern.

Plant nutrients can also have short-term negative as well as beneficial impacts. Nitrate released from large additions of organic materials might be several times greater than plant requirements during the first season after application and may leach into drainage water. For example peak nitrate levels of 145 mg l^{-1} were recorded in drainage water in the first winter after application of 150 dry tonnes of sludge pellets to a reclamation site in County Durham (Newell-Price and Allchin 2003); however, nitrate levels may subsequently drop to little more than plant uptake needs in the second year (USEPA 1995). Small quantities of phosphate might be leachable, but movement of phosphate off-site is mainly through the erosion of particulate-associated phosphorus. High nutrient levels are inappropriate for certain vegetated after-uses, such as species-rich grassland, which thrives in soils poor in phosphate and potassium. For such uses low nutrient applications are most successful (Newell-Price and Allchin 2003, Gibbs et al. 2004).

28. The problem of physical contamination is largely confined to CLO, although composts and anaerobic digestate produced from source-segregated feedstock may also be affected to a lesser extent (Cameron et al. 2008, WRAP and Environment Agency 2009). Material such as stones, glass, rubble, plastics and metal may be present in recycled organic material, particularly, but not exclusively, when produced from mixed waste feedstock. Materials that are not derived from Municipal Solid Waste, such as biosolids, PMS, water treatment sludges and industrial wastes do not tend to suffer from this type of contamination. The adverse visual impact of physical contamination becomes an issue in sites that are open to the general public, such as recreational areas or housing developments. Some inert materials, such as stones, do not cause any actual harm to a soil profile; they do not, however, contribute any benefit to the soil either. Provided their content is not excessive they are of limited concern. Limits for the quantity of inert materials are specified within PAS100. The impact of such material in the environment is largely visual; fragments of glass can be seen to glisten and even small fractions of plastic are highly visible at a distance (Mamo et al. 2008). There is also potential for harm to wildlife or domestic animals via the ingestion of larger fragments of plastic.

29. The potential risk from the use of material should always be considered in the context of the potential benefit that its use could bring. Typical concentrations of principal contaminants and other characteristics of a range of recycled organic materials are shown in Table 3.1 below.

Table 3.1 Summary of physical, chemical and other characteristics of recycled organic materials.

Characteristic		Biosolids	Compost	CLO	Water Treatment Sludge	Digestate	Paper Crumble
Nutrients	**N**	✓✓	✓✓	✓	✓	✓✓	✓
	P	✓✓	✓	✓	✓	✓✓	✓
	K	✓ (depends on the biosolid)	✓	✓	✓	-	-
C:N ratio		✓✓	✓✓	✓	✓✓	✓✓	**X** (high)
pH		6.0-8.0 (lime-conditioned sludges at the higher end of the range)	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	70-8.0
Trace elements	**Cd**	**X**	X	X	-	X	-
	Cr	**X**	X	X	-	X	-
	Cu	**X**	X	X	-	X	**X**
	Hg	**X**	X	X	-	X	-
	Ni	**X**	X	X	-	X	-
	Pb	**X**	X	X	-	X	**X**
	Zn	**X**	X	X	-	X	**X**
Pathogens	***E. coli***	X Levels in most biosolids should be relatively low	-	X	-	-	-
	Sal	X	-	X	-	-	-
	C	X	O	O	-	-	-
	L	X	O	O	-	-	-
	H	X	O	O	-	-	-
Organic matter content (dry wt)		50%	15-40%	15-30%	50%	30-40%	30-70%
Moisture content		5-95% depending on the type of biosolid	15-30%	15-30%	50%	Variable depending on whether the digestate is whole, fibre or liquor	60%
Cost		Transport costs; thermally dried products may be more expensive due to production costs	Transport costs; producers may charge for the material	Free or a gate fee may be chargeable; may charge for transport costs	Transport costs	Transport costs; producer may charge for digestate produced to PAS110	Transport costs; producer may charge
Availability		Countrywide	Widely available	Limited availability	Countrywide	Limited Availability	Limited availability

(✓✓ significant benefit, ✓ beneficial, X possibly detrimental, **X** detrimental, O not routinely tested, - no data)

Sal = salmonella, C = campylobacter, L = listeria, H = hepatitis

SOURCES: WRc 1999; BSI 2005a; Forest Research 2006f; Nason et al. 2007; SNIFFER 2008b; Environment Agency 2010.

The data included in this table are indicative only and should not be used as a substitute for actual test data.

4 Regulatory requirements

Para **Comments**

30. The Waste Strategies for each of the devolved administrations are the principal documents describing the targets and goals for waste management in each country (Defra 2007, Northern Ireland Environment Agency 2006, Scottish Government 2003, Welsh Assembly Government 2002). These follow the principal European legislation in the field, namely the Waste Framework Directive (European Union 2008) and the Landfill Directive (European Union 1999). Defra first published its Waste Strategy in 2000 and published a revised version in 2007 (Defra 2007), by which time waste was an issue managed by the devolved administrations rather than by central Government. As stated in the code, the policies of the Waste Strategies for each country are broadly similar: the overall aims are to reduce the amount of waste generated, to improve the way that waste is managed by reducing landfill and increasing composting and recycling and waste-to-energy, and in so doing to reduce the carbon footprint of the country as a whole. The strategies follow the principle of the waste hierarchy, which places the reduction in waste generated, reuse of materials, recycling and composting, energy recovery, and disposal in order of priority. At the time of writing, publication of a revised Welsh waste strategy was imminent. The weblink provided leads to the homepage for the current strategy. The Scottish Government and Welsh National Assembly are currently developing proposals for zero waste strategies, but these are at present out to consultation.

31. Although developed in collaboration with and published by the British Standards Institute, it is important to stress that PAS100 and PAS110 (BSI 2005a, BSI 2008a) are specifications rather than fully-fledged standards (PAS stands for ‘Publically Available Specification’). In spite of this they have effectively been the industry standard until the development of the Quality Protocol and still have an important role. Other standards have been developed by industry in the past, notably the APEX standard for compost, but these have effectively been superseded by PAS100. PAS100 for composts produced from source segregated waste materials was originally developed in 2005 and has recently been subject to review; the new version of PAS100 has been out to consultation and will be released shortly. The final version of PAS110 for anaerobic digestates was released in 2009. No specifications are planned for other recycled organic materials of relevance to this code.

It is also important to stress that the requirements of the PAS are a minimum and that quality can be higher still.

32. Material that qualifies for a PAS is still classified as a waste in England and Wales and must be applied to land according to the relevant legislation. In Scotland, material that complies with PAS100 is considered to be fully recovered and is no longer regarded as a waste material once applied to land. The Scottish position on digestate produced to PAS110 has yet to be finalised. In order to be fully recovered within England and Wales, green waste compost and anaerobic digestate must also comply with the relevant Quality Protocol. Currently in Northern Ireland PAS100 compost is considered to be fully recovered, but as Northern Ireland has recently joined the Quality Protocols project this position will be reviewed. No decision on PAS110 has been taken in Northern Ireland at the time of writing.

