PART 5:

RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Part 5 deals with specific restrictions and requirements for **continuous high rate application** of sludge for beneficial use. Sludge is not only applied to the soil to increase its fertility and physical soil properties, but also as fertilizer to sustain vegetation at rates higher than agronomic rates (more nutrients than is needed by the crop). Sludge can either be applied in liquid or dewatered form. This beneficial use option can include but is not limited to:

- Continuous application of sludge in natural forests and plantations;
- Use of sludge as growth medium for plants, flowers and seedlings;
- Cultivation of grain and fruit trees;
- Cultivation of industrial crops (cotton, oilseeds, aromatic plants, biofuel crops);
- Instant lawn cultivation.

Distinction is made between public access sites with high potential for public exposure or crops destined for the general public (growth medium, instant lawn) and private land with low potential for public exposure (plantations, industrial crops). The future land-use of the application site will also have an influence on what sludge qualities could be used.

SITE SELECTION REQUIREMENTS

Areas where continuous high rate sludge application is not permissible:

- Areas below the 1 in 100 year flood line (wetlands, vleis, pans and flood plains) to minimise water pollution;
- Unstable areas (fault zones, seismic zones and dolomitic or karst areas where sinkholes and subsidence are likely);
- Areas characterised by steep gradients where slope stability could be a problem and soil erosion would be prevalent;
- Areas of groundwater recharges on account of topography and/or highly permeable soils to minimise groundwater pollution;
- Areas immediately upwind of a residential area in the prevailing wind direction(s);
- Natural habitat of endangered plant and/or animal species.

Buffer zones:

- Depth to aquifer - >5m for dewatered sludge application and >10m for continuous irrigation with sludge;
- Distance from surface water/borehole - >400m.

Note: These buffer zones may be relaxed on condition that proof is provided that the groundwater and surface water is adequately protected.

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

INITIAL SITE INVESTIGATION

Initial site investigation is necessary to assess whether a site is suitable for continuous high rate sludge application. It is also important to collect background/baseline data which could be used to assess the impact of continuous high rate sludge application over time. The site investigation for existing and new application sites should include (as a minimum):

Topography

- The slope of the land application site should be considered to minimise run-off, erosion and ponding.
- The land application site should not be within the 1:100 year flood line of surface water resources.

Soil properties

- The soil structure, permeability and cation exchange capacity (CEC) will indicate whether the soil will act as a "natural liner/barrier" to minimise the leaching of contaminants.

> **Note**: Soils with clay content <20% should not be considered for continuous high rate sludge application

- The soil pH will indicate whether acidic conditions could cause metals to leach through the soil profile.

> **Note**: Soil pH(H_2O)>6.5 should be maintained to limit the mobility of metals

- The concentration of nutrients, trace elements and metals will give baseline concentrations to determine the incremental effects of sludge application on the soil.

Surface water

- Possible surface water receptors should be identified and the distance and likelihood that they could be affected documented.
- Where surface water contamination is a possibility, background water quality sampling is required to determine the baseline values which can be used for comparative purposes in future.
- Where surface water contamination is expected at existing sites, water samples should be analysed and compared to the relevant standards to assess compliance.

Groundwater

- Aquifer classification: determine the yield, depth and strategic value of the aquifer (Table 16). Continuous high rate sludge application will not be allowed within 200m of the recharge zone of major and sole-source aquifers as well as other strategic aquifers.
- The hydraulic gradient should be determined to assess the position of the monitoring boreholes.
- Groundwater quality (up gradient and down gradient) will give baseline information to assess future impact of sludge application on groundwater quality.

- Where groundwater contamination is expected at existing sites, water samples should be analysed and compared to the relevant standards to assess compliance.
- A qualified person should confirm cases where groundwater impact is unlikely due to depth of water table or other circumstances.

TABLE 16: TYPES OF AQUIFERS DIFFERENTIATED FOR GROUNDWATER QUALITY MANAGEMENT

Aquifer Type	Description
Sole-source aquifer	An aquifer used to supply 50% or more of urban domestic water for a given area and for which there are no reasonable available alternative sources of water.
Major aquifer	A high-yield aquifer system of good quality water.
Minor aquifer	A moderate-yield aquifer system of variable water quality.
Poor aquifer	A low- to negligible-yield aquifer system of moderate to poor water quality.
Special aquifer	An aquifer system designated as such by the Minister of Water Affairs and Forestry, after due process.

MANAGEMENT REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

The following management requirements will be necessary to protect the receiving environment as well as the general public against the potentially negative impact of continuous sludge application at high application rates.

Odour control

At least one of the vector attraction reduction options (Table 3) must be applied to minimise the production of odours when sludge is to be applied on land.

Run-off interception

Surface water resources near the application site need to be protected against contamination by constituents from the sludge. This could be achieved by:

- Constructing cut-off trenches or bund walls down-gradient of the application site to intercept run-off
- Increasing the buffer zone between the sludge application site and the water body to ensure no run-off will reach the water body
- Planting applicable crops/plants/trees with a high water demand that will intercept run-off.

Groundwater protection

Groundwater is a valuable resource in the South African context and sludge applied to land should not contaminate the aquifer. Aquifer contamination means introducing a substance that can cause the concentrations of constituents of concern in groundwater to increase above regulated limits. Groundwater is most vulnerable to nitrate present in sludge.

Although the crops cultivated on beneficial use sites will use some of the nitrate supplied with the sludge, the application rate is higher than the agronomic rate, leaving a surplus concentration of nitrate in the soil. The excess nitrate will leach through the soil profile into the aquifer.

The South African Water Quality Guidelines for nitrate (NO_3) in water for domestic use is presented in Table 17. It is recommended that the quality of the groundwater resource impacted by continuous high rate sludge application should not deteriorate more than 1 class (for example from acceptable to tolerable) due to sludge application with a **maximum permissible NO_3-N of 20 mg/l**. If there is any possibility that the groundwater may be used for drinking purposes, the maximum acceptable level of **10 mg/l NO_3-N** must not be exceeded.

TABLE 17: SOUTH AFRICAN WATER QUALITY GUIDELINE FOR NITRATE (DOMESTIC USE)

	Target Water Quality Guideline Class 0	Acceptable Class 1	Tolerable Class 2	Unacceptable Class 3
NO_3-N (mg/l N)	6	10	20	> 20

The owner/user should provide proof that groundwater is not contaminated by means of:

- Implementing a groundwater monitoring programme;
- Proof that groundwater monitoring is not required based on a detailed study by a qualified person, either because of the depth of the water table, the amount of sludge applied or other site specific factors.

Soil quality

The potential impact of pollutants during continuous high rate sludge application is mainly on surface and groundwater, but the crop quality may also be affected. Surface and groundwater can be protected by implementing limits for metals on the receiving soil. The total maximum threshold (TMT) for metals in soil will protect soils destined for agricultural land-use and land with public access, while the maximum permissible level (MPL) for metals in the receiving soil (Table 18) will protect industrial soils and land with limited public access to ensure that the soil quality does not degrade to such an extent that remediation would be necessary. **Figure 4** indicate the influence that soil quality will have on the beneficial use options.

