Forest Research

BPG

NOTE 2

Best Practice Guidance for Land Regeneration

LABORATORY ANALYSIS OF SOILS AND SPOILS

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Introduction

For the procurement of land or for establishing greenspace on derelict and underused land it is important to know what soil conditions and potential hazards are present. When the condition of soils or spoils are known, appropriate treatment can be applied to obtain the best end result in terms of achieving production of sustainable greenspace. Chemical analysis is often considered to have a relatively high unit cost. For this reason it is sometimes rejected and only sought later when problems arise, for example, when vegetation fails. It is important to stress that sensibly chosen chemical analysis of an appropriate number of samples is almost always cost-effective, and will prevent reclamation mistakes which may be very costly to correct later (Bending *et al.*, 1999).

Soils on brownfield sites are often considered infertile as they lack basic nutrients such as nitrogen, magnesium, calcium, potassium and phosphorus which are important to sustain plant growth. Quantification of soil nutrient levels through laboratory analysis allows prescriptive application of nutrients through mineral fertiliser application or soil amendments such as composts. Disregard for soil nutritional status can lead to either vegetative failure through deficiencies or eutrophication of water bodies through overapplication.

Similarly, soil texture, density, stoniness, pH, electrical conductivity, iron pyrite content, nutrients, organic matter content and carbon:nitrogen ratio have major implications on species choice, soil water holding capacity and associated risk of drought, long-term tree stability, effective rooting depth and nutrient holding capacity. In short, soil analysis (Figure 1) and a professional interpretation of its results is an imperative part of the decision process for sustainable vegetation establishment.

In addition, chemical analysis also allows quantification of important hazards such as contaminants which are very often present on brownfield sites. Such contaminants can pose a significant threat to receptors including human, water, ecosystem and plant health and at high concentrations these contaminants require appropriate treatment (remediation) before the site can be restored to a green end use. Therefore chemical analysis of the soil from these sites is essential before any development can take place. Further information on identifying and dealing with contaminated land can be found in Forestry Commission Information Note 44: *The opportunities for woodland establishment on contaminated land,* and Information Note 91: *Greenspace establishment on brownfield land: the site selection and investigation process.*

This BPG Note gives an overview of the general soil parameters to be looked at, what kind of contamination can be expected for different kinds of former soil use, and what kind of analysis should be requested from analytical laboratories. It also provides outline information on interpretation of analytical results. Reliable analytical results can only be achieved when good sampling practice is applied; for guidelines on this see BPG Note 1: *Soil sampling derelict, underused and neglected land prior to greenspace establishment.*

Figure 1 On-site analysis of heavy metals in a spoil heap.

General soil parameters

To obtain good plant growth on a soil or spoil, analysis of general soil conditions is essential in order to treat the soil for optimum results. Parameters that should be tested include: texture, density, stoniness, pH, electrical conductivity, iron pyrite content, nutrients, organic matter content and carbon/nitrogen ratio. Table 1 gives an overview of these parameters together with their target values. More detailed information on optimal soil conditions can be found in *Soil forming materials: their use in land reclamation* (Bending *et al.*, 1999). A guideline for improvement of soils using compost or mineral fertilisers is given in BPG Note 6: *Application of sewage sludges and composts* and BPG Note 7: *Fertiliser application*. It is important to use the method of analysis referred to in Table 1 to determine an analyte; deviation from the quoted method will compromise data quality.

Table 1 Minimum standards for soil-forming materials acceptable for woodland establishment (updated from Moffat and Bending, 1992; Dobson and Moffat, 1993; Bending *et al.*, 1999).

Parameter	Standard	Comments on method
Texture	No limitations; however, the placement location of materials of different texture on site should be related to site factors, e.g. topography	Texture (% sand, silt and clay) should be determined by pipette method. Preferred textures include materials with > 25% clay
Bulk density (after placement)	<1.5 g cm^{-3} to at least 50 cm depth <1.7 g cm^{-3} to below 1 m depth	
Stoniness — Clay or loam	<40 % by volume of material greater than 2 mm in diameter and <10 % by volume of material greater than 100 mm in diameter	Measure mass of stone >2 mm and >100 mm in a known mass / volume of soil; divide each value by 1.65 to calculate the volume
Sand	<25 % by volume of material greater than 2 mm in diameter and <10 % by volume of material greater than 100 mm in diameter	
pH	Must be within the range 4.0 to 8.0	Based on a 1:2.5 soil: $CaCl_2$ (0.01 M) suspension
Electrical conductivity	<0.2 S m^{-1}	Based on a 1:1 soil:water suspension
Iron pyrite content	<0.05 %	British Standard 1016 method
Topsoil nutrient and organic content	N: 1000 kg N ha^{-1} (see note a) P: 16 mg l^{-1} (ADAS Index 2) K: 121 mg l^{-1} (ADAS Index 2) Mg: 51 mg l^{-1} (ADAS Index 1) Organic matter content: 10%	N determination using the Dumas method P and organic matter determination K and Mg determination
Specific metal and organic contaminants	These should, in the first instance, be assessed using appropriate generic assessment criteria (GAC), such as Soil Guideline Values (SGVs). Where no GAC are available, acceptable limits should be derived using a risk-based approach for human health	Determination according to substance using a method comparable with the GAC being used. Approval should be sought from Forest Research on the guideline concentrations being used before soil placement begins

[a] Minimum standard is 1000 kg N ha^{-1}. The acceptable range is 1000–2000, with a recommended standard of 1500 kg N ha^{-1}. Does NOT apply in nitrate vulnerable zones (NVZ), where the limit is 250 kg N ha^{-1} yr^{-1}; applications rates must be appropriate to the ecological benefit sought and determined on a site-by-site basis. Two years' worth of application may be applied in one year in an NVZ under licence. Whether inside or outside of an NVZ, add the *minimum* amount required to get sustained growth and do not exceed the maximum recommended soil C:N ratio of 20:1.

