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Use of Sewage Sludges and Composts in Forestry

INFORMATION NOTE

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SUMMARY

This Information Note outlines the types of organic wastes that might be considered for application in forests or to land being prepared for woodland cover, especially brownfield land. It identifies important legislative controls over the use of these materials, and describes essential steps that must be taken in the decision process regarding their use. The Note should be read by forestry and land managers considering the use of these materials, and also by companies trading in sludge, compost and other waste that have an interest in recycling their materials on forest land.

INTRODUCTION

The 1980s and 1990s saw a large national research campaign to investigate the potential benefits of using sewage sludges as forest fertilisers. The main outcome of the research, A *manual of good practice for the use of sewage sludge in forestry* (Wolstenholme *et al*., 1992), set out where, when and how liquid and cake sludges might be used to increase forest productivity on infertile sites. The manual is now out of print, and its contents need revising, for several reasons. Firstly, changes in forestry policy and practice have occurred in response to falling timber revenues, and the need to embrace sustainable forest management. These require a holistic revision of thinking on the desirability of using sewage sludges to increase forest productivity. Secondly, technical developments in waste water processing have led to considerable diversification in sewage sludge types and qualities. Such materials are now sometimes called 'biosolids', or 'organic residuals'. Thirdly, national legislation has led to changes in regulations that control the application of sludge to land. Fourthly, sewage sludge is only one of several types of organic waste now being produced and for which recycling opportunities are being actively examined. Guidance on the use of organic wastes in forestry should take such materials into account.

This Information Note has therefore been written to update guidance on the use of organic materials, notably sewage sludges and composts, in forestry. However, more comprehensive guidance, akin to that contained in the manual of good practice, is likely to be issued when regulations currently progressing through European and national parliaments are established, and when the water and waste industries have had time to respond in the way they produce and market organic products.

THE VALUE OF ORGANIC WASTES IN FORESTRY

The potential value of various organic amendments to the soil is well known to those managing forest nurseries (Aldhous and Mason, 1994). Materials such as composted wood wastes, mushroom compost and spent hopwaste have all been used to maintain and improve soil organic matter levels, to stabilise soil structure and improve soil water holding and nutrient supplying capacity. Aldhous and Mason (1994) give guidance on appropriate application rates.

In conventional forestry in Britain, liquid and cake sewage sludges have been used to increase the fertility of infertile sites, a practice which is supported by a substantial research programme. This showed that sewage sludge could be used to improve foliar nutrition and forest productivity without deleterious environmental consequences, provided that amounts were appropriate to the needs of the tree (Bayes *et al*., 1991). Taylor and Moffat (1991) estimated that about 75 000 hectares of forest in Great Britain could benefit from the nutritional effects of sludge.

The greatest use of organic wastes in recent years has been in the reclamation of ex-mineral and brownfield land for woodland establishment. Soils and soil-forming materials on these kinds of sites commonly lack organic matter. They are consequently infertile, and possess poor physical structure and water holding capacity. Compared to established forests, adding relatively large amounts of suitable organic wastes to soils and soil-forming materials before tree planting can help to ensure sustainable tree growth, because such materials increase available water capacity and act as slow-release fertilisers. In fact, current guidance recommends the addition of organic materials unless natural soil materials are used in reclamation. Bending *et al.* (1999) and Bardos *et al.* (2001) have reviewed the role of organic wastes, and their application rates and application methodologies.

TYPES OF ORGANIC WASTES

A wide range of organic wastes might be considered for recycling in forests. These include waste products that have received only basic treatment, and others that have undergone considerable alteration compared with their raw feedstocks. This section gives brief descriptions of the most important of these materials, chosen for their widespread current or likely future availability.

Liquid sewage sludge

This has been the most common waste product from wastewater treatment. It consists of about 2–5% dry solids content, and has value as a nitrogen and phosphorus fertiliser. It is usually anaerobically 'digested' when bacteria and micro-organisms are used to reduce the volume of solids, and reduce odour and pathogen content. Digested materials are more acceptable for recycling to land compared to untreated liquid sewage sludges which have limited suitability for use in forestry. Liquid sludges have customarily been provided and transported to site by sludge producers free-of-charge. Transport costs will restrict the distance that the producer is prepared to take these types of sludge. Liquid sludges have received considerable testing in conventional forests (Bayes *et al.*, 1991) and on reclaimed land (Bending *et al.*, 1999).

Cake sewage sludge

This is produced by pressing or centrifuging liquid sludge – either untreated, or after digestion, treated with lime or other conditioning agents. It commonly contains 20–35% dry solids and also has a useful nitrogen and phosphorus content. Cake sludge derived from undigested liquid sewage sludge is generally not appropriate for use in forests because of its odour and pathogen content. Cake producers have also supplied these materials free-of-charge in the past. Like liquid sludges, considerable research has taken place on the use of cake sludges in both conventional forests (Bayes *et al.*, 1991) and on reclaimed land (Bending *et al.*, 1999). At the time of preparing this Note, cake from digested sludges is the most commonly available form of biosolids.

