Guidelines for the Utilisation and Disposal of Wastewater Sludge

Volume 4: Requirements for the beneficial use of sludge at high loading rates

Prepared for the
Water Research Commission
by

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FOREWORD

The publication of this report emanates from a project entitled: *Development of the South African wastewater sludge disposal guidelines dealing with land and ocean disposal, beneficial use, use in commercial products and thermal treatment*
(WRC Project No. K5/1622)

DISCLAIMER

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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FOREWORD

Traditional practices related to wastewater sludge management include dedicated land disposal, waste piling, landfill disposal and to a lesser degree use in agricultural practices. However, due to varying reasons, on-site land disposal and waste piling have become the standard management options for many wastewater treatment plants in South Africa today. With sludge production increasing on a daily basis, it has however become apparent that current practices are unsustainable with sludge management becoming a problem for many municipalities in South Africa. Innovative solutions need to be sought to create opportunities that provide a wide spectrum of options to the management of wastewater sludge.

Seeking innovative solutions requires a paradigm shift in our perception and understanding of wastewater sludge from a waste product to one of a resource. Such a shift creates an opportunity for local authorities and municipalities to generate a range of economic and social spin-offs to the benefit of their local communities thereby taking a small step towards achieving the goal of sustainable development.

Volumes 2, 3, 4 and 5 of the Sludge Guidelines Series aim to provide options and opportunities for this innovation and to encourage the beneficial use of wastewater sludge. Where wastewater sludge cannot be used as a resource, the guidelines also provide for its disposal in a responsible manner.

The potential benefits of the nutrients (nitrogen, potassium and phosphorus) and the high carbon content of sludge have been well demonstrated and have led to the beneficial utilization of sludge in many countries. Beneficial use of sludge as a soil conditioner is seen as an appropriate cost-effective management option for South Africa both for the sludge user and wastewater industry. Generally, soils in South Africa are low in organic matter due to its rapid decomposition in the type of climate experienced. Land-use can cause further soil degradation (mining and industrial activities) and has contributed to a widespread deterioration of soil physical properties. The improvement of the physical properties of soil (water holding capacity, permeability, etc.) as a result of an increase in organic carbon plays an important role in promoting the beneficial use of wastewater sludge on land in South Africa. Municipalities can particularly benefit from beneficial use, since it can serve as a source of income.

Volume 2 of the Sludge Guidelines focuses on the beneficial use of sludge in agricultural practices where sludge is added to soil at agronomic rates not exceeding an application rate of 10 tons dry mass per hectare per year. Volume 4 (this document) focuses on the beneficial use of sludge at high loading rates*,* i.e. exceeding 10 ton/ha/y.

The negative effects of high rate sludge application to land on environmental resources need to be managed, to ensure protection of human and animal health, water resources and land quality in general. This Guideline Volume has specifically been developed to maximise the responsible beneficial use of sludge applied at rates higher than agronomic, while still protecting the receiving environment.

The Guidelines were developed as a user-friendly document for regulatory authorities, managers, practitioners and operators responsible for sludge management. The development of the Sludge Guidelines were also supported by an extensive stakeholder consultation process (two consultative workshops and a training workshop in each province) which included sector stakeholders, regulatory authorities, government departments, industry experts, professional service providers, and interested individuals whose inputs significantly enhanced the final product. In the interest of transparency, the scientific basis, assumptions, thought processes and stakeholder consultation were documented as separate documents available from the Water Research Commission (WRC).

The Sludge Guidelines are living publications, and will be reviewed periodically based on comments received on the current requirements and approaches. All users are urged to take a critical view regarding the Guidelines in terms of usefulness and appropriateness. It is believed that valuable feedback will ensure continual improvement. Comments should be directed to the Director: Resource Protection and Waste, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001.

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"DEVELOPMENT OF THE SOUTH AFRICAN WASTEWATER SLUDGE DISPOSAL GUIDELINES DEALING WITH LAND AND OCEAN DISPOSAL, BENEFICIAL USE, USE IN COMMERCIAL PRODUCTS AND THERMAL TREATMENT"