The Quality Protocols (QP) project, a joint initiative by the Environment Agency and WRAP aims to identify the point at which a series of waste streams have been processed into a product and can cease to be classified as a waste material, therefore being released from the obligations of waste-related legislation (WRAP and Environment Agency 2007, WRAP and Environment Agency 2009). The principal goals of the project are to stop materials being landfilled unnecessarily and to increase the use as a resource of materials previously considered to be a waste. A Quality Protocol gives guidance on how waste should be recovered and removed from the regulatory regime. Materials that comply may be used more flexibly and may therefore be sold more readily, making better use of available resources while reducing waste to landfill. To date a total of 23 different waste streams have been included in the QP project and are at different stages of development. In some cases QPs have been prepared and published, while others are yet to be published but have been subject to consultation, and others have only recently been accepted into the waste protocol project. Green waste compost was the first protocol produced under the new scheme (Environment Agency 2008), while the Quality Protocol for anaerobic digestate was published this year. In the case of compost and anaerobic digestate, the Quality Protocols are closely linked to the relevant PAS, which also provides an input requirement to the Protocol in each case. Although the Quality Protocol is not a requirement in Scotland, if operators wish to do so they are free to comply with these regulations.

33. The Waste Management Licensing Regulations (HM Govt, 2005) were the principal form of regulating the application of waste materials to land across the UK until the inception of the Environmental Permitting Scheme. The Waste Management Licensing (Scotland) and Landfill (Scotland) Regulations are the principal Statutory Instruments in Scotland for managing waste. The Waste Management Licensing (Scotland) Regulations are due to be amended and will be introduced during 2010. The Waste Management Licensing Regulations (Northern Ireland) 2003 (HM Govt, 2003) are the principal Statutory Instrument affecting the classification and use of waste in Northern Ireland. If, according to the Waste Management Licensing Regulations of each devolved country, a material is a waste it may still be applied to agricultural land under a paragraph 7 exemption, or non-agricultural land under an paragraph 9 exemption (paragraph 11 in Northern Ireland). Not all organic materials are suitable for such exemptions and the application of the material must result in an agricultural benefit or an ecological improvement if it is to be acceptable and not considered as disposal. Further information on exemptions to the Waste Management Licensing Regulations in Scotland can be found at:

- http://www.sepa.org.uk/waste/waste_regulation/application_forms/exempt_activities.aspx

Further information on exemptions to the Waste Management Licensing Regulations in Northern Ireland can be found at:

- http://www.ni-environment.gov.uk/waste-home/authorisation/exemption.htm

34. The Environmental Permitting regime (HM Govt. 2007) does not apply in Scotland and Northern Ireland. Although it was officially launched in April 2008, the transition between the Permitting system and the old Waste Management Licensing regulations (HM Govt. 2005) is still underway. In England and Wales the majority of landspreading of organic materials for land restoration is undertaken under a paragraph 9 exemption from Environmental Permitting Regulations. The current Paragraph 9 exemption allows for the landspreading of the following organic wastes:

PART 1

Wastes from sugar processing - Soil from cleaning and washing beet.

Wastes from soil and groundwater remediation - Solid wastes from soil remediation (other than those containing dangerous substances).

Garden and park wastes (including cemetery waste) - Soil and stones.

PART 2

iv) Wastes from pulp, paper and cardboard production and processing - De-inked paper sludge and de-inked paper-pulp and lime mud waste.

v) Soil (including excavated soil from contaminated sites), stones and dredging spoil - Soil and stones other than those containing dangerous substances, and dredging spoil other than those containing dangerous substances.

vi) Wastes from aerobic treatment of solid wastes- Compost.

vii) Wastes from waste water treatment plants - Sludges from treatment of urban waste water.

viii) Wastes from the preparation of water intended for human consumption or water for industrial use - Sludges from water clarification.

ix) Wastes from soil and groundwater remediation- Sludges from soil remediation (other than those containing dangerous substances).

There are some notable omissions from the above list, which will be addressed when the Standard Permits system is operational. So far the Environment Agency has completed a consultation on sixteen new Standard Rules Permits, for which the following is the most direct replacement to the current Paragraph 9 exemption: Standard rule SR2009No10 Use of mobile plant for treatment of land for land reclamation, restoration or improvement. The view is that the transport of treated organic material to a site and subsequent application is equivalent to the use of a mobile treatment plant. A copy of this Standard Rule can be found at:

http://www.environment-agency.gov.uk/static/documents/Research/SR2009No10_Mobile_Plant_for_treatment_of_land_for_land_reclamation_restoration_or_improvement.pdf

35. The above draft Standard Rules Permit contains a new table of wastes which can be used in land restoration projects. While this table may be subject to amendment it does give a clear indication of the changes expected as a result of the move to Standard Permits. In addition to this Standard Rule, the draft report on exempt waste operations (Defra 2009d) was released to consultation in October 2009. It incorporates a new category, U11 ‘Spreading waste on non-agricultural land to confer benefit’, which is also an effective replacement of Paragraph 9.

Given that the draft regulations which deliver the Exemptions Review have been laid before Parliament the ‘go live’ date is expected to be 6th of April 2010. A copy of the draft Environmental Permitting Regulations, including the dates and transitional provisions can be found at:

http://www.opsi.gov.uk/si/si2009/draft/ukdsi_9780111487112_en_1

Further information on Environmental Permitting can be found in Defra (2009 b, c).

36. The Water Framework Directive and Groundwater Directive have only limited relevance to the use of recycled organic materials in land reclamation, and this will generally be in the case of large projects as they are the only ones that may notably affect the ecological status of water bodies. If necessary for the project, consultation with the regulatory authorities at a local level should be undertaken.

37. Although the prevention of nitrate pollution in the wider environment is a desirable outcome, it is not the focus of land reclamation. There are sound practical, ecological and soil science reasons for applying a greater quantity of nitrogen during organic matter application as part of at least some land reclamation activities than the quantity which is advocated in the Nitrates Directive for agricultural land (HM Govt. 2008). For example:

- In many cases the amount of organic matter required to improve highly degraded soils to functionality is significantly greater than the upper limits for nitrate application specified by the Nitrates Directive.

- Highly acidic substrates such as pyritic colliery spoil benefit greatly from the addition of organic material, but only in quantities that would exceed the limits for nitrate application to agricultural land.

- The level of nitrogen in soils on reclaimed land is typically far lower than that on agricultural land, therefore the arguments underpinning the Nitrates Directive that apply to agricultural land do not necessarily apply to typical soils requiring reclamation.