Cake sludges treated with liming agents (such as calcium oxide or hydroxide), or wastes such as cement kiln dust are usually highly alkaline in nature, and inevitably increase soil pH. These sludges have undergone only limited formal testing for their application in British forestry, but results suggest that tree nutrition and growth can be enhanced by their use (Luo and Christie, 2001). Such materials are not yet commonly available, but are likely to become more so in the future.

Thermally dried sludge

These granular or co-extruded pellitised materials are produced by heat removal of water from conventional sludges, both raw and digested. They commonly contain about 90–95% dry solids, and are easier to handle and incorporate in the soil than cake sludges. Thermally dried sludges are useful mineral fertiliser substitutes and have been traditionally regarded as slow release fertilisers because most of the nitrogen is in the organic form (Aitken, 1996). However, thermal drying may modify sludge organic matter, causing some forms to mineralise more quickly than conventional sludges (Smith *et al.*, 2000). Thermally dried sludges contain phosphorus in similar amounts to cake sludges, and also have some liming properties, (i.e. they reduce soil acidity). Thermally dried sludges are comparatively expensive to produce, and are usually sold on to users. There is a limited availability of thermally dried sewage sludges in the UK due to the small number of drying plants in operation.

Thermally dried sludges have received limited testing in conventional forests (Ferrier *et al.*, 1997), but have been widely used in land reclamation to forestry (Bending and Moffat, 1997; Bending *et al.*, 1999).

Composted sewage sludges

Sewage sludge can be composted by mixing sludge cake with other organic bulking agents such as straw, bark or green waste, in an aerobic composting plant. They have been advocated as useful amendments in horticultural and agricultural applications in the UK (Alexander *et al.*, 2002). However, they have not been tested in the UK for forestry applications at a field scale, and have received only limited testing overseas (Jokela *et al.*, 1990). Such composts are not yet commonly available.

Greenwaste compost

Green wastes and arboricultural arisings from domestic gardens, parks and transport corridors are the main feed-stock materials for composts produced by waste companies in central plants, often linked to waste transfer stations and landfill sites. Composts are being developed for a number of uses, especially domestic gardening and horticulture, but some may be available for more extensive use. Proposed benefits of compost include increased nutrient supply, soil cation exchange capacity, water holding capacity and soil structural improvement (Landscape Institute, 2003). Composts usually carry a charge depending on quality. Greenwaste compost has received only limited testing for its value to improve tree performance on reclaimed land in the UK, but there is good evidence that such material can be beneficial (Foot *et al*., 2003).

Other composts

A large range of other organic waste materials are composted, including seaweed, papermill sludge, putrescible municipal solid wastes (MSWs), spent mushroom production materials, forest and food processing wastes. Their availability is dependent on location of the composting plants. There has been no concerted study of these materials in a forestry context in the UK, though research overseas (e.g. US EPA, 1999) suggests that there can be beneficial effects on tree growth.

RECENT POLICY DEVELOPMENTS IN WASTE DISPOSAL

The 19th Report of the Royal Commission on Environmental Pollution 'Sustainable Use of Soil' was published in February 1996. It made specific recommendations about controlling the impact on soils from spreading of sewage sludge and other forms of waste disposal. In addition, there has been increasing pressure upon food producers to adopt strict standards in the use of sludge on agricultural land (ADAS, 2001). These initiatives have encouraged sludge producers to reconsider their products, and the desirability and commercialism of land recycling. As a result, only treated sludges are now available for application to food crops. A ban on the use of untreated sewage sludges on land for food production has been proposed (DEFRA/Welsh Assembly Government, 2002; Scottish Executive, 2002), which may increase interest in applying them to forest land. In a similar way, introduction of landfill tax in 1996 in anticipation of the EU Landfill Directive (CEC, 1999) has encouraged waste producers to recover more value from other waste products, for example through recycling or composting and to use more environmentally friendly methods of waste disposal. Consequently, there are more organic products available and greater interest from some waste producers and recycling companies in applying them to forests.

REGULATIONS AFFECTING THE USE OF ORGANIC WASTES IN FORESTS

Organic waste disposal is controlled by important legislation which has recently been revised across Great Britain. Waste Management Licensing Regulations currently limit the amount of wastes that can be spread on land in Great Britain, and the amount of heavy metals that the land can receive. The revised Regulations (Waste Management Licensing Amendment (Scotland) Regulations 2003, 2004; Waste Management Licensing (England and Wales) (Amendment and Related Provisions) Regulations 2005) identify those wastes where exemption from waste licensing may be granted if applied at no more than prescribed rates and where application will result in 'ecological improvement'. This has been defined in Scotland (but not in England and Wales) as 'the extent to which wildlife habitats which might otherwise deteriorate are maintained or supported. The creation of a new habitat, or the restoration of an old habitat, is an improvement'. The Regulations state that for most waste materials, no more than 250 tonnes ha^{-1} gross product may be applied in any period of twelve months, to an area of 50 hectares or less. Nevertheless, although these regulations control the maximum amounts of materials that can be applied on land exempt from a Waste Licence, they do not replace the need for a site-specific evaluation of the likely effects of waste utilisation and the risks associated with recycling. Table 1 should be used in conjunction with guidance in Table 2 to determine the suitability of a particular type of organic waste for a forestry use, and with Table 3 to ensure that the forest soil type is suitable for application.