When the total metal content (*aqua regia* digestion) of the soil exceeds the TMT, sludge application should be stopped on land where edible crops are grown and/or where public access is unlimited. In cases where the land is used to cultivate industrial crops, sites with limited public access and industrial areas (mine rehabilitation and forests) sludge application may continue until the total soil metal content reaches the MPL. The monitoring requirements are explained in the “Soil monitoring” section. At existing beneficial use sites the soil metal concentration may be higher than the MPL in which case a remediation plan should be implemented.

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

TABLE 18: METAL LIMITS FOR SOIL RECEIVING HIGH SLUDGE LOADS

Elements	Total Maximum Threshold (TMT) mg/kg	Maximum permissible level (MPL) mg/kg
Arsenic (As)	2	20
Cadmium (Cd)	3	5
Chromium (Cr)	350	450
Copper (Cu)	120	375
Lead (Pb)	100	150
Mercury (Hg)	1	9
Nickel (Ni)	150	200
Zinc (Zn)	200	700

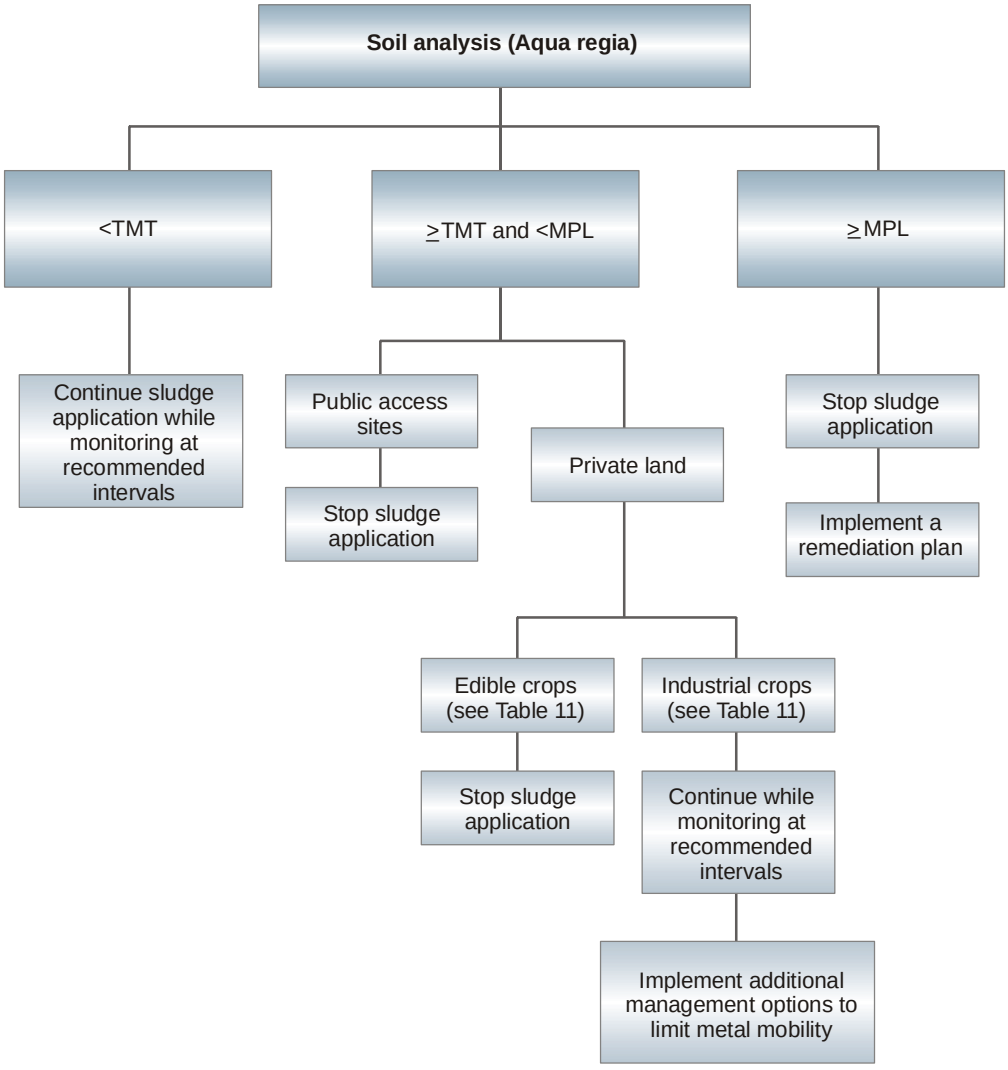


Figure 4: Influence of soil quality on beneficial use options

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Sludge application rate

The following important aspects of continuous high rate sludge application must be considered:

- Any excess nutrients (especially nitrate) applied that is not needed by the crop may leach through the soil profile into the groundwater.
- Small concentrations of metals and micronutrients applied with sludge will be taken up by the cultivated crop. High rate application will cause metal build-up in the soil and the soil quality will deteriorate.

The sludge application rate at continuous high rate application sites should ideally be based on the metal content of the soil prior to sludge application. However, even higher application rates may be required to sustain vegetation and therefore a maximum application rate as been adopted. These concepts are discussed in the sections that follow.

Permissible application rate (PAR)

It is recommended that the permissible application rate (PAR) or load should be based on the soil metal content prior to application. This will ensure that the metal content of the soil will not increase to a level above the TMT or MPL after a single application. Ideally, the PAR should be calculated before each sludge application and/or after each soil monitoring event. The PAR can be calculated by using the following equation:

$$PAR = \frac{TMT - Soil_{conc}}{Sludge_{conc}} * 3900$$

Where:

PAR = permissible application rate (ton/ha)

TMT = total maximum threshold (Table 9) in mg/kg. The MPL can be used where applicable

$Soil_{conc}$ = the actual metal content of the soil (mg/kg)

$Sludge_{conc}$ = metal concentration in the sludge that will be applied (mg/kg)

3900 = conversion factor to account for soil density (1.3 g/cm^3) and sludge incorporation depth of 300mm

Example: A sludge producer is cultivating and selling instant lawn as a source of income for the WWTP. The sludge classification is B1b (3500 mg/kg Zn). The analytical results of the soil samples indicate that the metal content of the soil is well below the TMT except for the Zn concentration of 180 mg/kg which is close to the TMT for soil. The permissible application rate for this sludge on this soil is:

$$PAR = \frac{TMT - Soil_{conc}}{Sludge_{conc}} * 3900$$

$$PAR = \frac{200mg/kg - 180mg/kg}{3500mg/kg} * 3900$$

$$PAR = 22ton_{\ drysludge}/ha$$

At an application rate of 22 ton $_{dry\ sludge}$/ha the Zn application will be 10 mg_{Zn}/kg_{soil} and the TMT of the soil will not be exceeded. However, since this is privately owned land and an industrial crop being cultivated, the MPL soil limit can be used. Therefore:

$$PAR = \frac{MPL - Soil_{conc}}{Sludge_{conc}} * 3900$$

$$PAR = \frac{700mg/kg - 180mg/kg}{3500mg/kg} * 3900$$

$$PAR = 580ton_{\ drysludge}/ha$$

Although an application rate of 580 ton $_{dry\ sludge}$/ha is permissible based on the metal content of the sludge and the soil, this high application rate will increase the Zn concentration to such an extent that further sludge application will be limited. Such a high application rate may also have other negative consequences (*i.e.* leaching of nutrients) and may even cause a decrease in yield. In these cases the maximum application rate (MAR) will apply.