- Unrestored soils on previously developed land may potentially release more contaminants to the environment due to their poor quality.

- The nutrient content of recycled organic matter is usually contained in less mobile forms than in inorganic fertilisers, therefore it is less prone to leaching when applied in large quantities.

To illustrate this, several of the case studies featured in this code of practice used organic matter application rates that would have exceeded the maximum permissible rates under the NVZ regulations applicable to agricultural land (e.g. Athersley Memorial Park, Stokesley Park, Lambton cokeworks).

38. Further information on waste protocols and licensing can also be obtained from the Environment Agency Customer Contact Centre on 08708 506506 or from the Environment Agency website at http://www.environment-agency.gov.uk/subjects/waste. Note that in this case the information supplied may not be relevant in Scotland or Northern Ireland. In Northern Ireland there is no enquiries service directly related to organic wastes. The Northern Ireland Environment Agency enquiries switchboard may be contacted on 0845 302 0008 and the Netregs enquiries line is available on 028 9056 9373; alternatively an email enquiry may be sent to netregs@doeni.gov.uk. In Scotland further enquiries should be directed to the local SEPA office in the first instance. Locations of the offices can be found at:

- http://apps.sepa.org.uk/map/index.html

T 4.1 No additional comments.

5 Case Studies

Para Comments

39. The case studies listed in the code are included in the first section of this chapter, where they are discussed in further detail. These case studies illustrate most of the possible situations in which recycled organic matter may be used (former industrial sites, quarries, open cast coal mines, landfill sites), the types of end use following restoration (golf courses, recreational land, biomass cultivation) and the types of material used for restoration (biosolids, composts, paper crumble). They also include examples from around the UK. Additional case studies are briefly described at the end of this chapter to provide more examples of how the principles of land restoration operate in practice.

Lambton cokeworks

40. The Lambton cokeworks restoration project was part of the WRAP Trailblazer programme (WRAP 2008a, b, 2009a). The restoration of the 66 hectare former industrial site to mixed use, including housing, recreational land and grassland required the establishment of a completely new soil profile. The legacy of the cokeworks and other industrial activity that predated it was a severely degraded soil profile with poor physical characteristics. Following a period of dereliction after the closure of the site in 1984, the site was redeveloped over the period 2007-8 and included 23 hectares of recreational woodland and 10 hectares of grassland (WRAP 2008b). This trial formed part of the WRAP Trailblazer programme, designed to encourage the use of PAS100 compost in land reclamation projects. As such, it had to comply with waste management regulations in force at the time and to conform with licence exemptions where applicable.

In order to sustain the woodland and grassland an entirely new soil profile had to be created at the site to a depth of up to 2 metres, depending on the planned end use of the area. The volume of soil material calculated to be needed was 59,500 m^3 of topsoil and 402,500 m^3 of subsoil; insufficient material was available on-site to satisfy these needs and organic amendments were a necessary as well as desirable addition (WRAP 2008b). The forest soil created was 2 metres deep and had three horizons: in the case of the subsoil two different organic amendments were prepared, one containing compost and paper mill crumb in equal proportions and the other containing 80% compost to 20% paper mill crumb. In each case the organic material was mixed in the ratio of two parts organic material to five parts colliery spoil (WRAP 2008b). The grassland soil was 0.25 metres deep and created using soil forming material found on-site and organic material (paper crumble) added to the subsoil only if necessary to increase the quantity of soil forming material.

T5.1 No additional comments.

41. Evidence collected during the setup of the site and immediately afterwards (WRAP 2008a, b) as well as subsequent monitoring to August 2009 (WRAP 2009a) showed that soils created using a bulldozer were compacted to a far greater degree and had poorer structure in both the topsoil and subsoil than the equivalent soils created by loose tipping (WRAP 2009a). There was no evidence that any of the different ratios of compost, paper mill crumb and coal spoil that were trialled at the site showed any significant advantage in terms of aggregate stability (WRAP 2009a). Tree growth also appeared to be significantly affected by the compaction caused by using bulldozers as opposed to loose tipping. In contrast the different ratios of organic amendments appeared to make little appreciable difference to tree performance (WRAP 2009a).

Stockley Park

42. Stockley Park was a highly contaminated 400 hectare gravel extraction pit that subsequently became used as a landfill site before being transformed into a business park/leisure development in the mid 1990s (Evans 1998). Air-dried anaerobically digested biosolids were used as the organic material to reconstruct the soil profile of the site, to the west of London near Heathrow airport.

The site had been landfilled since the 1940s and subsequently restored poorly once the site was full. Before reclamation work started in the 1980s it was derelict and a source of groundwater pollution. 4.6M m^3 of fill were excavated to expose 10 ha on which the campus-style business park was built using leftover gravel on the site to create rafts, on which new buildings were constructed over the contaminated areas (Evans 1998). The excavated material was contoured over the remaining 100 ha of the site to make a rolling landscape that is used as an 18-hole pay and play all year championship golf course. Integrated with the golf course are lakes, running and riding tracks. The design of this area has specifically been undertaken to minimise any environmental impact from the previous use of the site. The topsoil has also been tailored to suit the needs of the subsequent application, in particular the golf course (Evans 1998). The site would have needed more than 300,000 m^3 of topsoil; there was none on site, so it was constructed in situ using suitably textured mineral material found during the excavations and 100,000 m^3 of air-dried biosolids from old sludge-drying lagoons. The biosolids were spread across the site at a depth of 100-150mm and subsequently incorporated to a depth of 50mm (Evans 1998). The net result was an increase in organic matter content from almost nothing to between 3% and 5% (Evans, 1998). Following the establishment of the topsoil a sward of grass was established across the site and allowed to establish healthy roots before it was incorporated into the soil, and a final grass sward was sown along with tree planting as and where required (Evans 1998). More than 140,000 indigenous trees and shrubs were planted with very high rates of establishment and less than 5% failures (Evans 1998). Since the site was established there has been no evidence of significant environmental issues cause by the former use of the site as landfill, either through the generation of methane or leachate (Evans 1998).

Stockley Park was reclaimed before the Waste Management Licensing Regulations came into force and therefore the material used was not applied under an exemption.

St Ninian's colliery

43. St. Ninian's opencast coal site is located close to the town of Kelty, north of Dunfermline in Fife, Scotland. Also known as Greenbank, it is a working surface coal mine extracting around 6,500 tonnes of coal a week from a site immediately West of the M90. The site owner, Scottish Resources Group (SRG), is the largest private sector landowner of brownfield sites in Scotland (WRAP 2009b). They are also at the forefront of promoting energy crops in Scotland. As part of this initiative the company has obtained planning permission for a 50 MW Combined Heat and Power plant at Glenrothes, which will have a requirement for 25,000 ha of energy crop per year. The fuel for the plant will be supplied from a combination of sites owned by the company, such as St Ninian's, and by encouraging local farmers to grow Short Rotation Coppice willow (SRC), a crop that is well suited to the climatic conditions of Scotland (WRAP 2009b). St. Ninian's is owned and operated by SRG and during the time of this case study project (2007-2008) coal was being extracted from parts of the site, while at the same time much of the site had been restored after earlier mining activity to agricultural uses similar to those that were in place prior to mining operations (WRAP 2009b).