There are also proposals to modify the levels of heavy metal concentrations for agricultural soils treated with sewage sludge and other organic wastes in England and Wales (DEFRA/Welsh Assembly Government, 2002; Scottish Executive, 2002). In the past, the Forestry Commission has adopted metal level limits applied to

Table 1

Materials approved for exemption from waste management licensing in forests and woodlands in England, Wales and Scotland in the revised Waste Management Licensing Regulations*. Such materials are also approved for parks, gardens, landscaped areas, sports grounds and recreation grounds. Exemption will only be authorised if the application results in 'ecological improvement'.

Source of waste	Kind of waste
Wastes from forestry, aquaculture, horticulture and fishing (plus agriculture in Scotland).	Plant-tissue waste.
Wastes from sugar processing.	Soil from cleaning and washing beet.
Wastes from wood processing and the production of panels and furniture.	Waste bark and cork; sawdust shavings, cuttings, wood, particle board.
Wastes from pulp, paper and cardboard production and processing.	Waste bark and wood; pulp from virgin timber.
Soil (excluding excavated soil from contaminated sites), stones and dredging soil.	Soil and stones.
Wastes from aerobic treatment of solid wastes.	Compost of biodegradable garden and park waste (only off-specification compost in Scotland).
Garden and park wastes (including cemetery waste).	Biodegradable waste; soil and stones.

*This table does not include sewage sludges which, in the revised Regulations, are dealt with separately. From 'The Waste Management Licensing (England and Wales) (Amendment and Related Provisions) Regulations 2005' and 'The Waste Management Licensing Amendment (Scotland) Regulations 2003, 2004'.

Table 2

Constraints to the application of organic wastes in conventional forests (derived from Wolstenholme *et al.* (1992) and Bending *et al.* (1999).

Attribute	Instruction/comment
Forest stand history	Waste incorporation is only possible before tree planting, or restocking. Spreading within pole-stage stands is possible for liquid and pelletised/granular wastes from racks.
Slope	The greater the slope, the greater the risk of run-off. No liquid wastes should be applied on slopes >25° or on ploughed slopes >15°.
Groundwater	Wastes should not be applied in sensitive areas where there is a risk of groundwater contamination. In addition, it is recommended that introduction of organic wastes into forests situated in Nitrate Vulnerable Zones (NVZs) under the Protection of Water against Agricultural Nitrate Pollution Regulations (1996) adheres to the restrictions contained within these Regulations.
Soil type and fertility	Table 3 contains those soil types where waste application may be appropriate. However, if fertility is adequate for current or proposed use, then application is unlikely to be exempt from waste Management Licensing Regulations. Other soil types are unsuitable for waste application.
Soil drainage characteristics and wetness	Wastes must not be applied to land when the water table is less than 1 m from the surface or when the soil is saturated.
Nature conservation	Wastes must not be applied in Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs), Special Protection Areas (SPAs), Special Areas of Conservation (SACs) or woodlands and forest stands subject to management for nature conservation (e.g. ancient woodlands, plantations on ancient woodland sites (PAWS), Sites of Importance for Nature Conservation (SINCs) or Local Nature Reserves (LNRs)).
Archaeological sites	All scheduled archaeological sites should be excluded. Guidance should be sought from competent authorities about unscheduled sites or monuments.
Sporting and recreation interests	Areas to receive organic wastes should be located away from high public usage and recreation areas. Consultation between forest users and managers should take place.
Proximity to dwellings	Organic wastes with significant odour must be incorporated in the soil to prevent material lying on the surface. Community consultation is strongly advised in advance of finalising proposals.
Waste type	Composts, sludges and semi-liquid wastes should be incorporated into the soil before woodland establishment or restocking. Industrial wastes such as particle board and sawdust are unlikely to be suitable in most forests.

Table 3

Forest soils generally suitable for organic waste application.

Soil type	Forestry Commission soil classification code[1]	Ecological site classification class[2]
Podzols[3]	3, 3m, 3p	Very poor and poor soil nutrient class
Ironpan soils[4]	4, 4z, 4b, 4p	Very poor and poor soil nutrient class
Littoral (freely drained)[4]	15d, 15e, 15i	Very poor and poor soil nutrient class
Disturbed and restored sites	2g, 2s	Very poor and poor soil nutrient class

[1]Kennedy (2002). [2]Ray (2001). [3]Note that this soil type often supports forest land managed for nature conservation objectives. Organic waste recycling is not suitable on such sites. [4]Research by Campbell *et al.* (2001) suggests that application on these soil types should follow precautionary principles. It is recommended that expert advice be sought.

agricultural soils as appropriate for forest soils (Wolstenholme *et al*., 1992), and Table 4 summarises the consequences if the recommendations in these consultation papers are adopted. There are also limits on the metal content of sludges destined for application to land in these regulations, and these limits, once decided, are likely to be applicable for forest land too.