Maximum application rate

Although it is recognized that some sites might need very high sludge application rates to sustain vegetation, the application can not be unlimited (as for disposal). Therefore, a maximum application rate (MAR) have been adopted:

- Animal feed = 60 ton $_{dry\ sludge}$/ha during a 2 year period (either once-off or spread over time)
- Industrial sites / crops = 120 ton $_{dry\ sludge}$/ha/year (either once-off or spread over time)

Note: The Lead Authority can decrease or increase the MAR for continuous high rate application sites based on site specific data (soil properties, depth to aquifer, type of aquifer and distance from surface water resource etc.).

The PAR is still the preferable application rate and the user will have to prove that higher application rates will not cause negative environmental impacts.

Transportation and storage

Due to the potential high microbiological contaminant content of sludge, it should be handled as a hazardous material (containing infectious substances) during transportation. The following aspect should receive attention during the transportation of sludge from the WWTP to the landfill site:

- Identification of waste - the transporters must be provided with accurate information about the nature and properties of the load.
- Documentation - the transport operator must be provided with the relevant transportation documentation.
- Hazchem placard - the transport operator must be supplied with the appropriate Hazchem placards which should be properly fitted to the vehicle.
- Protection against effect of accident - the Generator - or his representative, i.e., transporter - must ensure that adequate steps are taken to minimise the effect an accident or incident may have on the public and on the environment.

- Notification - all road accidents must be reported to the Department of Transport on the prescribed documentation and a full report should be sent to the Local Authorities, the Competent Authority and the DEAT.

The storage of sludge in an open area for extended periods before application may result in leachate or highly contaminated seepage being generated. Therefore, any area where sludge is stored for a period exceeding 90 days is considered a disposal area and should be operated as such. This area must be included in the site permit for the continuous high rate application site.

RESTRICTIONS APPLICABLE TO CONTINUOUS HIGH RATE SLUDGE APPLICATION

Continuous application of sludge at high rates can have severe detrimental effects on the receiving environment and public health if it is not regulated and/or mitigated. Therefore a number of restrictions will be applicable to continuous high rate sludge application sites.

Sludge quality restrictions

Sludge quality is an important factor when deciding on continuous high rate sludge application to land as a management option. The constituents present in sludge may have a negative impact on the receiving environment, especially when applied at excessively high rates for a long time. To protect the receiving environment (public, animals, food-chain, soil and water resources), continuous high rate sludge application may not be permissible for certain sludge qualities under certain conditions. Table 19 indicates whether sludge of a specific quality can be used beneficially at high application rates for a long period of time.

It should be noted that beneficial use of unstable sludge will not be allowed. At least one vector attraction reduction option should be implemented. The applicable restrictions on crop selection and animal and public access control will be discussed in the sections that follow.

TABLE 19: SLUDGE QUALITY RESTRICTIONS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

South African Sludge Class		Public access sites	Private land	Crop type	
				Edible crops	Industrial crops
Microbiological Class	A	✓	✓	✓	✓
	B	!	!	!	!
	C	X	!	X	!
Stability Class	1	✓	✓	✓	✓
	2	!	!	!	!
	3	X	X	X	X
Pollutant Class	a	✓	✓	✓	✓
	b	!	!	!	!
	c	X	!	X	!
Legend:					
✓ = permissible		! = permissible with restriction		X = not permissible	

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Restrictions on crop production

Crop restrictions are implemented to prevent food-chain contamination. Table 20 lists different types of crops and the type of restrictions applicable to them. The specific restrictions are based on the quality of the applied sludge and detailed in Table 21.

TABLE 20: CROPS TO BE CONSIDERED FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

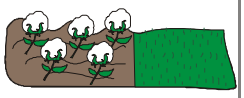
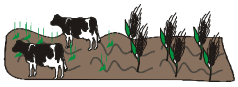
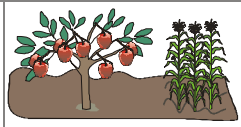
Industrial crops	Animal feed	Crops with harvested / edible parts that :		
		Usually do not touch the soil/sludge mixture	Usually touch the soil/sludge mixture	Are within soil/sludge mixture
				
Allowed with restrictions	Allowed with restrictions	Allowed with restrictions	Not allowed (Refer to Volume 2 - Agricultural use)	Not allowed (Refer to Volume 2 - Agricultural use)

TABLE 21: SPECIFIC RESTRICTIONS APPLICABLE TO CROPS RECEIVING CONTINUOUS HIGH RATE SLUDGE APPLICATION

Sludge Quality		Industrial crops	Animal feed	Grain and fruit trees
Microbiological Class	A	None		
	B	None	Allow 30 day rest period before harvest/grazing	
	C		Allow 90 day rest period before harvest/grazing	
Stability Class		No restrictions on crop type based on Stability class		
Pollutant Class	a	None		
	b	None	Sludge to be incorporated into soil	
	c		Not permissible	

Note: For **instant lawn** cultivation the following requirements apply:

- Microbiological class B – Sludge application must stop 30 days before harvest and lawn must be irrigated with clean water during this stage
- Microbiological class C – Not permissible

Restrictions on grazing animals

The restrictions on grazing animals are implemented mainly to protect the animals from the pathogens present in the sludge but also against high metal uptake of the cultivated crop. The applicable restrictions are detailed in Table 22.

No grazing animals should be allowed on land when the soil metal concentration > MPL.

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

TABLE 22: RESTRICTIONS ON ANIMAL GRAZING APPLICABLE TO CONTINUOUS HIGH RATE SLUDGE APPLICATION SITES

Sludge Quality		Restrictions
Microbiological Class	A	None
	B	No grazing allowed for 30 days after sludge application
	C	No grazing allowed for 90 days after sludge application
Stability Class	1	None
	2	Depending on the reliability of the vector attraction reduction measures implemented, additional management systems may be required
	3	Not permissible
Pollutant Class	a	None
	b	No grazing allowed unless sludge is incorporated into the soil
	c	Not permissible

Public access restrictions

Public access must be restricted at land application sites to minimise public contact with pollutants, including pathogens that may be present in the sludge. Beneficial use sites can be either public contact sites with high potential for public exposure (golf courses, public parks) or private land (plantations, farm land) with limited potential for public exposure. The specific restrictions on public access to these sites will depend on the quality of the applied sludge (Table 23).

TABLE 23: PUBLIC ACCESS RESTRICTIONS APPLICABLE TO HIGH RATE SLUDGE APPLICATION SITES

Sludge Quality		Public access sites	Private land
Microbiological Class	A	None	
	B	No public access for 30 days after sludge application	
	C	No public access for 90 days after sludge application	
Stability Class	1	None	
	2	Depending on the reliability of the vector attraction reduction measures implemented, additional management systems may be required	
	3	Not permissible	
Pollutant Class	a	None	
	b	No access unless sludge is incorporated into the soil	Incorporation of sludge into the soil is recommended
	c	Not permissible	

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

MONITORING REQUIREMENTS FOR CONTINUOUS HIGH RATE APPLICATION

Certain monitoring requirements have to be implemented to monitor the effect of continuous high rate sludge application on the soil, groundwater and surface water. The monitoring results will serve as an early warning system, indicating when sludge application will no longer be permissible.