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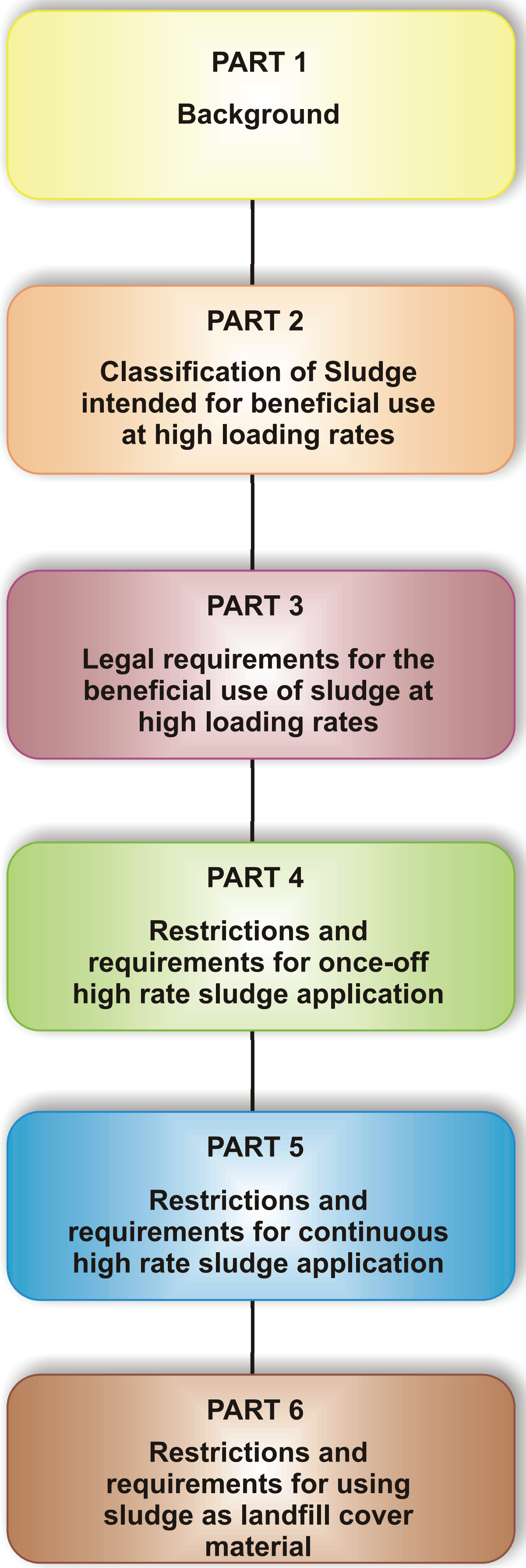
The project team also want to acknowledge Tiaan van Niekerk (cover page design) and Beulah Sanders (graphics design) for their assistance.

STRUCTURE OF THIS GUIDELINE VOLUME



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LIST OF ACRONYMS

AE	Acceptable Exposure
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
ECA	Environment Conservation Act 73 of 1989
EEC	Estimated Environmental Concentration
EIA	Environmental Impact Assessment
MAR	Maximum application rate
MPL	Maximum Permissible Level
NEMA	National Environmental Act, No. 107 of 1998
NWA	National Water Act 36 of 1998
PAR	National Water Act 36 of 1998
RoD	Record of Decision
TCLP	Toxicity Characteristic Leaching Procedure
TMT	Total Maximum Threshold Value
WWTP	Wastewater treatment plant

INTRODUCTION

These Guidelines were developed to encourage the beneficial use of wastewater sludge. Sludge has well known beneficial soil conditioning and fertilizing properties as well as potentially harmful substances and can therefore not be used as normal fertilizer. Volume 2 of the Sludge Guidelines covered the beneficial use of sludge in agricultural practices at agronomic rates, not exceeding 10 ton/ha/year. The fundamental premise of this volume (Volume 4) is that sludge can be used beneficially at high loading rates, provided that there is adequate management and control. These beneficial use options include once-off high rate sludge application to increase the organic content and nutrient status of degraded soils to sustain vegetative growth, continuous high rate applications on non-edible crops and the use of sludge as cover material on landfill.

High rate sludge application, especially practiced on a continuous basis, may have negative impacts on the environment. Therefore, the negative effects on environmental resources need to be managed and monitored to protect human and animal health, water resources and land quality in general. To achieve this, some of the principles of the Minimum Requirements[1] have been adopted for land application options. The Minimum Requirements are updated periodically and the reader would be referred to these documents, or any future updates of the documents, when necessary. However, Volume 3 and 4 of the Sludge Guidelines were developed recognising that the wastewater industry is not necessarily familiar with waste handling practices and legal requirements of the Minimum Requirements. Therefore, the basic principles of the Minimum Requirements, as adopted for sludge handling and disposal are included in these Volumes of the Sludge Guidelines to enable the wastewater industry to familiarise themselves with waste handling practices.

PURPOSE OF THIS VOLUME

The purpose of this Volume is:

- To give guidance on how to select appropriate beneficial use options
- To create an understanding of the operational and legal requirements of the different beneficial use options; and
- To present guidelines for the monitoring of beneficial use sites.

