Forest Research

APPLICATION OF SEWAGE SLUDGES AND COMPOSTS

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BPG

NOTE 6

Best Practice Guidance for Land Regeneration

Introduction

In the past organic amendments have been overlooked in favour of mineral fertilisers to kick-start vegetation establishment on poor soils. The success of organic 'wastes' as soil improvers in agriculture and horticulture (Figure 1) has led to increased interest in their potential value to forestry and land reclamation. The immediate action of organic amendments is to rapidly increase soil organic matter content, raising fertility and creating a more favourable environment for the establishment of vegetation. They stabilise soil structure, improve water-holding capacity and are a valuable source of macro- and micro-nutrients essential for plant growth. The long-term goal for addition of soil amendments is to improve both the chemical and physical properties of the soil.

This BPG Note discusses the properties of various organic amendments and their potential applications with reference to particular qualities. The regulations surrounding application of sewage sludges and other organic amendments are also discussed.

Figure 1 Wood residues stacked for sale to the horticulture industry.

Advantages of organic soil amendments

The advantages of using organic soil amendments are wide ranging; these, together with disadvantages, are outlined in Box 1.

Box 1 Advantages and disadvantages of organic soil amendments.

Advantages	Disadvantages
Chemical • Stabilise or increase pH • Most immobilise metal contamination • Act as slow release fertiliser (nitrogen and phosphorus) **Physical** • Decrease bulk density in compacted soils • Increase soil porosity • Increase soil water holding capacity • Increase hydraulic conductivity • Reduce surface crusting leading to improved water infiltration **Other** • Increase micro-organism activity	• Can immobilise plant-available nutrients if carbon:nitrogen (C:N) ratio is above 25:1 • Possible heavy metal contamination • Presence of potentially harmful organisms (plant, animal and human pathogens) in insufficiently composted materials • If C:N is below 10, amendments are more likely to contribute to nutrient leaching from the amended soil

Applications of sewage sludges and composts

Forestry

Tree growth on nutrient-deficient soils in productive woodlands can be enhanced through the application of organic wastes as a substitute for conventional fertilisers. The suitability of a site is dependent on the capacity of the tree species to utilise the nutrients without resulting in damage to the tree stand. Soil pH will be affected by the application of organic amendments and it is essential to match this pH after application of the amendment to the intended land use since some species prefer acidic conditions and others are better suited to more alkaline conditions. Sewage sludge can be used to increase or decrease the pH of soil by specifically adding alkali-conditioned or acidic sludge materials. Organic composts have only a small neutralising effect and tend to maintain rather than significantly alter pH. Table 1 sets out generalised constraints to 10 main site properties for the application of organic wastes to forests. Further information should be sought regarding specific details.

Table 1 Application constraints for organic wastes in conventional forests.

Site property	Information
Forest stand history	Ideally waste incorporated prior to planting. Surface application of liquid wastes is possible in young plantations up to pole stage.
Site slope	Risk of run-off is increased on sloped sites. Liquid waste should not be applied on slopes >25° (>15° on ploughed slopes).
Groundwater	If there is a risk of groundwater contamination waste should not be applied.
Soil	Podzols, ironpan soils, littoral, disturbed and restored sites are soil types suitable for organic waste application. Expert advice should be sought for information regarding specific soil types.
Soil drainage	Waste should not be applied when the water table is at or near (<1 m) the soil surface or when soil is saturated.
Ecology	Waste must not be applied in SSSIs, NNRs, SPAs, SACs or woodland/ forests managed for nature conservation.
Archaeological site	Waste should not be applied to any archaeologically significant site. Guidance should be sought from appropriate authorities.
Recreational usage	Waste application should be kept away from recreational or high public use areas.
Residential property	Malodorous (having an unpleasant smell) wastes should be thoroughly incorporated into soil. Community consultation is recommended.
Type of waste	Sewage sludges and other semi-liquid wastes should be incorporated into the soil before planting/restocking. Green wastes are only suitable for spreading on the land surface before planting/ restocking. Industrial wastes such as sawdust are unlikely to be suitable in most forests.

SSSI: Site of Special Scientific Interest. NNR: National Nature Reserve.
SPA: Special Protection Area. SAC: Special Area of Conservation.

