LABORATORY ANALYSIS OF SOILS AND SPOILS

BPG NOTE **2**

Best Practice Guidance for Land Regeneration

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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.

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

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 the forthcoming Information Note: *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.*

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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 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 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 >200 kg N ha^{-1} 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 fall between the Soil Guideline Values (DEFRA and EA, 2002) for residential without plant uptake and industrial / commercial. Where no SGVs are available acceptable limits should be derived using a risk-based approach for human health. See also Table 4.	Determination according to substance using a method comparable with the SGVs being used. Approval should be sought from Forest Research on the guideline concentrations being used before soil placement begins.

Contaminants

Types of contaminants can be divided into three groups: metallic, organic and others. 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	BTEX	Asbestos	PCB/ Dioxins	Herbicides/ pesticides	Solvents	Explosives
Colliery spoil	✔	✔		✔	✔					
Gas factory			✔	✔						
Metal melting/founding	✔	✔								
Wood treatment	✔	✔		✔						
Mining	✔	✔				✔				
Building site						✔				
Refinery				✔	✔				✔	
Petrol station				✔	✔				✔	
Paper mill	✔									
Chemical plant					✔			✔	✔	
Textile laundering									✔	
Textile painting	✔									
Transformer building						✔	✔			
Waste incinerator							✔			
Ammunition factory	✔									✔
Landfill	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

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	✔		✔	✔				

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, mines, the textile industry and paper mills. Table 4 lists the most important heavy metals; it is important to recognise that copper, nickel and zinc are not considered toxic for humans but are toxic for plants and for this reason there are also restrictions to their concentrations.

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 compost* and 7: *Fertiliser application*.

In the case of any concern of contamination further action is necessary. Table 4 gives an overview of Soil Guideline Values (SGVs) determined by the Environment Agency (Defra and EA, 2002) for several contaminants; the list of official determined SGVs is limited and intervention values determined by the Dutch Ministry of Housing, Spatial Planning and Environment (VROM, 2000) are given as a guideline. The most recent SGVs can be obtained from the Environment Agency.

Table 4 Levels (mg kg dry matter^{-1}) of contaminants above which further investigation is necessary.

Contaminant	Soil guideline value[a]		Dutch intervention levels
	Residential without plant uptake	Commercial/ industrial	
Arsenic	20	500	60
Cadmium	30	1 400	6
Chromium	200	5 000	30
Cobalt			100
Copper[b]			75
Lead	450	750	75
Mercury	15	480	0.3
Nickel[b]	75	5 000	75
Selenium	260	8 000	
Tin			900
Zinc[b]			800
PAHs[c]			40
Benzene			1
Toluene	3	150	130
Ethyl benzene	16	48 000	50
Xylene			25
Dioxins[d]			0.001
PCBs[e]			1
1,2-dichoorethene (as example of solvent)			0.3
free-cyanide			20
complexed-cyanide (pH<5)			650
complexed-cyanide (pH>5)			50

[a] Information on Soil Guideline Values can be sourced from the link www.environment-agency.gov.uk/subjects/landquality/ and then navigate to land contamination and to the CLEA home page and then to publications relevant to CLEA.

[b] Only toxic for plants.

[c] Total of 10 PAHs: anthracene, benzo(a)anthracene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, phenanthrene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, benzo(ghi)perylene.

[d] Total of all dioxins present expressed in their toxicity equivalent to the most toxic dioxin.

[e] Totals of PCB numbers: 28, 52, 101, 118, 138, 153 and 180.

If any of the contaminants approaches one of those values, a site specific risk assessment should be made considering the combination of contaminants as well as soil conditions and land use. Parts of this risk assessment are toxicity and leaching tests which give a better view of the actual risks within the soil. Toxicity is determined using bioassays where the survival rate of small insects or bacteria in the polluted soil or water extract from the soil is measured. The bioavailable fraction of the contaminants is determined using leaching tests and apart from a value for the bioavailability it is also an indication for the amount of contaminant leaching to the soil water. For confidence and reliability these tests should be performed according to standard guidelines provided by the British Standards Institute (BSI, 2002).

In the risk assessment, recommendations for possible remediation of the polluted soil or containment of the contaminants should be requested.

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.

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