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Landform and soil requirements for biosolids and effluent reuse

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NSW Department of Primary Industries' Organic Waste Recycling Unit (OWRU) undertakes studies for State Government, councils and private interests on the reuse of waste products. Reports produced are used to support submissions to relevant authorities for approval of these waste reuse schemes. Most studies currently involve effluent and biosolids reuse. Tables 1 to 4 refer specifically to effluent (sewage treatment plants) and biosolids (including composts).

To avoid potential damage to the land, waste reuse schemes must consider:

- quantity and quality of the waste product
- soil characteristics
- climate and topographic characteristics of the site
- land use and management requirements for the site
- surface water and groundwater.

Relatively inexperienced field personnel must be able to reproduce an effective sampling strategy. The costs associated with the development of the scheme should be minimised.

The OWRU developed landform and soil suitability tables (tables 1 to 4) after more than 200 detailed investigations within NSW and discussions with relevant authorities. These tables aim to eliminate unfavourable sites and identify the best sites for biosolids or effluent reuse.

LANDFORM AND PRELIMINARY SOIL INVESTIGATIONS

Preliminary soil investigations are those carried out to select potentially suitable sites for further, more detailed, soil investigations.

Landforms are determined using aerial photograph interpretation or field inspection, or both. Areas with 'severe' limitations are eliminated (Table 1 or 2).

Representative soil sampling points are selected using existing soil maps and aerial photographs or by expected differences in the soil due to the topography, geology or land use history. Electromagnetic (EM) surveys can be used to target soil sampling points.

Within each representative area, 1 or 2 soil profile cores are collected. Soil samples are collected from these profiles at set depths (effluent: 0–20, 20–40, 40–70 and 70–100 cm; biosolids: 0–15, 15–30, 30–60 and 60–90 cm).

Preliminary soil investigations include a field morphological description and laboratory tests of EC_e* and pH ** analyses. If a soil is found

Electrical conductivity of the saturated soil extract.
***pH measured in 0.01 M calcium chloride solution.*

to have any ‘severe’ limitations for EC_e, pH or depth (Table 3 or 4), the site is eliminated from further consideration.

DETAILED SOIL INVESTIGATIONS

Detailed soil investigations are undertaken on sites that are considered potentially suitable for the application of biosolids and effluent, based on the preliminary study. They require a more intensive sampling strategy than is used in preliminary soil studies. Sampling points need to be selected in an ‘unbiased’ manner, close enough to cover the topographical and geographical complexity of the area as well as the land use history. Experience suggests that one soil core every 200 to 250 m is usually sufficient. A minimum of five cores are normally taken on areas smaller than 5 ha. However, for a large area with few landform changes, a minimum of three soil cores are taken from each expected soil unit, based on geological, topographical and land use variation.

After soil morphological characteristics are recorded (using the definitions of McDonald et al. 1990), the soil is classified using The Australian Soil Classification (Isbell, 1996). Individual samples are usually analysed for pH and EC_e. A soil map is prepared using topographical and geological boundaries to estimate likely soil boundaries.

If salinity is not a concern (according to preliminary soils investigation), each group of soil profile cores collected from each sampling area are composite sampled at the set depth intervals outlined previously. These composite soil samples are then analysed for the properties listed in tables 3 or 4. Soil composites are also tested for heavy metals where biosolids are to be applied. The topsoil is tested for organochlorine pesticides.

Field characterisation of soil physical properties, such as saturated hydraulic conductivity, bulk density and available water-holding capacity, is time consuming and expensive. To reduce costs, tests are only undertaken in soil profiles found to be ‘typical’ or ‘limiting’ from the field and chemical characterisations. Often soil morphological properties can indicate soil physical limitations.

Where no or only ‘slight’ limitations are found (Table 3 or 4), the site is considered well suited to the proposed land use. Soil with ‘severe’ limitations is considered unsuitable. Sometimes a more extensive sampling regime can identify suitable areas within larger areas that were initially classed as having severe limitations. Soil with heavy metal or organochlorine pesticide levels above NSW EPA guidelines is also considered to have severe limitations for effluent or biosolids reuse.

When available land is limited, it may be necessary to investigate sites with ‘moderate’ or ‘severe’ limitations, and identify more stringent management conditions. For example:

- reduced application rates
- selection of irrigation systems that minimise spray drift
- amelioration of sodic soils with gypsum.

The overall assessment of the suitability of land for effluent or biosolid application should be based on the most limiting soil or land characteristic. The only exception to this is in situations where the areas with the greater limitations can be effectively isolated and managed differently from the rest of the site.

MONITORING

Monitoring programs are necessary to avoid degradation of soil and associated water resources as a result of the biosolids or effluent reuse scheme. Monitoring is site-specific and involves repeated sampling of soil and soil water over time: hence it represents a significant ongoing operational cost.

For this reason, results of analyses undertaken during the detailed investigations described above should be used to target properties that are likely to cause concern. For example, relatively high levels of sodium (Na) in the waste product or in the soil indicate the need to focus on Na concentrations in the soil.

Conversely, if the soil has a high phosphorus (P) sorption capacity and nutrient budgets show an expected minimal level of P build-up in the soil with the addition of the biosolids or effluent, then monitoring of this attribute could be reduced.

REFERENCES

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FURTHER INFORMATION

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This Agnote replaces Advisory Bulletin No. 14 *Landform and soil requirements for biosolids and effluent reuse.*

Table 1. Landform requirements for irrigation of land with effluent

Property	Limitation			Restrictive feature
	nil or slight	moderate	severe	
Slope (%) surface/underground sprinkler trickle/microspray	 <1 <6 <10	 1–3 6–12 10–20	 >3 >12 >20	Excess run-off and erosion risk.
Flooding	none, or rare	occasional	frequent	Limited irrigation opportunities.
Landform	crests, convex slopes, plains	concave slopes and footslopes	drainage lines and incised channels	Erosion and seasonal waterlogging risk. *
Surface rock and outcrop (%)	nil	0–5	>5	Interferes with irrigation and cultivation machinery, increases risk of run-off.