Land reclamation – brownfield land

The application of sewage sludges and other organic wastes can aid woodland establishment on brownfield and contaminated land. In addition to improving tree growth, sludge application helps to establish a cover of ground vegetation. Soils on these sites commonly lack organic matter, have little or no topsoil and low levels of essential macro-and micro-nutrients that plants need for growth and health. Soils on brownfield sites have characteristically poor physical structure, poor water-holding capacity and are conceivably contaminated with a diverse range of potentially toxic elements (PTEs). Incorporation of organic wastes into such soils prior to planting (Figure 2) can help to abate the structural issues by providing bulky organic matter, the growth and health issues by acting as slow release fertilisers and the contamination issues by reducing metal mobility and hence bioavailability. The addition of organic amendments containing a high proportion of organic matter has the potential to decrease the bioavailability of soil-borne contaminants to plants and permit re-vegetation of brownfield sites. The mobility of heavy metals may be reduced by the formation of insoluble complexes between organic matter and soil metals. This complex formation is pH dependent and can also result in metal mobilisation through the formation of soluble organic matter and metal complexes in the soil solution. Soluble metal complexes form at high pH and the uptake of metals into vegetation is increased. Many toxic organic compounds such as herbicides and hydrocarbons can be degraded by micro-organisms present in composted organic soil amendments.

Grassland

Organic amendments can be used to add nutrients to established or new areas of grassland. The application of organic amendments during seedbed preparation may significantly raise soil fertility, eliminating the need for costly inorganic fertilisers for several years and possibly altogether.

Figure 2 Incorporation of sewage sludge by excavator.

Types of organic amendments

The main types of organic amendments and their key properties are listed in Table 2.

Table 2 Key properties of organic amendments.

Type	Fertiliser value			C/N ratio	Organic matter content	Cost/availability	Other properties
	N	P	K				
Liquid sewage sludge	••	•	x	••	••	Free to users; transport costs to be paid	Generally unpleasant to use; biological pathogens likely although reduced in 'digested' sludges; heavy metals possible
Sewage sludge cake	••	••	x	••	••	Free. Most common biosolid currently available	Possible heavy metals, malodorous, pathogens likely if originated from undigested liquid sludge
Thermally dried sewage sludge	••	••	x	••	••	Comparatively expensive, limited availability	Liming properties
Alkali-conditioned sewage sludge	••	x	•	••	••	Cost charged, not commonly available	Increase soil pH, risk of nitrate leaching
Composted sewage sludge	•	•	•	••	••	Cost charged, not commonly available	Horticultural use
Greenwaste compost	••	•	•	••	••	Cost charged, available throughout UK	Mature composts provide slow release of N
Wood residues (various from forest industries)	xx	x	x	xx	xx	High production costs; widely available in a range of types	Principally increases soil porosity and drainage, can cause N deficiency: addition of N fertiliser recommended
Animal manure (cow)	••	x	x	••	••	Mainly transportation costs, readily available	Different sources of origin, e.g. cattle, pig. Properties vary dependent on source. Potential loss of N through volatilisation of NH_4-N
Industrial by-products (papermill sludge)	xx	x	x	xx	xx	De-watered papermill sludges widely available; generally provided free of charge	N immobilisation due to very high C:N ratio, possible presence of fungicides/ bactericides
Spent mushroom compost	••	•	••	••	••	Cost charged, readily available	Used as a surface mulch,can be detri-mental to young plants
Straw	xx	x	x	xx	xx	Low cost, commonly available	Can cause N deficiency
Blood and guts	••	x	x	•	•		Generally unpleasant to use unless processed

•• Very good; • good or adequate; x no effect; xx may be detrimental.

Regulations for use of organic wastes

The Waste Management Licensing Regulations (England and Wales, Amendment and Related Provisions 2005; Scotland, Amendment 2003, 2004) currently control the maximum application rate of organic wastes to land within the UK. Use and disposal of organic wastes is highly regulated and therefore the Environment Agency (in England and Wales) or SEPA (in Scotland) must be informed if waste amendments are to be used. The processing and end product quality of composted materials are controlled by the British Standards Institution's Publicly Available Specification (BSI PAS 100: 2005). The compost parameters laid out in PAS 100 are based on end use as shown in Table 3. The UK sewage sludge regulations (Sludge (Use in Agriculture) Regulations, 1989) provide controls for the heavy metal content of sludges destined for land application. They specify yearly limits for certain elements and also that the soil pH shall not be less than 5 (Table 4). Requirements for monitoring, records keeping and reporting are detailed in the regulations.

Table 3 BSI PAS 100 quality criteria for composted materials (adapted from WRAP, 2006).