44. Poor natural drainage conditions mean that even the undisturbed soils in the area are of restricted utility. The pre-working land use on the site was predominantly rough grazing with some improved grazing land, and the soils are described as mineral gleys (WRAP 2009b). They consist of 25-30 cm of poorly structured, stony, medium or heavy clay loam, overlying gleyed subsoil which is itself a very stony, unstructured heavy clay loam. There is no piped drainage system installed but there are ditches along the lower field boundaries to intercept surface run-off (WRAP 2009b). Chemical analysis of the topsoil prior to treatment with compost showed the pH to be slightly acid, soil phosphorous to be deficient, and soil potassium slightly deficient. Soil magnesium was satisfactory, indicating that the soil overall was relatively low in nutrients (WRAP 2009b).

45. Restored opencast soils may take between 5 and 10 years to recover from the physical degradation that can occur during the stripping, storage and spreading processes carried out during the opencast operation. PAS100 green compost has the potential to supply the necessary additional organic matter and nutrition to accelerate this recovery process and enable these soils to support SRC as a long term crop (WRAP 2009b). On this occasion the aim was to determine if the addition of compost, blended with the indigenous soils, had the potential to improve soil conditions and support a vigorous SRC crop. It was hoped that the addition of organic matter would improve soil structure and reduce compaction in the surface layer, improving water holding capacity and soil drainage. It also had the potential to initiate microbial activity and encourage nutrient recycling.

Plant growth trials were set up with a simple design of 3 rates of compost, replicated 3 times giving a total of 9 plots. Plot size was 1 hectare per plot with dimensions of 50 metres by 200 metres (WRAP 2009b). Compost was applied at 0 t ha^{-1}, 300t ha^{-1} and 600t ha^{-1}. Both the soil and the compost were sampled and analysed prior to setting up the trial and the soil was analysed six months after planting. Tree performance was assessed through measurements of plant emergence, survival and growth.

The addition of compost resulted in a decrease in laboratory bulk density and a large increase in organic matter, as well as increases in soil pH and conductivity, reflecting the higher salt concentrations in the compost amended plots (WRAP 2009b). This higher electrical conductivity is also reflected in higher levels of the plant nutrients nitrogen, phosphorous and potassium. Compost additions caused an increase in some potentially toxic metals, particularly zinc and lead, but even at the highest application rates the metal concentrations in the soil were well within acceptable levels (WRAP 2009b).

In the early stages of the trial weed growth was very notable, more so than tree emergence and greater in the plots where more compost had been applied (WRAP 2009b). In the initial stages, tree growth was better in the trial plots with lower compost applications; however this situation was reversed by the end of the growing season, with tree performance being significantly better with increased applications of compost (WRAP 2009b).

This trial formed part of the WRAP Trailblazer programme, designed to encourage the use of PAS100 compost in land reclamation projects. As such, it had to comply with waste management regulations in force at the time and conform with licence exemptions where applicable.

Cross Lane landfill

46. The Cross Lane landfill site to the west of Liverpool was a former municipal landfill site dominated by invasive species with soils unsuitable for plant establishment due to compaction and poor water retention (WRAP 2009c). When the 14.4 hectare site was closed in 1978 it was restored using a thin layer of subsoil, which failed to provide an adequate environment for vegetation establishment, hence the poor results. This case study provides an example of using organic materials to restore previously (poorly) restored land.

47. The renovation of the restored site used a combination of locally sourced silt from a nearby lake restoration project and sandy subsoil from a local redevelopment project combined with a PAS100 compost to create a new topsoil to support newly established woodland and native wildflower meadows. Experiments on site consisted of creating three different soils with different quantities of compost incorporated (15%, 30% and 45% respectively), as well as a control containing no compost. The manufactured topsoil was placed on the site surface to a depth of 30 cm. An additional treatment of soil containing 30% compost deposited on the surface as mulch was also prepared (WRAP 2009c). The amendments all produced increases in pH and reductions in bulk density, although two years after application there was little difference between the plots (WRAP 2009c). The site was also used as an investigation into using restored land for carbon sequestration. The results of this work were inconclusive; although generally positive, there were several issues remaining to be addressed at the end of the trial (WRAP 2009c).

This trial formed part of the WRAP Trailblazer programme, designed to encourage the use of PAS100 compost in land reclamation projects. As such, it had to comply with waste management regulations in force at the time and conform with licence exemptions where applicable.

Athersley memorial park

48. Athersley Memorial Park was created on the site of a spoil tip from the Warncliffe Woodmoor pits number 1, 2 and 3 on the fringe of Barnsley. The pit closed in 1966, leaving behind the spoil tip, which is surrounded on three sides by housing. The site had been reclaimed previously with the addition of a thin layer of topsoil which, while it promoted vegetation growth at first, was insufficient to maintain long-term plant growth due to the natural acidity of the coal spoil. The local colliery spoil contains a high level of pyrite, which produces sulphuric acid as it weathers. Application of lime, while it provides a temporary solution, is insufficient to counteract the natural acidity of the spoil material over a longer period.

The site was remediated for the final time in 1990. The creation of a completely new soil profile with large quantities of biosolids (50:50 with coal spoil appears to be the optimum ratio for these difficult materials) overcame the natural acidity of the site by providing sufficient buffering capacity and allowed vegetation to establish itself successfully. The site has become a well-used and valued local amenity and has helped to improve the image of the immediate area significantly.

Compliance of the imported biosolids with the prevailing environmental legislation was dealt with by the supply company, Yorkshire Water, rather than the site developer, Barnsley City Council. In terms of actual intervention in the site design, the only additional requirements of the regulator were furrows and rips to prevent incursion of biosolids into watercourse. In practice such risks were considered to be very low.

Ebbw Vale steelworks

49. Corus Ebbw Vale Tinplate Works closed in July 2002 and was decommissioned and demolished during 2004. A Masterplan and Development Framework for the redevelopment of the 90 hectare site was produced in mid 2003 (WRAP 2009d). This focused on the opportunity presented by the decommissioning of the site to improve the overall economic, social and development prospects for Ebbw Vale and Blaenau Gwent. As well as urban and infrastructure developments, the plan proposed significant areas of formal and informal open space as a key feature intended to integrate the infrastructure into the surrounding landscape (WRAP 2009d).