WHO SHOULD USE THIS VOLUME?

Volume 4 was developed to enable beneficial use of sludge at higher than agronomic rates without harming the receiving environment. Any person who effectively applies the Guidelines will comply with all the environmental requirements. This Guideline was developed for:

- **Wastewater treatment plant operators** – to implement acceptable good practice pertaining to the beneficial use of sludge at high application rates.

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[1] Department of Water Affairs and Forestry. Waste Management Series. Document 1: Minimum Requirements for the Handling, Classification and Disposal of Hazardous waste. Latest edition.

- **Wastewater treatment service providers** – to implement beneficial use of sludge at higher than agronomic rates as a sludge management strategy while managing the environmental impact.

- **Local authorities and town/city councils that own and operate wastewater treatment plants** – to design, operate and maintain a sustainable beneficial sludge use strategy that would not negatively impact on the receiving environment.

- **Landfill site owners/operators** – to manage the wastewater sludge accepted on the site as landfill cover material.

- **Wastewater engineers/scientists** – to design and develop improved treatment methods and monitoring protocols which will ensure sustainable beneficial use of sludge.

- **Technical advisors** – to encourage beneficial use of sludge and provide appropriate advice on management and monitoring requirements.

- **Legislators** – to assess compliance in cases where the Sludge Guideline Volumes have been referred to in a water use authorisation or waste disposal site permit.

- **Sludge users** – to effectively and responsibly utilise sludge in beneficial use options.

- **Educators** – to build capacity and create awareness.

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- Description of beneficial use options

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PART 1:

BACKGROUND

Volume 4 of the Guidelines was developed with a view to maximise the beneficial use of sludge. This Volume deals specifically with sludge application to land, for beneficial purposes, at rates higher than agronomic rates with specific management, technical and legislative aspects as well as restrictions and monitoring requirements to protect the receiving environment. It provides ceiling limits for metals and microbiological constituents in sludge intended for beneficial use and encourages the implementation of vector attraction reduction options to stabilize sludge.

APPROACH FOLLOWED TO DEVELOP VOLUME 4

The Guidelines for the beneficial use of sludge is based on the following information:

- Local and international research findings
- Local legislative and guiding documents
- International guidelines and legislative trends
- The results of risk assessment
- Practical considerations

The scientific premise for this Volume was based on a risk assessment and risk management process. All the potential risks associated with the beneficial use of sludge were identified. The process revealed which potential receptors could be affected and methods/limits were developed to protect these receptors.

It was assumed that the employers comply with the provisions of the Occupational Health and Safety Act (OSH Act) and that the workers are equipped with personal protective equipment (PPE). The impact of the sludge on workers would therefore be covered by this Act and is not considered to be a sludge application issue.

The following constituents and properties of sludge received particular attention due to their potential negative effects:

- Nutrients – soil, surface and groundwater should be monitored to ensure that high rate land application of sludge does not increase the concentrations of nutrients in these receptors or that the maximum nitrogen level for surface and groundwater is not exceeded.
- Metals – maximum permissible levels (MPL) were developed for sludge and the receiving soil environment. These metal limits will protect the receiving soil and water environment.
- Odours – odours and vector attraction affect the public negatively (and could affect public health), therefore the stability of sludge, the reduction of odours and vector attraction potential received attention in these Guidelines.

- Pathogens – locally achievable pathogen standards were set for sludge destined for beneficial use with restrictions to protect the receiving environment and receptors.

The potential negative effects resulting from high rate application were managed by specifying management requirements and restrictions to isolate potential receptors from the potential risk (such as implementing access restrictions and buffer zones to protect the general public). Some beneficial use options such as using sludge for daily or final landfill cover need to comply with the Minimum Requirements and other documents that already exist. In these cases additional guidance is provided that could assist the user to simplify the process required. Therefore, Volume 4 expands on the existing requirements without contradicting them. The conceptual thinking, development process and assumptions are presented in separate documents which is available from the WRC[2 & 3].

MOTIVATION FOR DEVELOPING GUIDELINES FOR BENEFICIAL USE OF SLUDGE

The beneficial use of sludge is encouraged throughout the Sludge Guidelines to ensure sustainable sludge management and Volume 2 (Agricultural use), Volume 4 (Beneficial use) and Volume 5 (Saleable products) deal with these aspects. The major benefits of sludge application are:

- Supply of major plant nutrients
- Supply of some essential micronutrients and
- Improvement of soil physical properties to improve water retention, soil water transmission and increased soil structure.