** Certain plant species are often good indicators of poor site drainage and waterlogged conditions, for example, rushes and sedge species.*

Table 2. Landform requirements for land application of biosolids

Property	Limitation				Restrictive feature
	nil or slight	slight to moderate	moderate to severe	severe	
Slope (%) Surface application* Incorporation	 <3 <8	 3–6 8–10	 6–8 10–15	 >8 >15	Increases risk of movement of soil and biosolids downslope. Difficult to spread and incorporate.
Flooding	none	rare	common (within 1 in 100 year floodline)	frequent (more than 1 every 5 years)	Potential contamination of surface waters. Consider injecting liquid biosolids to overcome constraints.
Landform	hill crests, convex sideslopes and plains	concave sideslopes	footslopes	drainage lines and incised channels	Potential contamination of surface waters and seasonal waterlogging risk.
Surface rock and outcrop (%)	nil	0–2	2–10	>10	Interferes with machinery. Risk of run-off.

**Under NSW regulations, biosolids classified as 'Restricted Use' must be incorporated and cannot be surface applied (EPA 1997).*

Table 3. Soil requirements for irrigation of land with effluent

Property	**Limitation**			**Restrictive feature**
	nil or slight	moderate	severe	
Exchangeable sodium percentage (ESP, 0–40 cm)	<5	5–10	>10	Structural degradation and waterlogging [f]
Exchangeable sodium percentage (ESP, 40–100 cm)	<10	>10	–	Structural degradation and waterlogging
Salinity measured as ECe (dS/m, 0–70 cm)*	<2	2–4	>4	Excess salt restricts plant growth
Salinity measured as ECe (dS/m, 70–100 cm)	<4	4–8	>8	Potential seasonal groundwater rise
Depth to top of seasonal high watertable (m) [g]	>3 [a]	0.5–3 [a]	<0.5	Wetness, risk to groundwater
Depth to bedrock or hardpan (m)	>1	0.5–1	<0.5	Restricts plant growth, excess runoff, waterlogging
Saturated hydraulic conductivity (Ks, mm/hr, 0–100 cm)	20–80	5–20 >80	<5 –	Excess runoff, waterlogging, risk to groundwater
Available water capacity (AWC, mm/m)	>100	<100	–	Little plant available water in reserve, risk to groundwater
Bulk density (g/cm3, 0–70 cm) sandy loam loam and clay loam clay	 <1.8 <1.6 <1.4	 >1.8 >1.6 >1.4	 – – –	Restricts root growth
Soil pH ($CaCl_2$) (surface layer)	6.0–7.5	3.5 [b]–6.0 >7.5	<3.5 [b] –	Reduces optimum plant growth
Effective cation exchange capacity (ECEC, cmol(+)/kg, average 0–40 cm)	>15	3 [c]–15	<3 [c]	Unable to 'hold' plant nutrients
Emerson aggregate test (0–100 cm)	4, 5, 6, 7, 8	2, 3	1	Poor structure
Phosphorus (P) sorption (kg/ha, total 0–100 cm)	>6000 [d]	2000–6000 [e]	<2000 [e]	Unable to immobilise any excess P

[a] *Often impossible to excavate to 3 m, hence local knowledge and lack of evidence of watertable to sampling depth (1 m) is used.*

[b] *Where effluent is alkaline or lime is available, opportunities exist to raise the pH. If acid sulfate soil is present, land levelling may not be appropriate.*

[c] *This could be overcome by adding soil amendments such as biosolids or liming agents.*

[d] *Assuming the sorption strength is higher than 20% of the sorption capacity. If this is not the case, a higher sorption capacity is required to immobilise excess P.*

[e] *These limitations exist only if there is a sensitive groundwater source.*

[f] *Overcome by gypsum application.*

[g] *Quality and potential impacts on groundwater should also be considered.*

* *Plants vary in their sensitivity to salt.*

Table 4. Soil requirements for land application of biosolids

Property	Limitation				Restrictive feature
	nil or slight	slight to moderate	moderate to severe	severe	
Excessive drainage	other soils	highly structured soils, sandy loams	fine sands (e.g. sandy alluvium)	coarse sands (e.g. beach sand)	Risk to groundwater from biosolids, nutrients and contaminants.
Poor drainage	other soils	poorly structured clay loams	poorly structured clays	hardpans	Potential anaerobic soil that can restrict plant growth and increase the risk of runoff.
Depth to top of seasonal high watertable (m)	>3[a]	0.6–3[a]	0.5–0.6	<0.5	Risk to groundwater from biosolids, nutrients and contaminants.
Depth to bedrock or hardpan (m)	>1.0	0.5–1.0	0.5–1.0	<0.5	Increased risk of run-off generated after significant rainfall events. As such presents a risk to surface waters. Where the underlying bedrock is fractured there is an increased risk of soluble contaminants reaching the groundwater system.
Salinity measured as mECe (dS/m, 0–60 cm)	<2	2–4	4–8	>8	Biosolids may increase salinity. At levels >4 many plant species will not grow. At ECe >8 most plant species will not grow.
Emerson aggregate test (0–90 cm)	4, 5, 6, 7	3	2	1, 8	Poor structure.
pH(CaCl2) (0–60 cm)	>5.5	4.5–5.5	3.5–4.0	<3.5	Too acid. The use of lime amended biosolids may overcome this constraint.

[a] *Often impossible to excavate to 3 m, hence local knowledge and lack of evidence of water to sampling depth (90 cm) is used.*

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