USE OF SEWAGE SLUDGE AND COMPOST ON MINERAL AND BROWNFIELD LAND*

Application of organic wastes for the purpose of reclaiming land is subject to legal limitations separate to those applying to conventional forests. Approved wastes can be used, provided that they result in 'ecological improvement' (Table 5), defined in Scotland as before. The Waste Management Licensing Regulations stipulate a maximum application rate of 20 000 m^3 ha^{-1} for land reclamation in general, and there are also restrictions on the depths of application which are site specific. However, Bending *et al*. (1999) have recommended that organic waste applications be restricted so that no more than *c*. 1500 kg total N ha^{-1} are supplied as a one-off treatment before tree establishment, to reduce risk of leaching and excessive weed growth which can be difficult to control. Table 6 gives approximate amounts of various wastes that contain this quantity. These application rates are appropriate to the needs of the young trees, while the more vigorous weed growth inevitably encouraged by organic amendment should still be controllable by conventional means. However, this guideline is a general one and actual application rates should be based on the

*Brownfield land is the common term for 'Previously Developed Land'. 'Previously Developed Land' is defined in Planning Policy Guidance Document 3 (PPG3) 'Housing' (DETR, 2000) as land which 'is or was occupied by a permanent structure (excluding agricultural or forestry buildings), and associated fixed surface infrastructure'.

Table 4

Limit of total heavy metal concentrations in soils treated with sewage sludge (mg kg^{-1}). These limits are likely to be relevant for other forms of organic waste recycled in conventional forestry.

Element	Limit according to soil pH			
	5.0<5.5	5.5<6.0	6.0–7.0	>7.0
Zinc	200	200	300	300
Copper	80	100	135	200
Nickel	50	60	75	110
Lead	200	200	200	200
Cadmium	3	3	3	3
Mercury	1	1	1	1

From DEFRA/Welsh Assembly Government (2002).

Table 5

Wastes that may be exempt from waste management licensing if applied to brownfield land, and 'ecological improvement' can be demonstrated.

Source of waste	Kind of waste
Wastes from pulp, paper and cardboard production and processing.	De-inked paper sludge and de-inked paper pulp; lime mud waste.
Soil (including excavated soil from contaminated sites), stones and dredging spoil.	Soil and stones other than those containing dangerous substances; dredging spoil other than those containing dangerous substances.
Wastes from aerobic treatment of solid wastes.	Off-specification compost consisting only of biodegradable waste.
Wastes from waste water treatment plants not otherwise specified.	Sludges from treatment of urban waste water.
Wastes from the preparation of water intended for human consumption or water for industrial use.	Sludges from water clarification (England and Wales only).
Wastes from soil and groundwater remediation.	Sludges from soil remediation (other than those containing dangerous substances).

From 'The Waste Management Licensing (England and Wales) (Amendment and Related Provisions) Regulations 2005' and 'The Waste Management Licensing Amendment (Scotland) Regulations 2003'.

Table 6

Typical quantities of different organic amendments required to provide 1500 kg total nitrogen per hectare.

Waste or product	Dry solids added (t)	Wet tonnes added (t)	Phosphorus applied (kg)
Digested cake sewage sludge	50	200	760
Thermally dried sewage sludge	45	48	870
Well-rotted manure	107	179	430
Processed wood residue	94	104	470
De-ink papermill sludge	375	1250	300
Spent mushroom compost	58	115	400

From Bending *et al.* (1999).

degree of plant available nitrogen in the organic waste used, the supply or immobilisation of nitrogen in the soil or soil-forming material, the type of woodland to be established and its likely ground flora. All these factors are taken into account in the 'Nitrogen Balance Approach' for the calculation of organic waste application rates (Henry *et al.*, 1999). It is recommended that anyone considering the use of organic wastes should take independent professional advice if in any doubt about the appropriate application rate.

SLUDGE AND COMPOST STANDARDS AND QUALITY CONTROL

Waste producers are increasingly required to demonstrate the standard and qualities of the materials they produce, in order to allow proper methods for their use and to instil confidence. For many years, UK legislation has required sewage sludge producers to meet minimum requirements for the quality of sludge going to land application, and this has helped in the development of materials containing considerably smaller concentrations of contaminants and lower levels of pathogens than was the case in the past. This process is set to continue with tighter controls on sludge quality in the proposed revision of the Sludge Regulations (DEFRA/Welsh Assembly Government, 2002; Scottish Executive, 2002; Crathorne *et al.*, 2002). These regulations will provide tighter controls on the heavy metal contents of sludges destined for land, the introduction of microbiological standards for sludge quality, and increased requirements for monitoring, record keeping and reporting. Further, the processors of sewage sludge will be required to adopt the HACCP (Hazard Analysis and Critical Control Point) approach (used in food production) to ensure that products are above minimum quality standards.

In parallel, the rise in compost production using a wide range of feedstocks has necessitated that a common standard was developed to facilitate best practice in compost production and use (British Standards Institution, 2005). This 'PAS 100' standard contains limits for potentially toxic elements ('heavy metals'), human pathogens, phytotoxins and weed propagules which are set to ensure safe use of composts for a range of purposes. The standard has not yet been critically evaluated for use in forestry, but as a precautionary measure, the Forestry Commission strongly advises that composts to be used in forests meet this standard. In addition, recent guidance (Landscape Institute, 2003) has defined standards for important agronomic qualities of compost to be used in the manufacture of soil materials (i.e. to be used as amendments to soil-forming materials); these are also recommended in the forestry context (Table 7).