Contaminants

Table 2 shows a selection of former land uses and provides a general overview of the range of contaminants that can be expected on such sites. This list is not definitive and it should be kept in mind that parallel contamination might have occurred, e.g. illegal dumping of other contaminated waste or other unknown activities on the site. If in doubt the whole range of contaminant analysis should be sought; an overview of possible analysis to be requested is given in Table 3.

Table 2 Overview of possible soil contamination for historical soil uses.

Former use	Heavy metals	Arsenic	Cyanide	PAH[a]	BTEX[b]	Asbestos	PCB[c]/ dioxins	Herbicides/ pesticides	Solvents	Explosives
Colliery spoil	✓	✓		✓	✓					
Gas factory			✓	✓						
Metal smelting/foundries	✓	✓								
Wood treatment	✓	✓		✓						
Mining	✓	✓				✓				
Building site						✓				
Refinery				✓	✓				✓	
Petrol station				✓	✓				✓	
Paper mill	✓									
Chemical plant					✓			✓	✓	
Textile laundering									✓	
Textile painting	✓									
Transformer building						✓	✓			
Waste incinerator							✓			
Ammunition factory	✓									✓
Landfill	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[a] PAH: polycyclic aromatic hydrocarbons. [b] BTEX: benzene, toluene, ethyl benzene, xylene. [c] PCB: polychlorinated biphenyl.

Figure 2 Metallic contaminants can cause severe plant toxicity as shown on this former foundry site.

Table 3 Overview of chemical analysis to be requested for sites where the given types of contamination are suspected.

Type of contaminant	Total metal concentration	PAH analysis	Aromatic compound analysis	Hydrocarbon analysis	Chlorinated hydrocarbon analysis	Herbicide/ pesticide analysis	Free and complexed cyanide	Asbestos
Heavy metals	✓							
Arsenic	✓							
Cyanide							✓	
PAH		✓		✓			✓	
BTEX			✓					
Asbestos								✓
PCB/dioxins					✓			
Herbicides/pesticides	✓					✓		
Solvents			✓	✓	✓			
Explosives	✓		✓	✓				

Types of contaminants can be divided into three groups: metallic, organic and others.

Metallic contaminants

Contaminants in this category are mainly heavy metals and arsenic. They generally occur on sites previously used for industrial activities such as former metal smelting works and foundries (Figure 2), mines, the textile industry and paper mills.

Organic contaminants

The group of organic contaminants is very broad; it ranges from heavy coal tar to volatile solvents and also includes chlorinated compounds such as polychlorinated biphenyl (PCB), dioxins and chlorinated solvents. Together with the wide nature of organic contaminants there is also a wide variety of sites where they occur, varying from gasworks and petrol stations to textile laundries (Table 2).

Other contaminants

This group incorporates all contaminants that do not fit into either of the other two groups, one of the most important being asbestos. Sources of asbestos are buildings in which the material was used for fire prevention, making every site with buildings or where buildings have been demolished possibly contaminated. Other contaminants are cyanide, explosives such as RDX or TNT, and radioactive waste.

Interpretation of results

Outcome of the analysis of general soil parameters should be used to decide upon performing any soil improvement. Table 1 gives an overview of standards for the different parameters. If the soil has to be improved to reach these standards useful BPG Notes for this purpose are 6: *Application of sewage sludges and composts* and 7: *Fertiliser application*.

In the case of any concern of contamination, a risk-based approach should be adopted in line with Part 2A (Amended) of the Environmental Protection Act 1990 and related documentation. In the first instance, the levels of contaminants present should be assessed against the appropriate generic assessment criteria (GAC), such as Soil Guideline Values (SGVs) – published by the Environment Agency – or the *Generic assessment criteria for human health risk assessment* (LQM/CIEH, 2009). As this requires informed understanding of how and for what purpose the GAC were derived, analysis and interpretation should be conducted by a suitably qualified experienced practitioner.

BPG Note 1 gives a more detailed overview of soil sampling and interpreting the data from sampling.

References and further reading

Bending, N.A.D., McRae, S.G. and Moffat, A.J. (1999). *Soil-forming materials: their use in land reclamation.* The Stationery Office, London.

BSI (2002). *Characterisation of waste – Leaching – Compliance test for leaching of granular waste materials and sludges.* British Standards Institute, London.

Department for Environment, Food and Rural Affairs. (2012). *Environmental Protection Act 1990: Part 2A. Contaminated land statutory guidance.* April 2012. TSO, London.

Dobson, M. and Moffat, A.J. (1993). *The potential for woodland establishment on landfill sites.* HMSO, London.

Doick, K. and Hutchings, T.R. (2007). *Greenspace establishment on brownfield land: the site selection and investigation process.* Forestry Commission Information Note 91. Forestry Commission, Edinburgh.

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Land Quality Management/Chartered Institute of Environmental Health. (2009). *Generic assessment criteria for human health risk assessment.* 2nd Edition. LQM/CIEH, Nottingham.

Moffat, A.J. and Bending, N.A.D. (1992). *Physical site evaluation for community woodland establishment.* Forestry Commission Research Information Note 216. Forestry Commission, Edinburgh.

Useful links

Details of Contaminated Land and Contaminated Land Legislation can be found on the Defra website.

Details of the UK SGVs can be found on the EA website.

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