Sludge monitoring

Sludge monitoring is recommended to ensure that the sludge quality does not deteriorate to a point where it can no longer be used beneficially. Table 24 indicates the frequency of sampling and analyses needed for sludge monitoring purposes.

TABLE 24: SLUDGE SAMPLING AND ANALYSES FOR MONITORING

<table>
<tr><td>What should be monitored ?</td><td colspan="3">○ Microbiological quality
○ Physical characteristics
○ Chemical characteristics</td></tr>
<tr><td rowspan="5">How often should samples be taken ?</td><td colspan="2">Amount of sludge produced (t _{dry weight})</td><td rowspan="2">Monitoring frequency</td></tr>
<tr><td>Daily average</td><td>Yearly average</td></tr>
<tr><td><1</td><td><365</td><td>Once per year</td></tr>
<tr><td>1 - 5</td><td>365 - 1 825</td><td>4 times per year</td></tr>
<tr><td>5 - 45</td><td>1 825 - 16 500</td><td>6 times per year</td></tr>
<tr><td>>45</td><td>>16 500</td><td>Monthly</td></tr>
<tr><td>Type of samples</td><td colspan="3">Grab samples of pathogens and composite samples for metals.</td></tr>
<tr><td>How many samples should be taken?</td><td colspan="3">At least 3 samples of each sludge stream destined for disposal.</td></tr>
<tr><td>When to sample ?</td><td colspan="3">Before disposal</td></tr>
<tr><td rowspan="6">Where to collect samples ?</td><td>Anaerobic digested</td><td colspan="2">Collect from sampling valves on the discharge side of sludge pumps</td></tr>
<tr><td>Aerobic digested</td><td colspan="2">Collect from sampling valves on the discharge side of sludge pumps</td></tr>
<tr><td>Thickened</td><td colspan="2">Collect from sampling valves on the discharge side of sludge pumps</td></tr>
<tr><td>Heat treated</td><td colspan="2">Collect from sampling valves on the discharge side of sludge pumps after decanting</td></tr>
<tr><td>Mechanical dewatered</td><td colspan="2">Collect from discharge point</td></tr>
<tr><td>Dewatered by drying beds</td><td colspan="2">Divide bed into quarters, sample from each quarter and combine samples</td></tr>
<tr><td>Sample sizes</td><td colspan="3">At least 500g _{dry mass}</td></tr>
<tr><td>Analyses methods</td><td colspan="3">See volume 1 - Appendix 2 (microbiological constituents) and Volume 3 - Appendix 1 (TCLP test for metals)</td></tr>
</table>

Groundwater monitoring

Groundwater should be monitored to ensure that no aquifer contamination occurs due to continuous high rate sludge application. Monitoring boreholes should be located to intersect groundwater moving away from the application site.

- Boreholes should be located on either side of the application site in the direction of the groundwater flow (up-stream and down-stream)

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

- Monitoring boreholes must be such that the section of the groundwater most likely to be polluted first is monitored
- Groundwater levels must be recorded on a regular basis to detect any changes or trends
- The monitoring frequency is higher for liquid than dewatered sludge since the impact of liquid sludge on soil and groundwater is larger
- At existing sites where the water table <5m the monitoring frequency should increase to quarterly monitoring for dewatered sludge application or monthly monitoring for liquid sludge application.
- Groundwater analyses should include:
  - Groundwater chemistry
  - Groundwater microbiology
- Water sampling, preservation and analyses should be done according to described procedures (Table 25)
- If the sludge producers adhere to all the requirements in this guideline, groundwater should be adequately protected. However, it is recognised that in some unforeseen circumstances groundwater contamination may be observed for which a closure and remediation plan will be needed.

TABLE 25: GROUNDWATER SAMPLING AND ANALYSES FOR MONITORING

<table>
<tr><td>What should be monitored ?</td><td colspan="3">○ Chemistry - pH, EC PO_4, NH_4, NO_3, COD
○ Microbiology - Faecal coliforms and E.coli depending on sludge quality</td></tr>
<tr><td rowspan="4">How often should samples be collected and analysed?</td><td></td><td>Dewatered sludge</td><td>Irrigated sludge</td></tr>
<tr><td>Chemistry</td><td>Biannually / quarterly*</td><td>Quarterly / monthly*</td></tr>
<tr><td>Microbiology</td><td>Biannually / quarterly**</td><td>Quarterly / monthly**</td></tr>
<tr><td colspan="3">* - existing sites with water table <5m (dewatered sludge) or < 10m (liquid sludge)
** - Microbiological class B / Microbiological class C</td></tr>
<tr><td>What sampling equipment should be used?</td><td colspan="3">Plastic bottles with a plastic cap and no liner within the cap are required
Glass bottles are required if organic constituents are to be tested (see Appendix 3)
Sterile plastic / glass bottles for microbiological samples</td></tr>
<tr><td>How should samples be taken?</td><td colspan="3">Appendix 3 (Sampling procedures)</td></tr>
<tr><td rowspan="3">How should samples be preserved?</td><td>For pH, EC, PO_4 analyses</td><td colspan="2">For NH_4, NO_3, COD analyses</td></tr>
<tr><td>No additives, refrigerate and analyse as soon as possible</td><td colspan="2">Add H_2SO_4 to pH<2</td></tr>
<tr><td colspan="3">Microbiological analyses
No additives, keep in cooler box with ice and analyse within 24 hours</td></tr>
<tr><td>How many samples should be taken?</td><td colspan="3">At least 2 samples from each borehole, 1 sample for pH, EC and PO_4 analyses and 1 sample for NH_4, NO_3 and COD analyses.
An additional sample needed for microbiological analyses (if applicable)</td></tr>
<tr><td>Sample sizes</td><td colspan="3">At least 100 ml for each sample would be needed</td></tr>
<tr><td>Analytical methods</td><td colspan="3">Appendix 1 (Analytical methods)</td></tr>
</table>

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Note: The frequency for groundwater monitoring could be relaxed under the following circumstances:

- Water table >10m (dewatered sludge application) or >20m (liquid sludge application)
- Soil clay content >35%
- When monitoring results over a 5 year period indicate an insignificant impact

Frequency can also be **increased** at the discretion of the regulating authority when contamination becomes inevitable.

Surface water monitoring

Surface water should be monitored to ensure that near-by surface water bodies are not contaminated by continuous high rate sludge application. Surface water monitoring includes run-off monitoring.