Table 7

Recommended compost properties for use in amendment to soils and soil-forming materials.

Property	Reported as (units of measure)	Recommended range
pH	pH units (1:5 water extract)	6.5–8.7
Electrical conductivity	$S\ cm^{-1}$ (1:5 water extract)	3000 $S\ cm^{-1}$*
Moisture content	% by mass of fresh weight	35–55
Organic matter content	% dry weight basis	>25
Particle sizing	% by mass of air-dried sample passing the selected mesh aperture size	95% pass through 25 mm screen; 90% pass through 10 mm screen
C:N ratio		20:1 maximum
Contaminant parameters	Various	Meet BSI PAS 100 criteria**

From the Landscape Institute (2003).
* If compost possesses a conductivity of above 2000 $S\ cm^{-1}$, apply it at proportionally reduced application rate.
** British Standards Institution (2005).

Previous guidance for use of sewage sludges in forestry (Wolstenholme *et al*., 1992) accepted that raw, undigested sludges could be used under certain circumstances. There is now a general presumption against the use of these products for land application to satisfy stakeholder perceptions, and it is now strongly recommended that only digested forms of liquid and cake products are used in forestry unless the undigested materials are thermally dried or alkali stabilised and/or appropriate incorporation can be assured.

APPLICATION IN PRACTICE

Conventional forests

The suitability of a forest site for the application of an organic waste will depend on the capacity of the crop to use the nutrients that it contains without detrimental effects – on or off-site. To ensure this, consideration should be given to physical, biological and environmental site factors, land-use and land management objectives and public health. Tables 2 and 3 give further information on these issues for conventional forestry sites, although detailed guidance is beyond the scope of this Information Note. Amounts of sewage sludge should normally be limited to provide no more than 1000 kg ha^{-1} of total N over the course of the planting/establishment stage or a similar amount over the pole stage. The *maximum* application in any one year should be 200 m^3 ha^{-1} liquid sludge or 50 wet tonnes ha^{-1} cake sludge. These application rates follow instructions in Wolstenholme *et al*. (1992) and are in agreement with more modern American guidance (Henry *et al*., 1999).

Application and incorporation methodologies for organic wastes are very dependant on the type of waste (e.g. liquid, solid or semi-solid), the life-stage of the forest in which the waste is to be applied and the equipment available to the contractor who undertakes the task. For new woodland, injection of liquid sludges and incorporation to bury solid wastes can follow standard practice for agricultural land. Application should be planned to tie in with other operations which are used to prepare the site for tree planting such as cultivation (Paterson and Mason, 1999; Willoughby and Moffat, 1996). It is unlikely that deep incorporation, below about 40 cm depth, is warranted – nutrients below the main root zone will be more likely to leach, and in seasonally waterlogged soils, the organic matter will further reduce soil oxygen, endangering root survival. However, further research is required to confirm the extent of these effects.

In established woodland, specialised tankers or retracting reel irrigators can be used for surface application of liquid waste, using extraction racks for access into the stand. Care should be taken to minimise tree and site damage through judicious timing of operations. Dry pelletised or granular wastes may be surface spread using conventional lime and fertiliser spreaders mounted, if necessary, on a forwarder (Alexander, 1996). It is unlikely to be appropriate to dispose of cake sludges or other semi-solid wastes in established woodland.

Mineral and brownfield sites destined for community woodland

Organic wastes should be incorporated into the soil or soil-forming materials used to establish woodland on the reclaimed site. If mineral materials are at their final resting place and in a compact state, then organic materials can be spread and incorporated in the course of the cultivation. The complete cultivation methodology, which involves the preparation of successive strips using an excavator, can readily be modified to permit addition of an organic amendment to the upper part of the reconstructed 'profile'. Spreading of wastes across the site in a single operation is not recommended as this will increase the risk of pollution. Deep ripping, used an alternative to complete cultivation to decompact soil materials, is ineffective at mixing organic wastes into them (Bending *et al*., 1999), and may increase the risk of water pollution, particularly if liquid sludges are used. If mineral materials have yet to be put in final position, then it is wise to employ 'loose tipping' to place them. This involves transporting the materials in dump trucks, and spreading the deposited soil materials using an excavator standing on the overburden. Incorporation of organic wastes can take place in tandem with the spreading operation, the whole process being undertaken in a strip system the width of which is determined by the reach of the excavator (Bending *et al*., 1999; Welsh Assembly Government, 2004). Existing guidance stresses the need for intimate mixing of organic and mineral matter in the root zone (Bending *et al*., 1999), and it is evident these materials can restrict downward root growth when placed unmixed in the soil. They may also pose a risk of leachate generation.