Although sludge does not comply with the criteria to be classified as organic fertilizer (<20% ash and <40% water) it can still be used to improve the organic status of soils. However, certain substances present in sludge (metals and human pathogens) compromise the beneficial use. Therefore the benefits of sludge should always be weighed against the restrictions.

DESCRIPTION OF BENEFICIAL USE OPTIONS

Once-off high rate sludge application

Since sludge is known to improve not only the physical characteristics of soils but also to provide essential nutrients and micro elements, it can benefit soils under the following circumstances:

- Rehabilitation of disturbed/degraded soils (nutrient depletion, erosion, acidity and salinity, poor physical properties, reduced biological activity) after mining activities, intensive farming and industrial activities;
- Establishment of golf courses, race courses, vineyards, road embankments, public parks.

[2] Herselman, J.E. and Snyman, H.G. 2008. Guidelines for the utilisation and disposal of wastewater sludge: Literature review and technical support document for Volumes 3-5. WRC Report 1622/1/09, 1622/2/09 and 1622/3/09.

[3] Snyman, H.G. and Moodley, P. 2008. Guidelines for the utilisation and disposal of wastewater sludge: Legal review. WRC Report 1622/4/09.

Sludge can be added once-off to soil at high rate (higher than agronomic rates) to improve its chemical and physical characteristics to enable it to sustain vegetation. In some instances once-off application may not be enough to improve the soil's capacity to sustain vegetative growth and additional application may be required. However, if sludge is applied to the same piece of land more than three times in a 5 year period at rates higher than agronomic rates, it will classify as continuous sludge application.

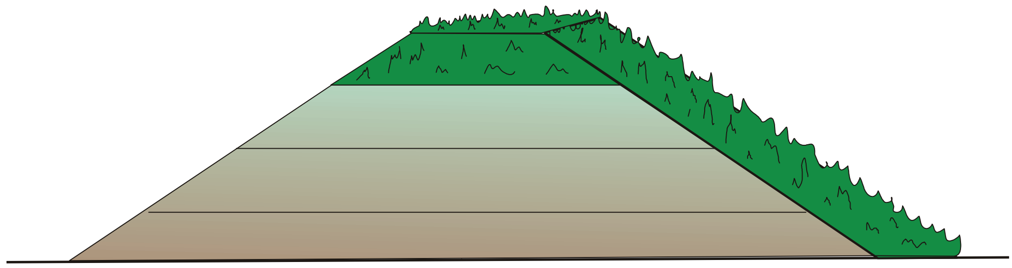

Figure 1: Illustration of once-off high rate application of sludge to rehabilitate disturbed soils

Although rehabilitation of mine tailings can be seen as once-off high rate sludge application beneficial use, there are certain specific considerations for mine rehabilitation that are different from that of other beneficial uses (acid mine drainage and high baseline metal concentrations) which will be discussed in a dedicated section in Part 4 of this document.

Continuous high rate applications

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 (non-food crops); and
- Instant lawn cultivation.

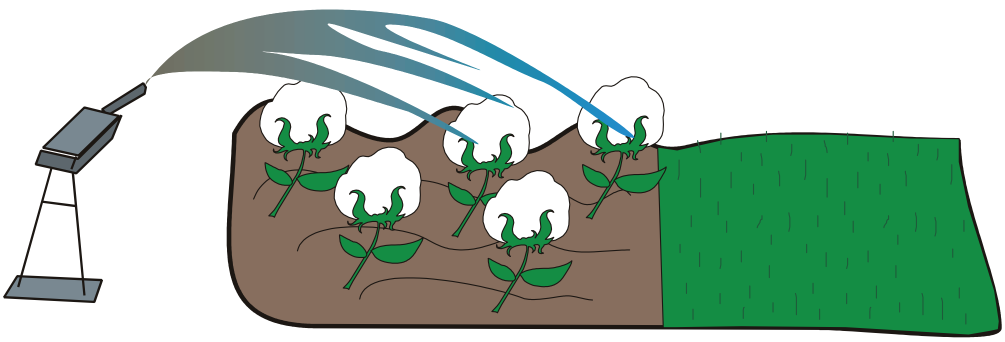

Figure 2: Illustration of continuous high rate application of sludge to industrial

crops

Sludge as landfill cover material

Stabilised sludge can be used as daily and/or final cover on General or Hazardous landfills. Sludge with a solids content of 50% looks and functions much like soil. It will increase the water holding capacity of the final cover of the landfill facility and has high odour absorbing abilities. Using sludge as cover material is, in essence, seen as co-disposal of sewage sludge with municipal solid waste on landfills.