50. Significant site clearance and remediation of contamination was required prior to redevelopment, including the clearance of approximately 15 ha of reinforced concrete slabs underlain by 47 basements occupying a void space of some 220,000 m^3, capping off of more than 20 mine entries and the re-engineering of over 5 kilometres of unstable slopes, mostly supported by retaining walls in poor condition (WRAP 2009d). This is an example of the type of work that may be necessary to remediate contamination on a site prior to further work, as discussed in paragraph 62; in this case the remediation work was undertaken by a sub-contractor (WRAP 2009d).

Site investigation confirmed the absence of any natural soil cover on the site and the impracticality of recovering the glacial drift located beneath the made ground of the former site as soil-forming material. While the importation of topsoil might in the past have been regarded as the conventional approach to overcoming soil shortage on the site, this was discounted on the basis of it being unsustainable and at odds with UK and EU initiatives for the protection of soils. The soil strategy developed for the site focused on the use of industrial spoils (basic steel slag and colliery spoil) as soil-forming material, both of which were present on-site in significant quantity. These two mineral wastes were not ideal soil-forming materials, with issues including but not limited to hardness, alkalinity, poor water retention capacity, poor nutrient availability, high sulphur content, high levels of contamination, and heterogeneity of material (WRAP 2009d).

Within the plan there was a requirement for steep vegetated slopes to be developed; hence the slopes had to have an engineering function as well as the need to support vegetation (WRAP 2009d). Cost was also an issue due to the large quantity of material required to manufacture approximately 70,000 tonnes of topsoil. In the end a topsoil was manufactured using steel slag and colliery spoil sieved to 40mm, PAS100 compost, and gritstone fines (a by-product of sandstone production) that was necessary to replace the fine inorganic material that was not present in the slag and spoil (WRAP 2009d). Thermally dried sewage sludge was also added to provide a more immediate source of nutrients than that supplied by the PAS100 compost.

Across the site there was a need for five individual soil types derived from the soil forming materials described depending on the nature of the slope and vegetation (WRAP 2009d). Other design considerations related to drainage, particularly on the steep slopes that formed part of the site profile. Special provisions included intercepting water on slope crests via ditches, reducing slope length by the construction of drainage berms, rough surfaces to limit runoff, ‘scarred’ surfaces to encourage percolation to groundwater, and deeper soil profiles with drainage (WRAP 2009d). Some or all of these measures may be considered in sites where soil erosion by runoff is expected to be a concern.

Other considerations related to the selection of vegetation, in particular in relation to moisture control, but also in relation to the relatively alkaline environment created by using the organic amendments in combination with steel slag and colliery spoil, and in avoiding the use of wildflower plants on steep slopes, where they would struggle to establish themselves in competition against species necessary to avoid erosion (WRAP 2009d).

A total of 65,000 m^3 which equates to nearly 100,000 tonnes of soils were used at Ebbw Vale to create 20 ha of urban greenspace, including a significant component of woodland especially on the steeper valley slopes. The technical challenges presented by the site have not resulted in erosion: the site has withstood several intensive rainfall events and the only gullying which did occur was attributable to the overtopping of the interception ditch at the top of the slope. This highlighted the need for the drainage system to be maintained as fully effective throughout the duration of works (WRAP 2009d).

This trial formed part of the WRAP Trailblazer programme, designed to encourage the use of PAS100 compost in land reclamation projects. As such, it had to comply with waste management regulations in force at the time and conform with licence exemptions where applicable.

Polkemmet opencast site

51. The total area of the Polkemmet-Heartlands regeneration project comprises over 600 hectares, of which 120 ha is derelict land resulting from several decades of deep coal mining with associated spoil heaps comprising discarded colliery shale and much disturbed ground (WRAP 2009e). There were three mines across the site: Cultrig (closed in 1929), Greenrigg (closed in 1960) and Polkemmet (closed in 1984/5). There were also five smaller mines - Dumback, Murraysgate, Heads, Crofthead (Pits Nos. 4, 7 and 8) and Stonehead (Pits Nos. 1, 2 and 3). The spoil heaps that were created as a result of this mining activity have remained largely unvegetated, steep-sided and unsightly, and seriously detract from the surrounding landscape which includes moorland, woodland and a country park. It is estimated that there is approximately 4 million m^3 of colliery spoil left in the spoil heaps on site; these heaps cause significant environmental problems. Spoil heap No. 3 to the south of the site has been burning intermittently for over 30 years and the resultant fumes have caused nuisance to the local population. Rainwater percolating through the spoil heaps becomes contaminated with high concentrations of iron and aluminium, which in turn contaminates the two main watercourses draining the site and subsequently contaminates the River Almond (WRAP 2009e). The shale has a pH in the range 3.4 to 5.2 and the water draining from the spoil heaps into the watercourses was very acidic (pH values 3-4).

The site was acquired by a development company in 2002 with the aim of restoring the site to beneficial use by creating two championship grade golf courses, housing, plus hotel and leisure facilities. The decision to create golf courses as a major part of the Polkemmet restoration resulted from the need to combine a low sensitivity end-use with a high added value. As part of the restoration the site was to be mined by opencast methods. As well as winning a significant amount of high quality coal and providing income to help finance the restoration, the opencast mining enables the spoil heaps to be buried (so that no waste material has to be removed to landfill), stabilises the ground and provides a suitable landform for the golf course. This will greatly enhance the local area and provide a variety of new habitats of benefit to a range of plant and animal species, including water voles, otters and moorland plant and animal species (WRAP 2009e).

The overall site is around 400 hectares, which includes the area of derelict land from previous mining activity (120 ha) plus coniferous plantation, peat bog and low grade agricultural land (WRAP 2009e). This site is therefore an example of a restoration project involving more than just land disturbed by industrial activity.

Drainage was an important issue at the site and sustainable drainage systems were installed, as well as shale sub-layers formed from coal spoil beneath the areas of the site destined to be the golf course (WRAP 2009e). The manufactured topsoil is placed over the drainage layer and the appropriate grass seed mixture is sown. Infrastructure installation, comprising paths, access roads, electricity cables for lighting, irrigation, etc, will be installed at a later date.

Three main specifications for the manufactured topsoil were identified: high quality topsoil for specialized areas such as golf course fairways and other important grassed areas (about 70% shale to 30% compost); medium quality topsoil for golf course roughs and general landscaping purposes (coarser graded composts and on-site material); landscaping of woodland areas with trees in planting pits (planting pits use coarse composts and on-site materials). The compost has been sourced from several local producers (WRAP 2009e). Subsequent planting with trees has largely taken place with local specimens rescued from the site prior to the open cast mining phase (WRAP 2009e).

The Polkemmet project started in 2007 and is continuing in phases with an anticipated completion date in 2010, when the golf courses are expected to be at least partially opened. This trial formed part of the WRAP Trailblazer programme, designed to encourage the use of PAS100 compost in land reclamation projects. As such, it had to comply with waste management regulations in force at the time and conform with licence exemptions where applicable.