The use of organic materials in land reclamation will improve site fertility to the advantage of the trees planted on the site. However, weed growth will also be encouraged and it is vital to put in place a rigorous system of weed control. Tree shelters can be valuable in aiding establishment where organic waste materials are used and also make it easier to protect trees from herbicide applications. Establishing a sward of non-vigorous grass species will tend to suppress the emergence of annual and perennial broadleaved weeds between weeded areas.

Consultation and permission

The use of organic wastes is tightly controlled, and it is strongly advised that those considering their use consult with the Environment Agency (in England and Wales) or SEPA (in Scotland) as soon as possible. Formal application will also need to be made to gain an exemption from Waste Management Licensing, providing the various stipulations in the Regulations are adhered to. The new sludge and waste regulations also place certain responsibilities on the waste producer and land owner/manager for record keeping and reporting. Those intent on using organic wastes must follow these Regulations closely.

Prevention of pollution

Application rates and amounts of waste allowed on land discussed above are maximum amounts permitted or advised. It is very important that even if there are no constraints on usage (Table 2), only types and amounts of waste that result in ecological benefit are considered for application, and due care is taken of possible leaching, run-off and odour. It is difficult to be prescriptive because decisions must be based on individual site characteristics, especially slope, soil infiltration rate, tree crop life stage, antecedent and likely future weather conditions, and proximity to surface water courses and groundwater level. Expert advice should be taken if in doubt.

HEALTH AND SAFETY ASPECTS OF ORGANIC WASTE USE IN FORESTRY

Untreated sewage sludge contains a range of pathogenic organisms, the most common of which are bacteria (e.g. pathogenic strains of *Escherichia coli*, *Salmonellae* spp.), viruses (e.g. Adeno virus, Hepatitus virus) and parasites (e.g. *Giardia lamblia*, *Taenia saginata*, *Ascaris lumbricoides*) (CIWEM, 1995; Krogmann, 2000). Sewage sludge treatment is designed to reduce pathogens to a defined level, but inevitably this is not zero. Nevertheless, modern treatment can drastically reduce pathogen populations and this is an important reason why only treated materials are now considered suitable for recycling in UK forests. In addition, the soil is a generally hostile for pathogens whose natural environment is the human gut. Survival in the soil will depend on a number of factors, including soil moisture content, temperature, sunlight, pH, organic matter and antagonistic soil microflora. Some research from north America has suggested that access to treated sites should be denied for more than a year, and preferably two years, and that access should be conditional upon bacteria counts returning to satisfactory levels (Vasseur *et al.*, 1996). No comparable research has been carried out under UK conditions, but the relatively warmer soil conditions will benefit pathogen die-off rates compared to the north American studies. Carrington (2001) suggested that sludge incorporation will reduce exposure and risk to wildlife and recreational users of the land, but that the effects of environmental factors such as sunlight and temperature will also be reduced. Nevertheless, the research on this subject, coupled with the need for risk assessment and duty of care over forest visitors now suggests that the three month period for excluding people from forests treated with digested sludge in the UK recommended by Wolstenholme *et al.* (1992) may be too short. Certainly, it seems sensible to recommend strongly the injection or thorough incorporation of sludge materials, and raises questions over the spreading of liquid sludges in thinned stands unless these are located in remote areas and there is a prospect of successful deterrence.

Depending on source and subsequent treatment, composts have variable populations of human pathogens, but generally much smaller than in most biosolids due to the heat treatment that they undergo. For the reasons outlined above, there are increasing controls put on human pathogen content, and a recent specification supported by the UK composting industry has included (a) the absence of Salmonella species in 25 g representative samples taken after composting, and (b) *Escherichia coli* at <1000 CFU (colony forming units) g^{-1} (British Standards Institution, 2005). These standards should be sufficient to ensure safe use of composts in forestry.

SUMMARY OF RECOMMENDATIONS

Those considering the use of organic materials to improve site fertility and tree growth on conventional forest and brownfield land should consult with appropriate waste regulatory bodies at an early opportunity, and satisfy the needs of the relevant Regulations, which should be fully understood. Professional advice should be sought if in any doubt about the suitability of a particular organic material, or the application rate and method. Legal limits for application must not be exceeded, but appropriate rates of application are likely to be much smaller. Users of organic materials must consider fully the effects of using such materials on the wider environment, including the site biodiversity, water (surface and groundwater) draining from the site, visitors to the site or woodland, and people living nearby.

Recycling of organic wastes in conventional forests has the potential for increasing crop production, but is very dependent upon correctly matching material to site type. In contrast, on brownfield sites restored using soil-forming material, woodland establishment and subsequent performance will invariably be improved by incorporation of organic materials such as composts and biosolids.

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REFERENCES AND USEFUL SOURCES OF INFORMATION

ADAS (2001).
The safe sludge matrix. Guidelines for the application of sewage sludge to agricultural land.
www.adas.co.uk/matrix/SSM.pdf

AITKEN, M.N. (1996).
Use of sludge products in agriculture. In: *Proceedings of CIWEM/AquaEnviro 1st European biosolids and organic residuals conference, Wakefield, 1–2 October 1996.*

ALDHOUS, J.R. and MASON, W.L. (1994).
Forest nursery practice.
Forestry Commission Bulletin 111. HMSO, London.