- Water sampling, preservation and analyses should be done according to described procedures (Table 26)
- Run-off should be collected on a daily basis and analysed before discharge. No analyses needed when run-off is re-cycled into the treatment system.
- Surface water quality should be monitored monthly during the rainy season, 20–50m upstream and downstream of the application site.
- Analyses should include:
  - Surface water chemistry
  - Surface water microbiology

TABLE 26: SURFACE WATER SAMPLING AND ANALYSES FOR MONITORING

What should be monitored ?	○ pH, EC PO_4, NH_4, NO_3, COD ○ Faecal coliforms (Microbiological class B) and *E.coli* (Microbiological class C)	
How often should samples be taken?	Monthly from streams above and below the application site (20 - 50m down stream)	
What sampling equipment should be used?	Plastic bottles with a plastic cap and no liner within the cap are required for most sampling exercises Glass bottles are required if organic constituents are to be tested (see Appendix 3)	
How should samples be taken?	Appendix 3 (Sampling procedures)	
How should samples be preserved?	**For pH, EC, PO_4 analyses**	**For NH_4, NO_3, COD analyses**
	No additives, refrigerate and analyse as soon as possible	Add H_2SO_4 to pH<2
	Microbiological analyses	
	No additives, keep in cooler box with ice and analyse within 24 hours	
How many samples should be taken?	At least 2 samples from each borehole, 1 sample for pH, EC and PO_4 analyses and 1 sample for NH_4, NO_3 and COD analyses. An additional sample needed for microbiological analyses (if applicable)	
Sample sizes	At least 100 ml for each sample would be needed	
Analytical methods	Appendix 1 (Analytical methods)	

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Note: The frequency for surface water monitoring could be **relaxed if**:

- The distance to the nearest surface water resource or borehole is > 1km;
- The user can prove that the surface water resource is adequately protected through run-off interception
- When monitoring results over a 5 year period indicate an insignificant impact.

The monitoring frequency may be **increased** at the discretion of the regulating authority.

Soil monitoring

Soil monitoring will serve as an early warning system on the mobility of constituents of concern in the soil profile and the potential for groundwater contamination. Soil sampling and analyses should be done according to described procedures (Table 27).

- Sample the beneficial use site area according to different soil types (if applicable).
- Increase the sample frequency when the soil pH<6.5 and/or soil clay content <20%.
- Sample at 100mm depth increments up to 500mm.
- Collect numerous samples, mix well and submit at least three composite samples for each depth increment for every hectare of the land where sludge is added.
- Analyse samples for nutrients and metals and determine soil pH.

TABLE 27: SOIL SAMPLING AND ANALYSES FOR MONITORING

What should be monitored ?	pH, nutrients (total N, P and NO_3-N) and 8 metals (total) specified in classification	
Sampling frequency	**Dewatered sludge**	**Irrigated sludge**
	Yearly / biannually*	Biannually / quarterly*
	* - Existing land application sites with soil pH <6.5 and/or clay content <20%	
How to sample?	Sample at 100mm intervals to at least 500mm Appendix 3 (Sampling procedures)	
How many samples?	At least 3 composite samples of each application area at each depth (see Appendix 3)	
Sample sizes	At least 1kg	
Analytical methods	Appendix 1 (Analytical methods)	

REMEDIATION PLANS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION SITES

Due to regular monitoring, new application sites will not deteriorate to such an extent that remediation and rehabilitation will be necessary. However, existing sites may be contaminated to such an extent that remediation will be necessary. Therefore a site remediation plan should be developed for **existing sites** by a responsible person when:

- Groundwater quality deteriorated due to sludge application; or

- Surface water quality was affected due to sludge application; or
- The total soil metal content exceed the MPL; or
- Mobility of metals and nutrients in the soil profile is observed.

CLOSURE PLANS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION SITES

Once the operation has ceased, aftercare is necessary to ensure sustained acceptability. A closure plan is required for all sites that continuously received sludge at high rates and should be developed by a responsible person.

Aspects that should be addressed include:

- Remedial design to address identified problem areas (or future problems)
- Final land-use
- Final landscaping and re-vegetation
- Permanent storm water diversion measures, run-off control and anti-erosion measures
- Post-closure monitoring plan and implementation.

RECORD KEEPING REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

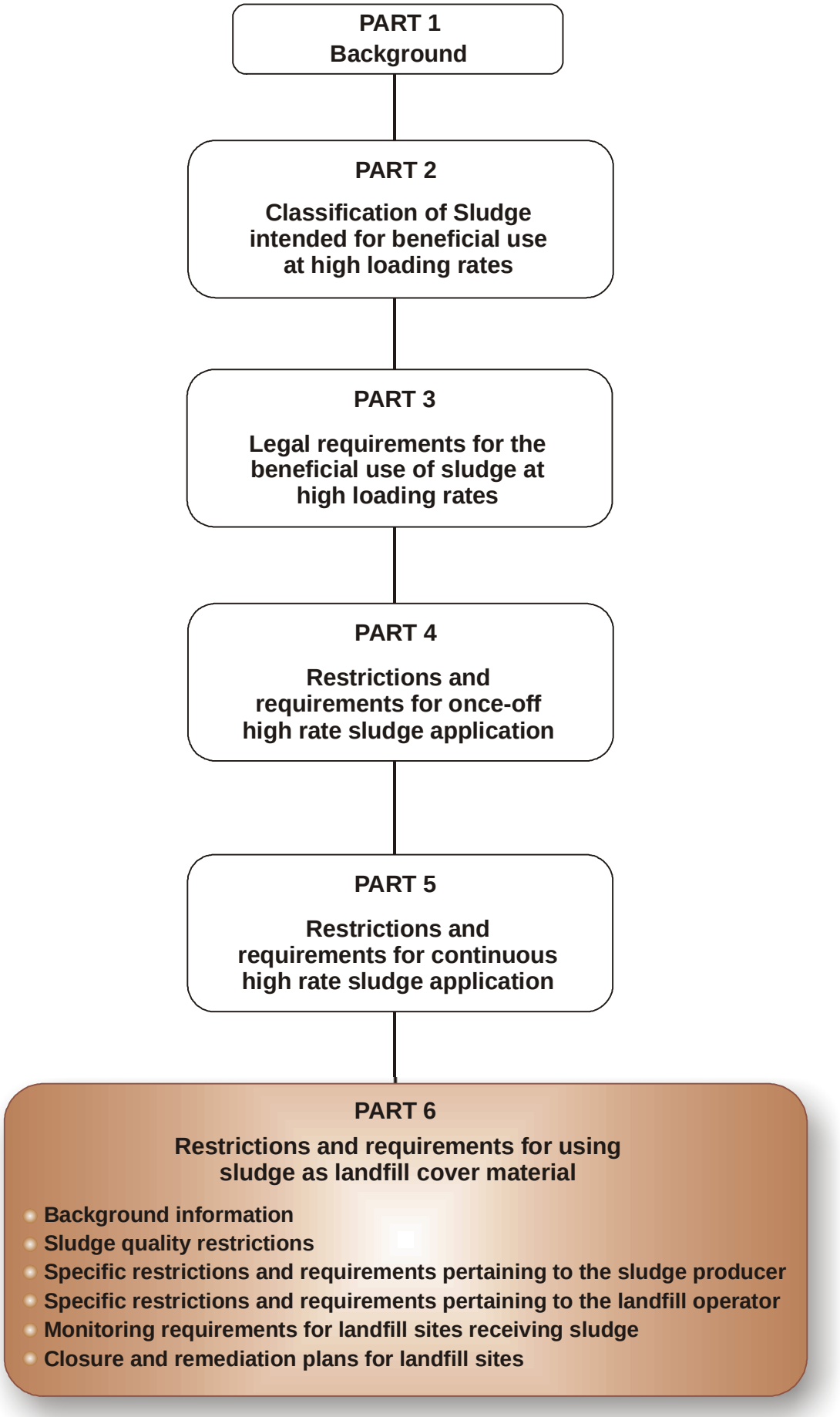
Once the applicable permits and licences have been granted, sludge utilization essentially becomes self-regulatory. This implies that certain records must be kept by the sludge producer and sludge user. Table 28 summarises the record keeping requirements for the sludge producer supplying sludge to be used beneficially at high rates for extended periods (irrespective of the class of sludge produced). It is the responsibility of the producer to obtain data from the sludge user as per their contract (see Appendix 3).