Machair sand dunes

52. The project on the Western Isles of Scotland was unusual in several regards. The sparse population, widely distributed on an island chain with difficult transport connections, the fact that much of the area was of natural and scientific environmental significance, the recent problem of biosolids and the concern over erosion combined to produce a unique situation. It also illustrates the possibility of using recycled organic material in sensitive areas, provided that it is undertaken in agreement with the relevant environmental protection body as outlined in the code.

Other sites

53. As well as the sites specifically mentioned within the code there are many more besides. Some of these are summarised in Table 5.2 below. Many of these sites are in England, many are colliery restoration projects, and many use compost as the source of organic material. Most of the sites mentioned have been restored as part of the WRAP Trailblazer scheme. Others have been restored as part of the work of the Land Restoration Trust. The use of compost has become more widespread in the past five years. Many colliery restoration and other land reclamation projects up until this point used biosolids. The geographical spread of the projects should not be taken as an indication that the need to reclaim sites is not an issue elsewhere in the UK

Table 5.2 Additional case study examples of land reclamation projects using recycled organic materials

Case Study	Location	Former use	End goal	Organic material(s)	Size of site (ha)
Aberbaiden Tips	Wales	Quarry	Restoration	Biosolids	3
Ayrshire	Scotland	Contaminated soil	Remediation	Manure compost/ PAS100 compost	
Blaenau Gwent	Wales	Steelworks	Remediation	PAS100 compost/ immature compost/ oversize green waste compost	
Bromsgrove	England	Quarry	Restoration	Biosolids	10
Chorley	England	Industrial	Mixed use	PAS100 compost	265
Collyweston	England	Limestone quarry	Restoration	MSW digestate	50
Conkers	England	Colliery	Visitor centre and National Forest	Biosolids (sludge cake)	50
Cromwell	England	Quarry	Restoration	Paper crumble	5
Cronton	England	Colliery	Habitat restoration	PAS100 compost	43

Case Study	Location	Former use	End goal	Organic material(s)	Size of site (ha)
Dubbers	England	China Clay Spoil	Restoration	Biosolids, Woodchip, Compost, Harbour Dredgings	50
Glynneath (Ynys Dawley /Darryl)	Wales	Colliery spoil	Grassland restoration	Biosolids	20 ha
Hawthorn	England	Colliery and cokeworks	Public open space and wildflower meadows	Biopellets	75
Lee Moor	England	China Clay Spoil	Restoration	Biosolids, Woodchip, Compost, Harbour Dredgings, Road Sweepings	50
Lumley North/ Coxhoe East	England	Landfill	Biomass production	PAS100 compost	60
New Park Springs	England	Coal Washing Tip	Restoration	Paper Crumble and Biosolids	65
Nottinghamshire tips	England	Colliery spoil tips	Green space and woodland	Biosolids (sludge cake)	450
Parc Penallta	Wales	Colliery spoil	Public open space	Biogran	180
Park pit (Bodmin Moor)	England	China clay spoil	Heathland/acid grassland Restoration	Water treatment works sludge	20
Penrhyn	Wales	Slate Quarry	Restoration	Sludge cake/paper crumble	-
Rabbit Ings	England	Colliery/cokeworks	Country Park	Sludge compost	50
Ravenscraig	Scotland	Steelworks	Mixed housing/ recreational	PAS100 compost	450
Shap Fell	England	Quarry	Restoration	Biosolids and Paper Crumble	3
Silverdale	England	Colliery Tip	Restoration	Biosolids, Water treatment sludge, paper crumble, green waste compost and PAS100 compost	65
Stannon (Nr Camelford)	England	China clay spoil	Heathland/acid grassland Restoration	Water treatment works sludge	20
Summerlee Bing	Scotland	Colliery waste tip	Agriculture	Biosolids (sludge cake)	50
Town Lane, Southport	England	Landfill site	Public open space	Paper crumble and biosolids	8
Woolley	England	Colliery spoil tips	Restoration	Biosolids, Compost, Woodchip	50

6 Code of practice for using recycled organic materials in land reclamation

Para **Comments**

54. The code has been divided into four discrete sections for clarity. It covers the assessment of sites for their suitability for organic matter application, site specific testing, application and aftercare. It does not specifically mention the planning process. The assumption of the code is that it is specific to the application of organic material to land, therefore planning applications do not form part of this assessment. For guidance on the planning process for land reclamation we recommend contacting the Planning Office of the relevant Local Authority. If you are unsure whom to contact we recommend the website of the Local Government Association (http://www.lga.gov.uk) as a starting point.

Each of the four parts of the code is independent; it is not essential to follow one before starting the next; for example a user of the code may wish to consult the section on aftercare for a project that has already begun or been completed. Clearly if a new project is being undertaken we recommend that the code is followed in its entirety. It is anticipated that Section one of the code will not take a great deal of time to complete and therefore commissioning for sampling and analysis can be undertaken at the same time as Section one actions to ensure a smooth transition between the two sections. Sections three and four must take place in sequence and cannot overlap either with each other or with Section two

55. Stakeholder interaction is increasingly becoming an obligation rather than a desirable extra, but it is also a valuable means of avoiding disagreements and disputes that could arise if there is no dialogue between the parties involved. This is not to say that dialogue will eliminate disputes, but it should help to resolve them more quickly and effectively. The scale of interaction may vary from informal discussions on-site, to full scale formal meetings and presentations, depending on the scale of the project. It is recommended to keep the number of stakeholders in proportion to the scale of the project to avoid unnecessary over-complication. Examples of the types of stakeholder that may be desirable include Local Government (planning and environmental departments), regulators from local or national offices, landowners from adjacent property, water authorities, local residents associations, and non-Governmental organisations.

General appraisal of potential for using organic materials on a site

56. The first stage of the code is a straightforward assessment of site suitability for reclamation. Most of the criteria at this stage are restriction criteria. The aim is not to prevent reclamation at this early stage but to define how and where reclamation activities may take place.

57. No additional comments.

58. If the site is part of an environmental protection area, consultation with the relevant environmental protection bodies as outlined in the code is essential. It is possible that some sites, particularly on the fringes of derelict sites, may provide valuable habitats; this is particularly likely to be the case on sites that have stood derelict for a long time, giving any flora and fauna time to establish themselves. If there is sufficient reason to believe that the reclamation site adjoins a habitat of environmental significance, advice should be sought on how best to ensure protection of the site while continuing with the reclamation work. It is not likely that this criterion would result in much land being eliminated from a reclamation process.