ALEXANDER, A.C. (1996).
Ability of lime/fertiliser spreader equipment to apply sewage pellets/granules to restocking sites at Kielder: a desk study. Forestry Commission Technical Development Branch Report 8/96. Forestry Commission, Ae.

ALEXANDER, R., SZMIDT, R. and CRUZ, P. (2002).
Factsheet on composting biosolids. Remade Scotland, Glasgow.
www.remade.org.uk/Organics/organics_documents/20020713_BiosolidsFactsSheet.pdf

BARDOS, P., FRENCH, C., LEWIS, A., MOFFAT, A. and NORTCLIFF, S. (2001).
Marginal land restoration scoping study: information review and feasibility study.
Ex Site Research Project Report 1. Land Quality Press, Nottingham.

BAYES, C.D., TAYLOR, C.M.A. and MOFFAT, A.J. (1991).
Sewage sludge utilisation in forestry: the UK research programme. In: *Alternative uses for sewage sludge*, ed. J.E. Hall. Pergamon Press, Oxford, 115–138.

BENDING, N.A.D. and MOFFAT, A.J. (1997).
The use of thermally dried sludge as an organic amendment to coal minespoils: experience in the establishment of amenity and forest trees on reclamation sites in South Wales, UK. In: *Proceedings of CIWEM/AquaEnviro 2nd European biosolids and organic residuals conference, Wakefield, November 1997, Paper No. 44.*

BENDING, N.A.D., McRAE, S.G. and MOFFAT, A.J. (1999).
The use of soil-forming materials in land reclamation.
The Stationery Office, London.

BRITISH STANDARDS INSTITUTION (2005).
Specification for composted materials.
British Standards Institution Publicly Available Specification 100:2005, London.

CAMPBELL, C.D., PATON, G.I., TOWERS, W., PATERSON, E., DAWSON, J.J.C., CAMERON, C.M., COULL, M.C. and CHRISTIE, P. (2001).
A biological classification scheme to assess the sensitivity of Scottish and Northern Ireland soils to heavy metals.
Final Report to SNIFFER, No. SR (00) 09.
Macaulay Institute, Aberdeen.

CARRINGTON, E.G. (2001).
Evaluation of sludge treatments for pathogen reduction – final report. WRc Report CO 5026/1. European Communities, Luxembourg.
http://europa.eu.int/comm/environment/waste/sludge/sludge_eval.pdf

CEC: COUNCIL OF THE EUROPEAN COMMUNITIES (1991).
Council Directive of 12 December 1991 concerning the

protection of waters against pollution caused by nitrates from agricultural sources. (91/676/EEC). Official Journal of the European Communities No. L 375/1–8.

CEC: COUNCIL OF THE EUROPEAN COMMUNITIES (1999).
The landfill directive (1999/31/EC). Official Journal of the European Communities No. L 182/1–19.

CIWEM (1995).
Sewage sludge utilization and disposal. CIWEM, London.

CRATHORNE, B., ROWLANDS, C.L., BRYSON, P., COCHRANE, J. and SWEET, N. (2002).
Implementation of HACCP controls under the new Sludge (Use in Agriculture) Regulations. In: *Proceedings of CIWEM/AquaEnviro 7th European biosolids and organic residuals conference, Wakefield, 18–20th November 2002*.

DEFRA/WELSH ASSEMBLY GOVERNMENT (2002).
Proposals to amend the statutory controls for the agricultural use of sludge. Consultation Paper.
DEFRA, London.
www.defra.gov.uk/environment/consult/sewagesludge/pdf/sewagesludge.pdf

DETR (2000).
Housing. Planning Policy Guidance Note 3.
The Stationery Office, London.

FERRIER, R.C., PATERSON, E., DUTCH, J., DAVIDSON, J., WOLSTENHOLME, R. and HALL, J.E. (1997).
Application of thermally dried sewage sludge granules to early establishment Sitka spruce.
WRc Report UC 2899. WRc, Medmenham.

FOOT, K.J., HISLOP, M. and McNEILLY, S. (2003).
The effect of composted green waste on tree establishment on landfill. In: *Land Reclamation. Extending the boundaries*, eds. H.M. Moore, H.R. Fox and S. Elliot, Balkema, Lisse, 213–221.

HENRY, C., SULLIVAN, D., RYNK, R., DORSEY, K. and COGGER, C. (1999).
Managing nitrogen from biosolids. North West Biosolids Management Association. Seattle, WA.
http://faculty.washington.edu/clh/nmanual/nmanual.html

JOKELA, E.J., SMITH, W.H. and COLBERT, S.R. (1990).
Growth and elemental content of slash pine 16 years after treatment with garbage composted with sewage sludge. *Journal of Environmental Quality* **19**, 146–150.

KENNEDY, F. (2002).
The identification of soils for forest management.
Forestry Commission Field Guide.
Forestry Commission, Edinburgh.

KROGMANN, U. (2000).
Land application of sewage sludge (Biosolids). #8: Pathogens.
Rutgers Cooperative Extension Fact Sheet FS958.
Rutgers University, New Jersey.