PART 5: RESTRICTIONS AND REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

TABLE 28: RECORD KEEPING REQUIREMENTS FOR CONTINUOUS HIGH RATE SLUDGE APPLICATION

Description of records to be kept by the sludge producer	
Sludge records	
1	Classification of sludge applied to land
2	Results supporting sludge classification in terms of the: • Microbiological class • Stability class • Pollutant class
3	The original or certified copy of the agreement/contract between the sludge producer and the sludge user (if applicable)
4	Copies of the applicable permits and/or licences
Monitoring records	
5	Sludge data pertaining to the: • Microbiological class • Stability class • Pollutant class
Description of records to be kept by the sludge user	
General information	
1	Sludge application rate (ton/ha)
2	Frequency of application
Initial site investigation records	
3	Proof that application site is not located in a sensitive area
4	Location of site map (map or co-ordinates)
5	Groundwater data including: • Aquifer classification (yield, depth, strategic value) • Hydraulic gradient • Groundwater quality (up gradient and down gradient)
6	Surface water quality data
7	Soil data including: • Soil structure, pH, clay content, permeability and cation exchange capacity (CEC) • Soil classification and soil map of the area • Concentration of nutrients, trace elements and metals (total)
Monitoring records	
8	Groundwater data including: • Groundwater levels • Groundwater monitoring data (chemistry and microbiology if applicable)
9	Surface water data including: • Run-off volumes and quality (if applicable) • Water quality from nearby stream
10	Soil data including: • Nutrient status with depth • Metal content of the soil with depth (total)

DOCUMENT ROADMAP



PART 6: RESTRICTIONS AND REQUIREMENTS FOR USING SLUDGE AS LANDFILL COVER

Part 6 deals with restrictions and requirements applicable to using sludge as daily and final cover material on General or Hazardous landfill sites. The following definitions and requirements for daily and final cover are supplied in the Minimum Requirements:

Daily cover - material may be on-site soil, builders' rubble or, with permission from the Competent Authority, ash or other material. Daily cover is applied to compact waste, eliminates odours, reduces littering and risk of fires.

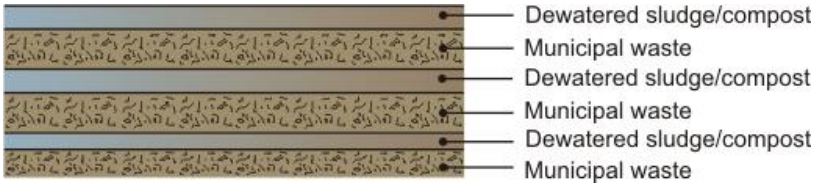


Figure 5: Use of sludge as daily cover

Final cover - material must be capable of supporting vegetation. The thickness of the final cover must be consistent with the design requirements of the landfill, but the sludge will generally only be mixed with the top 100mm of soil.

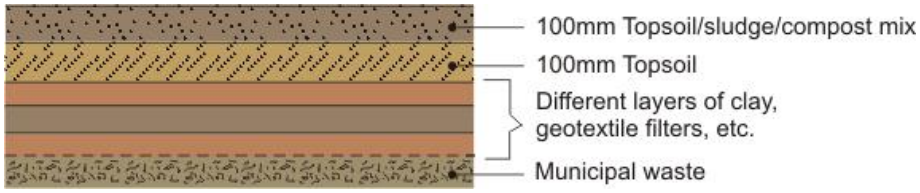


Figure 6: Use of sludge as final cover

The use of sludge as cover material or mixing of sludge with other material is not specifically addressed in the Minimum Requirements (latest edition). However, the use of sludge as cover material has certain advantages which are discussed in sections that follow.

Since sludge is classified as hazardous waste according to the Minimum Requirements it would have to meet the appropriate requirements as described in the latest edition of the Waste Management Series: *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste* and *Minimum Requirements for Waste Disposal by Landfill*. All actions required in the operation, monitoring and closure of landfill sites in South Africa are described in these publications. Volume 3 of the Sludge Guidelines presents procedural guidelines for co-disposal of sludge in landfill and Volume 4 (this document) addresses specific restrictions and requirements for use of sludge as cover material on landfills.

BACKGROUND INFORMATION

The following apply for wastewater sludge:

- sludge applied/disposed at a site other than the WWTP itself, falls under the definition of waste as stipulated in Section 1 of the Environmental Conservation Act, 1989;
- sludge falls under the definition of high volume/low hazard waste.

PART 6: RESTRICTIONS AND REQUIREMENTS FOR USING SLUDGE AS LANDFILL COVER

Landfill classification

Landfill designs in the Minimum Requirements are based on the specific landfill classification. Waste type, waste volumes and the water balance determine the waste classification (Table 29).

TABLE 29: LANDFILL CLASSIFICATION

Waste type	Waste volumes	Water balance
General waste - **G**	Communal (**C**) - <25 t/day	**B$^+$** - precipitation exceeds evaporation
Hazardous waste - **H**	Small (**S**) - 25-150 t/day	**B$^-$** - evaporation exceeds precipitation
	Medium (**M**) - 150-500 t/day	
	Large (**L**) - >500 t/day	

Sites accepting general waste (municipal and delisted hazardous waste) have a classification describing these three aspects.

Example: GLB$^+$ landfill - receives more than 500 tons per day of general waste and is expected to generate leachate more than one year in five.

Sludge may only be used as cover material at B$^+$ sites provided that the site is equipped with an appropriate leachate management system. When sludge application is planned at a B$^-$ site, the site should be engineered as a B$^+$ site with the appropriate liners and leachate collection system.

Note: These restrictions may be relaxed in certain areas on a site specific basis, if adequate proof is provided to the authorities that no leachate will be generated at the landfill site.

Advantages of using sludge for landfill cover

The advantages of sludge as daily and final cover material for landfills are:

- Water holding capacity of sludge – limits leaching into the landfill
- The nutrients in the sludge can help to sustain vegetation on the final cover
- Metal adsorption capacity of sludge aids the precipitation of metals from the leachate.

SLUDGE QUALITY RESTRICTIONS

Table 30 indicates the sludge quality that may be used as cover material on general and hazardous landfills.