59. The investigators undertaking the initial assessment of the site should be sufficiently qualified to identify whether or not there are likely to be any potential areas of contaminated land in the site. The previous use of the site, records of previous site investigations and evidence of contamination beyond the site boundary may all provide further, more detailed sources of information. Guidance on whether the site is, or can be, classified as contaminated land can be found in Defra (2008).

60. Any risk of transfer of contamination beyond the site boundaries should be minimised, hence the recommendations of buffer zones and avoidance of areas with shallow groundwater or those that are prone to flooding. It should be confirmed from any previous documentation related to the site that the groundwater is not habitually shallow and that the current measurements are not abnormally high. On large sites it may be possible that drinking water abstraction points existed to supply the previous use of the site; whether this would still be considered as an abstraction point following removal of the point of demand is not clear as it may also be a supply point for other users in the vicinity; this should be discussed with the local utility company and the regulator on a site by site basis.

61. The recommended buffer zones are guides that relate to the potential level of nuisance caused by odour from the applications. Permanent residents are those most likely to be affected by the application and consequently the most likely to complain if affected, although odour problems tend to be transient. Workers may be affected by odour, but would be less likely to complain as it is not their place of permanent residence. As road users are only likely to be passing for a short period of time they are unlikely to be unduly affected by odour, but may be affected by any dust from spreading operations.

62. If it is possible to undertake earthworks to re-grade any steep slopes on the site it is recommended that this is done as it will make subsequent remediation work far more straightforward. If possible avoid creating slopes that terminate in a watercourse. However, it is possible that the nature of the end use of the site may require steep slopes, or that the possibility of exposing a contaminated substrate, or the design of a site (e.g. a colliery spoil heap) may mean that steep slopes are inevitable across the site.

63. The map, along with a brief report describing the site and any potential issues of concern, is the key output of this stage of the process. It should be used as the main source of information to guide the subsequent design and planning of the project.

F. 6.1 No additional comments.

Site-specific investigation and sampling, and assessment of appropriate soil amelioration methods

64. No additional comments.

65. It is the responsibility of the main development contractor to ensure that an appropriate soil survey has been conducted by an appropriately qualified soil scientist. This is in the interests of the site developer as it will give a good level of knowledge about the nature of the site and the presence of any usable material on-site.

66. If soil forming materials are present and required for the development the site should be sampled according to standard methods (e.g. BSI 2000, BSI 2002a). The information given in the code is a summary of the key points of the standard that provides the essential information. A suitably qualified member of the site investigation team should be able to provide more detailed advice on sampling and collection strategies if required.

67. Published standard methods that may be of relevance include BSI (2006) - Soil quality: pre-treatment of samples for physico-chemical analysis; BSI (1998) - Soil quality: chemical methods[2]); BSI (2008b) - Guidance on leaching procedures for subsequent chemical and ecotoxicological testing of soils and soil materials; BSI (2002b) - Soil quality: characterisation of excavated soil and other soil materials intended for reuse; and BSI (2005b) - Testing of pH. This is not an exhaustive list and standard methods are often withdrawn or updated. For the latest information on relevant standard test methods it is recommended to search the BSI website (http://www.standardsuk.com).

T 6.1 The basic physical and chemical properties and nutrient and contaminant content of the soil are vital pieces of information to determine the appropriate rate of application of recycled organic material.

68. The organic material(s) intended for the site, as well as any other inorganic materials to be used in the soil forming process should undergo a similar series of analyses. Alternatively, a typical composition based on a minimum of 30 analyses of equivalent material undertaken by a UKAS accredited laboratory should be provided. This may be sourced from the provider of the material, who should keep a record of the chemical quality of the material, or from the laboratory itself; in this case the data should be supplied without identification to protect confidentiality.

69. The potential for metals to leach from soil is greatly increased in acidic soils (SNIFFER 2008d), hence the recommendation to avoid application to such sites; for example, the sludge (use in agriculture) regulations (as amended) stipulate that sludge should not be applied to agricultural land with pH values below 5.0. However, there is also evidence that application of recycled organic material to acidic soils significantly improves the overall pH of the soil and therefore decreases the risk of leaching. There is also evidence from research undertaken by the Forestry Commission that leaching of heavy metals from acidic soils does not occur at pH values lower than 5.0 provided application rates are appropriate (Forest Research 2006f, Moffat 2006). As previously mentioned, in many cases this is the best approach to take for the improvement of many sites and the protection of the environment. If the average pH at the site is below 5.0 it is recommended that an organic amendment with a high pH is used for the application, bearing in mind the ideal conditions for the ultimate end purpose of the site. Discussion with the regulatory authorities should be undertaken to agree the best practical environmental approach to be taken in sites with highly acidic soils.

70. Calculating anticipated addition of contaminants to the soil based on the organic material and the soil forming material to be used is a straightforward process that should be undertaken by the site investigators or their relevant sub-contractors prior to application.

71. Environmental protection is an important priority and land reclamation should be undertaken with this in mind. However, if the ultimate goal of the site is to reclaim it for further onward

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[2] There are numerous individual standard tests included within BS 7775 covering a wide variety of analyses for various parameters.

use, the quality of the land post-reclamation should also be considered if applications of organic material would cause concern over the potential level of contaminants post-application. This should be justifiable in terms of the project itself (i.e. supporting evidence should be presented, if required, to demonstrate that the amount of organic material to be applied is actually necessary to the success of the project); it should also be justifiable in terms of the material used (i.e. the material to be applied has the lowest levels of contamination compared to alternative sources of material that are available within a reasonable transport and cost range); it also needs to be justifiable in terms of waste management (i.e. that the application will ultimately result in ecological improvement, despite the elevated contaminant concentrations). If required these issues should be discussed with the regulator at a local level and agreement reached that the level of application is appropriate.

T 6.2 Information sourced from the code of practice for agricultural use of sewage sludge (DoE 1996).

72. The characteristics of the final soil produced for a site can be predicted reasonably well on the basis of the characteristics of the soil forming materials to be used. The range of soil conditions tolerated by the plants that are planned for the site will also be known in advance; consequently plant performance can be reasonably forecast without resort to growth trials. However, such trials would provide site-specific information on performance and would provide a useful means of fine-tuning application rates or forestalling any unforeseen issues. They may also be used to provide a source of wider information such as leachate characterisation. Although not absolutely essential they are desirable on many grounds.

F 6.2 No additional comments.

Application of recycled organic matter as part of the restoration process

73. No additional comments.

74. The information provided in the table is for guidance only, based on the most likely end use of the land. The actual application rate should be determined for the individual site on the basis of the soil-forming materials to be used. It should not be assumed that the guideline maximum application rate should be used, as this may not be appropriate either for the site or the end goal of the reclamation project.