Parameter	BSI PAS 100 limit
Material of origin	Input materials not contaminated Source-separated biodegradable materials
Human pathogens	*E. coli* < 1000 CFU g^{-1} *Salmonella* species absent in 25 g sample
Potentially toxic elements	Cadmium ≤ 1.5 mg kg^{-1} (dry matter) Chromium ≤ 100 mg kg^{-1} (dry matter) Copper ≤ 200 mg kg^{-1} (dry matter) Lead ≤ 200 mg kg^{-1} (dry matter) Mercury ≤ 1 mg kg^{-1} (dry matter) Nickel ≤ 50 mg kg^{-1} (dry matter) Zinc ≤ 400 mg kg^{-1} (dry matter)
Physical contaminants • Total glass/metal/plastic ≥ 2 mm • Stones/other mineral contaminants ≥ 2 mm	 ≤ 0.5 % (m/m) of air-dried sample (of which ≤ 0.25 % is plastic) ≤ 7 % (m/m) of air-dried sample
Phytotoxins	Plant growth ≥ 80 % of the performance achieved by controls
Weed propagules	Viable weed seeds ≤ 5 per litre

Table 4 Limit of potentially toxic element concentrations in soils with applied sewage sludge (mg kg^{-1} dry matter). From The Sludge (Use in Agriculture) Regulations 1989.

	Limit according to soil pH			
Potentially toxic element	5.0 < 5.5	5.5 < 6.0	6.0 < 7.0	> 7.0
Zinc	200	250	300	450
Copper	80	100	135	200
Nickel	50	60	75	110
Lead	300	300	300	300
Cadmium	3	3	3	3
Mercury	1	1	1	1

Practical application of organic amendments

Brownfield site application for woodland establishment

Organic wastes should be incorporated into the soil during site cultivation. Tree growth will be enhanced for the reasons given in this BPG Note, however weed growth will also be accelerated and proper control measures must be put in place. The application rate for organic waste is strongly dictated by specific site characteristics. Decisions must be based on factors such as degree of slope, soil infiltration rate, prior weather conditions and future weather patterns, proximity to surface watercourses and groundwater level. The application of organic wastes in land reclamation is subject to legal limitations (The Waste Management Licensing (England and Wales) (Amendment and Related Provisions) Regulations, 2005; The Waste Management Licensing Amendment (Scotland) Regulations, 2003, 2004). Waste regulations state a maximum application rate of 20 000 m^3 ha^{-1}. Bending *et al*. (1999) suggest that in general no more than 1500 kg nitrogen ha^{-1} be applied in a single treatment. Application rates should be based on the amount of plant available nutrients in the organic waste and the mobility of soil nitrogen. Advice should be sought regarding specific application rates as overdosing can dramatically increase weeding costs and in some cases actually threaten or destroy the environment you are trying to create. When using organic amendments for woodland establishment the choice of tree species must be carefully considered. The nutrient demand varies between different species of trees. Ash, English oak and Sitka spruce are difficult to establish on nutrient-deficient sites and will therefore require a higher application rate of organic amendment while alders are able to establish quickly on infertile sites. Alders can also be beneficial to species with high nitrogen demands because of their ability to fix nitrogen; on infertile sites nitrogen demanding species can gain nutritionally by co-planting with alder.

Forestry application

Once the need for soil improvement has been established through systematic soil sampling (see BPG Note 1) the application method for organic amendments is largely dependent on the type of waste being used and the stage of crop development. Waste can be applied and incorporated into new woodlands during site preparations for planting such as cultivation. In mature woodland, specialised tankers or retracting reel irrigators can be used for surface application of liquid wastes. Pellet wastes can be applied to the soil surface using conventional spreaders. It is important to consider forest characteristics on a site-by-site basis, taking into account individual physical, biological and environmental factors as well as land use and management and public health. Application rates for sewage sludge should be such that no more than 1000 kg ha^{-1} total nitrogen is provided during the planting / establishment stage. No more than 200 m^3 ha^{-1} of liquid sludge or 50 wet tonnes ha^{-1} of cake sludge should be applied in any one year. Further information regarding application rates can be found in Moffat (2006).

Grassland application

It is difficult to predict the amount of organic matter required to produce permanent fertility effects for grassland. Application of compost to a newly prepared seed bed should be at 25–50 mm and incorporated to a depth of 100–150 mm. If applying to established grassland composts screened to less than 25 mm should be applied in order to allow the compost to fall readily to the root zone.

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