PART 6: RESTRICTIONS AND REQUIREMENTS FOR USING SLUDGE AS LANDFILL COVER

TABLE 30: SLUDGE QUALITY RESTRICTIONS FOR USE OF SLUDGE AS LANDFILL COVER

Sludge Quality		General landfills	Hazardous landfill
Microbiological Class	A	✓	✓
	B	!	!
	C	X	!
Stability Class	1	✓	✓
	2	!	!
	3	X	X
Pollutant Class	a	✓	✓
	b	!	!
	c	!	!
Legend:			
✓ = permissible		! = permissible with restriction	X = not permissible

SPECIFIC RESTRICTIONS AND REQUIREMENTS PERTAINING TO THE SLUDGE PRODUCER

Although the use of sludge as landfill cover material has advantages, certain restrictions and requirements will apply to this beneficial use option. This section deals with the restrictions and requirements pertaining to the **sludge producer**.

Minimum solids content

Sludge with solids content of 50% has properties similar to soil. It will increase the water holding capacity of the final cover of the landfill facility and has high odour absorbing abilities. Unless the sludge is dried, composted or mixed with soil it is too wet and odorous to apply as daily or final cover material. The high moisture content makes surfaces unstable for traffic and has vector attraction properties. The landfill operator may accept sludge with lower solids content when it is mixed with other material at the landfill or left to dry further at the waste preparation area to achieve the required solids content.

Delisting of sludge

All sludge types may be used as cover material at appropriately lined G:B^+ landfills, provided that it passes through the delisting process. A schematic presentation of the delisting process is shown in Figure 7.

Delisting is based on the estimated environmental concentration (EEC) and the acceptable exposure (AE) of a particular pollutant. The determination of EEC establishes potential

exposure to target populations or organisms. A TCLP analysis of the sludge should be done before delisting. The TCLP method is presented in Appendix 1.

Pollutant class **a** sludge will automatically delist and can be used for landfill cover. Pollutant class **b** sludge will probably delist if lime is added at 25 kg_{lime}/ton_{sludge}. The treated sludge will have to be tested and re-analysed to confirm the efficacy of the treatment (Pollutant class **b** → Pollutant class **a**). In the case of Pollutant class **b** and **c** sludge that cannot be delisted after liming, landfill cover can still be regarded as a beneficial use option, but there would be a limitation on the amount of sludge that can be mixed with other cover material. However, the total load and mixing ratio will be the responsibility of the landfill operator and not that of the sludge producer.

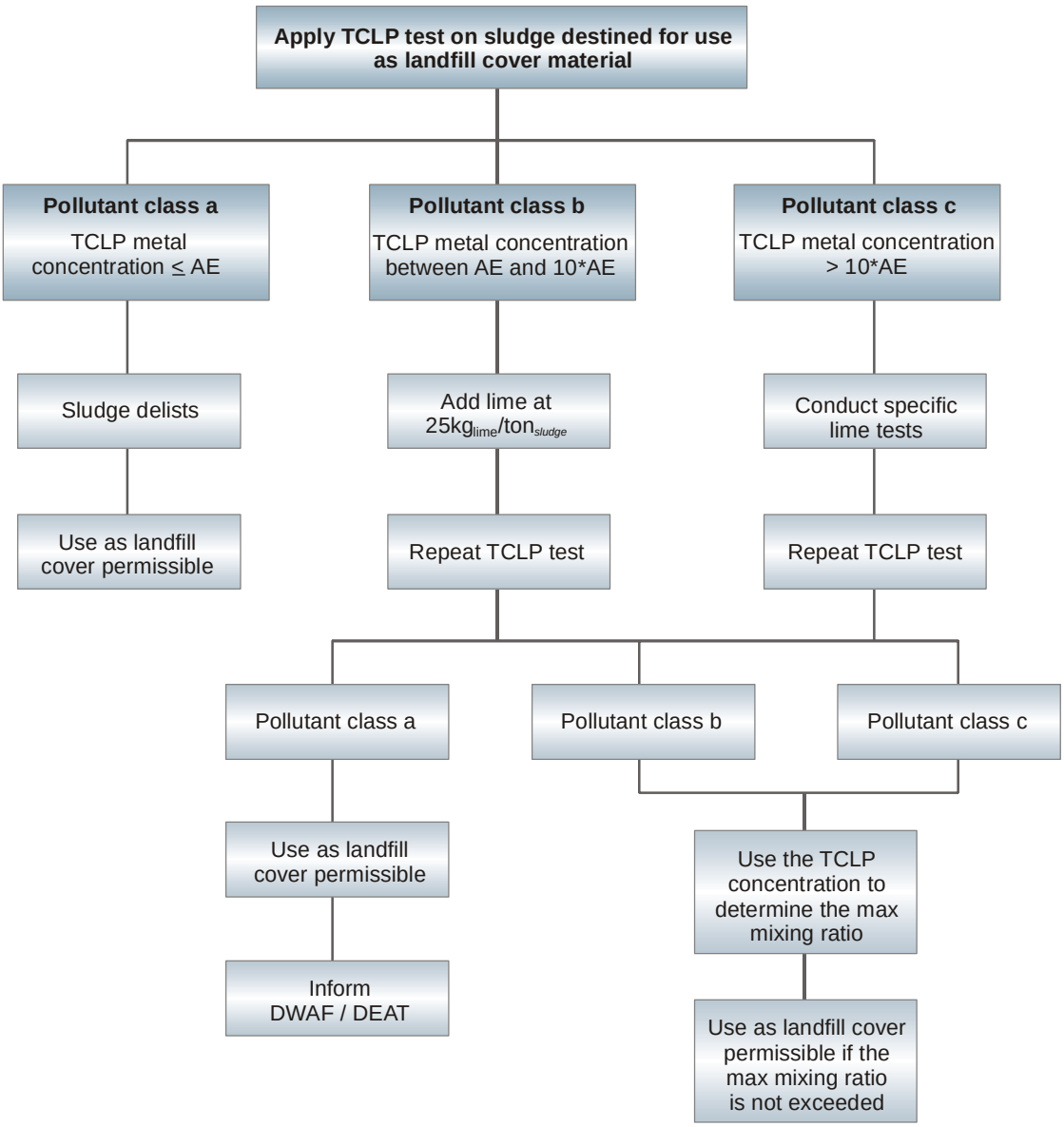


Figure 7: Schematic presentation of sludge delisting process

PART 6: RESTRICTIONS AND REQUIREMENTS FOR USING SLUDGE AS LANDFILL COVER

Sludge monitoring

Sludge should be monitored on a regular basis to ensure that the quality stays within the limits required for application to landfill. The same sampling analyses and frequency apply as for other sludge use options (Table 24). The sampling frequency for monitoring purposes depends on the amount of sludge produced and can be summarised as follows:

- <1 t $_{\text{dry weight}}$/day - yearly
- 1-5 t $_{\text{dry weight}}$/day - quarterly
- 5-45 t $_{\text{dry weight}}$/day - biannually
- >45 t $_{\text{dry weight}}$/day - monthly

However, the landfill operator may require additional monitoring, especially in the case of Pollutant class b and c sludge that needs to be treated before it can delist.