T 6.3 The information on application rates included in the Table has been left deliberately broad. This is a reflection of the wide variety of conditions found at individual sites, which will necessitate very different rates of application. The range also reflects the different end goals of the reclamation projects, particularly in the case of soil formation. Colliery spoil varies greatly in quality, particularly in terms of its acidity, which is the main driver for very high application rates of organic materials. As stated in the notes accompanying the table and elsewhere within the code, these application rates must be fine-tuned according to the site-specific information gathered about the physical and chemical quality of the site. If an application in excess of the maximum rate given in Table 6.3 can be justified in the site–specific circumstances, it should be justified to and agreed with the regulatory authorities in advance of work commencing.

75. Any applications that are made in excess of that actually required to fulfil the reclamation goal of the site will be considered as an act of disposal rather than reclamation of recycled organic material. The judgement as to whether an application is excessive will be made on the basis of the analysis of soil forming materials and the planned end use of the reclamation project. If good dialogue is maintained with the regulatory authorities at a local level and all discussion on this issue is held prior to application, this potential problem should be avoided relatively easily.

NVZ legislation (HM Govt. 2008) does not apply to reclamation projects or reclaimed land during the aftercare period. If possible within the wider goals of the reclamation project, nitrogen applications that are appropriate for the NVZ legislation should be used. However, this should not override the need to provide nutrients to what is often very poor quality soil. Consideration should also be given to the availability of nitrogen in the organic matter to be used and to the pool of nitrogen in the soil forming material when establishing an appropriate rate of application.

Careful selection of organic materials will help to reduce the impact of excess nutrients in cases where the NVZ limit must be exceeded in order to achieve the desired land reclamation goals.

76. The on-site material and any imported materials should be either mixed to form a topsoil-like material prior to being deposited across the site or the organic material should be applied directly to the surface of the site. The topsoil material thus formed should not be compared to a standard such as BS3882 (BSI 2007). This standard is intended for topsoils that will be traded on the open market, whereas soils manufactured on a reclaimed site are intended for use on that site and therefore do not qualify as a tradable material. Removal of such material would create a waste that requires disposal and the quality of the material itself may well not match that required by BS3882 (BSI 2007).

- Application of liquid sludge through conventional slurry spreading or shallow injection is becoming a far less common practice, due to the expense of transporting the sludge, odour and human health risks. Dewatered cake is more commonly used, is generally applied to the surface using an agricultural muck spreader, and is incorporated into the surface layer of soil by a heavy duty disc cultivator. Heavier applications can be worked more deeply into the rooting zone using a 360° excavator. Incorporation of material as soon as possible after application is the best means of ensuring minimal environmental impact due to runoff. The depth guide is based on rooting depth; in the case of trees it would need to be deeper (see the Lambton case study in section 5) but in this case it is recommended to dig holes for the trees at the relevant places to produce a pocket of soil rather than applying a blanket of soil material across the site.

- No additional comments.

- Applications on saturated or ponded surfaces provide an immediate link to water bodies; rainfall immediately after an application results in the same effect, particularly if material has not been incorporated.

- Compaction of soil can lead to significantly reduced plant performance as the structure of the soil is badly affected, reducing porosity and moisture holding capacity and increasing bulk density (WRAP 2009a); this makes root development more difficult and consequently plant performance suffers. Loose tipping is a beneficial method of soil preparation, although on large scale projects it is impossible to avoid the use of all machinery. If it is impossible to avoid creating tractor wheelings running downslope (due to limited access, for example) it may be best to access the slope via one route, creating a single set of tractor wheelings that can be subsequently reworked.

- No additional comments.

- o Although on occasions sites with very steep slopes are formed (See the Ebbw Vale case study for an example), these require very specific engineering to ensure their stability. In general, slopes steeper than 25 degrees present a hazard to the use of machinery and are more vulnerable to erosion. However, the addition of organic matter to soils improves its aggregate stability, which helps to prevent erosion. Options available for steep slopes are reworking the slope to a lesser incline as previously discussed, or no organic matter addition. On moderate slopes between 15 and 25 degrees, the main concerns are that material might be eroded away or washed off before it has had a chance to provide benefit to the soil. Lighter materials such as composts, materials with a high moisture content such as liquid sludges and digestate liquor, and biopellets, which are small, dry and lightweight, are all materials that are susceptible to erosion from water. As a result it is recommended that denser organic materials such as digested sludge cake are applied on steep slopes. Whichever material is applied it is recommended that the material is incorporated into the soil surface as soon as possible after application in order to avoid removal by erosion. Applications to sites in general, but on slopes in particular, are inadvisable if heavy rain is imminent (i.e. before incorporation can take place). On lower slopes the organic material intended for the whole site may be used as for the rest of the site. However, the advice regarding incorporation remains the same.

- o A sward of vegetation cover is one of the most effective means of preventing soil erosion on all ground and on slopes in particular. Planting should take place on-site as soon as possible after incorporation and ideally emergence should have taken place before any heavy rainfall.

- o No additional comments.

77. No additional comments.

78. The need for, and scale of, subsequent applications of organic matter, as well as the specification of the organic material can be determined as part of the ongoing monitoring programme described in the following section.

T 6.4 No additional comments.

Monitoring and aftercare of a site once reclaimed

79. Many reclamation projects subsequently failed or produced poor results at least in part because of poor aftercare of the site (Moffat and Laing 2003). A well planned, carefully engineered site with properly prepared soil and good growing conditions should require very little onward maintenance; however, even in these circumstances it is advisable to have a properly planned aftercare programme to ensure ongoing health of the site. An aftercare programme should be designed in conjunction with suitably qualified staff or sub-contractors; the exact content of the programme will depend on the nature of the site, the type of vegetation and the long-term goals of the project. For example, areas that have had their fertility boosted with an organic material and are subsequently planted with trees might need a frequent spraying programme to control weed growth until the trees become established.

- o No additional comments.

- Timing and frequency of aftercare monitoring will vary according to the individual site and the agreed aftercare programme; those suggested in the code are not mandatory and are provided for guidance. If there is no evidence of serious problems or issues that require monitoring, it is the responsibility of the survey contractor to recommend that the aftercare programme be terminated earlier than planned and the responsibility of the site manager to act on this advice as they see fit.

- No additional comments.

- The suggested contents of the aftercare survey cover all the likely requirements of such a survey. It may be that not all of the suggestions are appropriate, or that additional requirements are made. The key requirements of the aftercare survey are that it is carried out by suitably qualified staff who are capable of making a sound judgement on the nature of progress and identify the nature of any problems encountered, as well as recommending remedial action, and that the reports produced are clear and concise. It is assumed that the survey will not include any invasive techniques (such as soil pits, or root inspections) but this is not to say that they should not be undertaken. This would be at the discretion of the investigator undertaking the work on-site. If necessary, permission to undertake invasive assessments should be obtained from the site manager at the initiation of the aftercare programme.

- No additional comments.

- No additional comments.

80. No additional comments.

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