LANDSCAPE INSTITUTE (2003).
Compost specification for the landscape industry.
www.l-i.org.uk/Publications/Composting%20 Specifications.pdf

LUO, Y.M. and CHRISTIE, P. (2001).
Short-term effects of alkaline biosolids on pH and trace metals in oligotrophic forest peat and on growth of *Picea sitchensis*. *Forestry* **74**, 145–159.

PATERSON, D.B. and MASON, W.L. (1999).
Cultivation of forests soils.
Forestry Commission Bulletin 119.
HMSO, London.

RAY, D. (2001).
Ecological Site Classification. A PC-based decision support system for British forests.
Forestry Commission, Edinburgh.

ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION (1996).
Sustainable use of soil. 19th Report of the Royal Commission on Environmental Pollution.
The Stationery Office, London.

SCOTTISH EXECUTIVE (2002).
Safer sludge. The Scottish Executive's consultation paper on proposals to amend the statutory controls and the UK Code of Practice for the agricultural use of sewage sludge.
Scottish Executive, Edinburgh.
www.scotland.gov.uk/consultations/environment/sscd.pdf

SMITH, S.R., DURHAM, E., ANDREWS, M.J. and JOHNSON, A. (2000).
Nitrogen release and fertiliser value of thermally dried biosolids. In: *5th European biosolids and organic residuals conference*, vol I, Wakefield, 20–22 November, eds by P. Lowe and J.A.Hudson.

TAYLOR, C.M.A. and MOFFAT, A.J. (1991).
The potential for using sewage sludge in forestry in Great Britain. In: *Alternative uses for sewage sludge*, ed. J.E. Hall. Pergamon Press, Oxford, 103–114.

US EPA (1999).
The effects of composted organic materials on the growth factors for hardwood and softwood tree seedlings.
www.epa.gov/epaoswer/non-hw/compost/trees.pdf

VASSEUR, L., CLOUTIER, C., LABELLE, A., DUFF, J.-N., BEAULIEU, C. and ANSSEAU, C. (1996).
Responses of indicator bacteria to forest soil amended with municipal sewage sludge from aerated and non-aerated ponds. *Environmental Pollution* **92**, 67–72.

WELSH ASSEMBLY GOVERNMENT (2004).
Minerals Planning Policy Wales. Minerals Technical Advice Note (Wales) 1. Aggregates. Annex C. Soil. National Assembly for Wales, Cardiff.
www.wales.gov.uk/subiplanning/content/minerals/mtan1/mtan1-aggregates-e.pdf

WILLOUGHBY, I. and MOFFAT, A.J. (1996).
Cultivation of lowland sites for new woodland establishment. Forestry Commission Research Information Note 288. Forestry Commission, Edinburgh.

WOLSTENHOLME, R., DUTCH, J., MOFFAT, A.J., BAYES, C.D. and TAYLOR, C.M.A. (1992).
A manual of good practice for the use of sewage sludge in forestry. Forestry Commission Bulletin 107.
HMSO, London.

Useful links

The Composting Association
www.compost.org.uk/dsp_home.cfm

DEFRA (Water quality/sewage)
www.defra.gov.uk/environment/water/quality/index.htm

DEFRA (Recycling and waste)
www.defra.gov.uk/environment/waste/index.htm

Environment Agency (Waste to land Regulations)
www.environment-agency.gov.uk/subjects/waste/232052/?version=1&lang=_e

SEPA
www.sepa.org.uk

Water UK
www.water.org.uk

Wastewatch (Availability of composted products)
www.recycledproducts.org.uk

WRAP (Waste Resources and Action Programme)
www.wrap.org.uk/index.asp

Welsh Assembly Government (Brownfield soil management)
www.wales.gov.uk/subiplanning/content/minerals/mtan1/mtan1-aggregates-e.pdf

Legislation

The Landfill Tax Regulations 1996
www.opsi.gov.uk/si/si1996/Uksi_19961527_en_1.htm

The Protection of Water against Agricultural Nitrate Pollution Regulations 1996
www.opsi.gov.uk/si/si1996/Uksi_19960888_en_1.htm
www.opsi.gov.uk/si/si1996/Uksi_19961564_en_1.htm
www.opsi.gov.uk/sr/sr1996/Nisr_19960217_en_1.htm

The Sludge (Use in Agriculture) Regulations 1989
www.opsi.gov.uk/si/si1996/Uksi_19961527_en_1.htm

The Sludge (Use in Agriculture) (Amendment) (England and Wales) Regulations 2002.
This is a public consultation paper only.

The Waste Management Licensing Regulations 1994
www.opsi.gov.uk/si/si1994/Uksi_19941056_en_1.htm

The Waste Management Licensing (England and Wales) (Amendment and Related Provisions) Regulations 2005
www.opsi.gov.uk/si/si2005/20050883.htm

The Waste Management Licensing Amendment (Scotland) Regulations 2003
www.opsi.gov.uk/legislation/scotland/ssi2003/20030171.htm

The Waste Management Licensing Amendment (Scotland) Regulations 2004
www.opsi.gov.uk/legislation/scotland/ssi2004/20040275.htm

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