Transportation of sludge

Due to the potential high microbiological contaminant content of sludge, it should be handled as a hazardous material (containing infectious substances) during transportation. The following aspect should receive attention during the transportation of sludge from the WWTP to the landfill site:

- Identification of waste - the transporters must be provided with accurate information about the nature and properties of the load.
- Documentation - the transport operator must be provided with the relevant transportation documentation.
- Hazchem placard - the transport operator must be supplied with the appropriate Hazchem placards which should be properly fitted to the vehicle.
- Protection against effect of accident - the Generator - or his representative, i.e., transporter - must ensure that adequate steps are taken to minimise the effect an accident or incident may have on the public and on the environment.
- Notification - all road accidents must be reported to the Department of Transport on the prescribed documentation and a full report should be sent to the Local Authorities, the Competent Authority and the DEAT.

SPECIFIC RESTRICTIONS AND REQUIREMENTS PERTAINING TO THE LANDFILL OPERATOR

This section deals with the specific restrictions and requirements pertaining to the **landfill operator** should the landfill be permitted to use sludge as cover material.

Sludge analyses/monitoring information

Since the sludge quality is fundamental in the management of the landfill site, the landfill operator should be certain of the sludge quality. This is especially important in cases where the sludge had to be treated (limed) before it could be delisted. The landfill operator should regularly request for the sludge analyses results and/or monitoring information. Small WWTPs may only be required to monitor on yearly or quarterly basis and this may be too

irregular for the landfill operator to ensure compliance to the permit. Therefore, landfill operators may require additional sludge monitoring.

Total load / Maximum mixing ratio

The total load of a hazardous substance is the amount of the specific substance that may be accepted at a certain landfill site. The maximum mixing ratio is the total load of sludge that may be mixed with other cover material before application. The TCLP concentration of the substance that would limit the maximum load should be used for the calculations. When the concentration of more than one substance is elevated, the one with the biggest influence of the load should be used. An example for the calculation of the maximum mixing ratio is presented in Appendix 5.

Compaction properties of the soil/sludge mixture

The moisture of the sludge and its rheological properties are very important in terms of the final properties of the soil-sludge mixture. The optimal compaction density and moisture content for the mixture will be different to that of the soil used in the mixture and this needs to be considered for operational purposes. Regardless of any maximum sludge loads calculated, the mixed material must conform to construction criteria, and it is a requirement that the compaction properties of all soils or modified soils used in the capping layers be established according to the Standard Proctor Compaction Test (*Minimum Requirements for Waste Disposal by Landfill*. Latest edition). In addition, the shear interface friction between the compacted mixture and the layer below must be considered to ensure that the layer will not slip at the final landfill profile slopes (*Minimum Requirements for Waste Disposal by Landfill*. Latest edition).

MONITORING REQUIREMENTS FOR LANDFILL SITES RECEIVING SLUDGE

The landfill owner/operator is responsible for monitoring at the landfill site. Monitoring serves to quantify any effect of the operation on the environment, especially the water regime, and act as an early warning system, so that any problems that arise can be identified and rectified. Such problems would include:

- malfunctioning drainage systems,
- cracks in the cover,
- leaking liners, and
- surface or groundwater pollution.

Note: The monitoring requirements in *"Landfill Operation Monitoring" (Minimum Requirements for Waste Disposal by Landfill, Latest edition) and the "Water Quality Monitoring" (Minimum Requirements for Water Monitoring at Waste Management Facilities, Latest edition)* should be complied too.

Operational monitoring

The general objective of operational monitoring is to verify that all aspects of the site, including any leachate management and treatment systems, conform to the required standards and the site Permit conditions. More specific objectives are:

- To ensure that the accepted site design is properly implemented

- To function as a control measure to ensure that the operation conforms to the required standards
- To quantify any effect that the operation has on the environment and, in particular, any effect on the water regime
- To serve as an early warning system, so that any problems that arise can be *timeously* identified and rectified.

The extent and frequency of monitoring will depend on the site classification and will be indicated in the Permit. It is the duty of the Responsible Person to ensure that the Minimum Requirements for operation monitoring are applied to a degree commensurate with the class of the disposal site, the situation under consideration and the risk of polluting the environment, more specifically the water regime.

For further information see: *Minimum Requirements for Waste Disposal by Landfill, "Landfill Operation Monitoring" (Latest edition).*

Leachate and water quality monitoring

The Permit Holder must ensure regular sampling and analysis of ground and surface water, leachate, the effluent, sludge or concentrates from any treatment system. The Permit Holder must also ensure interpretation of the findings. Records must be maintained of any impact caused by the operation on the quality of the water regime in the vicinity of the site**. This is required in terms of the Permit conditions**. Additional samples may be taken at other times, if this is considered necessary (Table 31).

TABLE 31: MINIMUM FREQUENCY OF WATER QUALITY MONITORING AT LANDFILL SITES

Leachate	m (if applicable)
Run-off water quality	d
Surface water quality	m
Groundwater chemistry	3m
Legend: m = monthly; 3m = 3-monthly; d = daily	

Methane monitoring

Landfill gas can result in an explosion hazard, where methane gas reaches concentrations of between 5% and 15% by volume of atmospheric gas composition and must therefore be monitored continually. If monitoring indicates that there is any safety risk on account of landfill gas accumulation and/or migration, controls must be considered in consultation with the Competent Authority.

Air quality monitoring

At all landfills there is some risk of dust and the escape of contaminants by wind action. Hazardous air pollutants may therefore be dispersed from a landfill site as dust, or as gaseous substances. These have to be monitored separately.

PART 6: RESTRICTIONS AND REQUIREMENTS FOR USING SLUDGE AS LANDFILL COVER

CLOSURE AND REMEDIATION PLANS FOR LANDFILL SITES

Note: The section on "*Rehabilitation, closure and end-use" (Minimum Requirements for Waste Disposal by Landfill, Latest edition)* applies.

The objectives of disposal site closure are:

- To ensure public acceptability of the implementation of the proposed End-use Plan.
- To remediate the site to ensure that it is environmentally and publicly acceptable and suited to the implementation of the proposed end-use.

CONCLUSION

Volume 4 of the Sludge Guidelines informs the reader regarding the classification and legal requirements for the beneficial use of sludge on land at high application rates (higher than agronomic rates) and the use of sludge as landfill cover material. Due to the potential constituents in the sludge that may impact on the receiving environment at these high application rates, specific restrictions and requirements pertaining to the different sludge classes are also detailed. These restrictions and requirements become more stringent with deteriorating sludge quality and the vulnerability of the receiving environment. Especially at existing sites, where the necessary site selection criteria are not met, the management and monitoring requirements increase substantially.

Specific restrictions and requirements also apply for the different beneficial use options. Once-off high rate sludge application will have less of an impact on the receiving environment than continuous high rate sludge applications and therefore management and strict monitoring requirements will apply for the latter. The data collected during the monitoring programme will broaden the knowledge base on the actual impact of these beneficial use options on the environment.

It is recognized that new information is constantly generated and is recommended that the Sludge Guidelines be revised every 5 to 10 years. This will allow the South African wastewater industry sufficient time to implement these Guidelines and highlight shortcomings, constraints and operational difficulties.