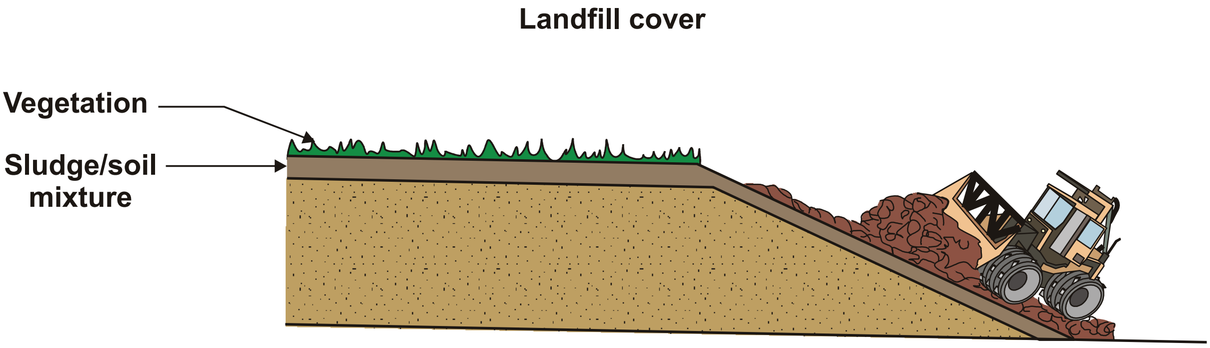

Figure 3: Illustration of sludge used as cover material on landfill

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PART 2:

CLASSIFICATION OF SLUDGE INTENDED FOR BENEFICIAL USE AT HIGH LOADING RATES

All sludge producers must confirm the classification of the sludge before land application, even if a preliminary classification was done as stipulated in Volume 1 of the Guidelines.

CLASSIFICATION SYSTEM

The South African Wastewater Sludge Classification System must be applied to classify the sludge intended for beneficial use (Table 1).

TABLE 1: CLASSIFICATION SYSTEM FOR SLUDGE

Microbiological class	A	B	C
Stability class	1	2	3
Pollutant class	a	b	c

The characterisation and classification should be repeated if any major sludge production or processing changes occur that could affect the classification. This could include:

- When major extensions are implemented at the wastewater treatment plant;
- When major operational changes are made at the wastewater treatment plant; and
- When the raw influent quality to the wastewater treatment plant changes in such a way that the sludge quality could be affected. In other words, when any major new wastewater contributor starts/ceases to discharge to the plant.

The sampling procedure (number of samples, sampling frequency and sample location) for the classification of sludge is the same as for the monitoring of the sludge. This is discussed in Part 5, "Monitoring Requirements for continuous high rate sludge application: Sludge Monitoring". The laboratory analyses and methods required for sludge classification are detailed in Appendix 1.

Microbiological classification

The results of the microbiological analyses of the sludge samples can be used to determine the Microbiological class (Table 2).

TABLE 2: COMPLIANCE AND CLASSIFICATION CRITERIA: MICROBIOLOGICAL CLASS

Microbiological class	Unrestricted use quality		General use quality		Limited use quality
	A		B		C
	Target value	Maximum permissible value	Target value	Maximum permissible value	
Faecal coliform (CFU/g_{dry})	< 1 000 (5 log reduction)	10 000 (4 log reduction)	< 1×10^{6} (2 log reduction)	1×10^{7} (1 log reduction)	> 1×10^{7} (no reduction)
Helminth ova (Viable ova/g_{dry})	< 0.25 (or one ova/4g)	1	< 1	4	> 4
Compliance requirements					
Requirements for classification purposes (Minimum 3 samples)	All the samples submitted for classification purposes must comply with these requirements	Not applicable	Two of the three samples submitted for classification purposes must comply with these requirements	The sample that failed may not exceed the Minimum Permissible Value	Not applicable
Requirements for monitoring purposes	90% compliance	The 10% (maximum) of samples that exceed the Target Value, may not exceed the Maximum Permissible Value	90% compliance	The 10% (maximum) of samples that exceed the Target Value, may not exceed the Maximum Permissible Value	Not applicable

Note: Table 2 requires 90% compliance for the monitoring requirements. Some plants such as those producing < 1 t dry sludge/day are required to collect only three samples once a year. These plants will therefore only be able to prove 90% compliance after a few years. Larger plants will be able to prove compliance on an annual basis.

Note to plants that produce Microbiological class A sludge: The product produced by these facilities **could** be distributed to the public without any restrictions, depending on the Stability class and Pollutant class classification.

Stability classification

The Stability class can be determined analytically and/or by complying with a vector attraction reduction requirement. A sludge producer is required to prove compliance to at least one of the vector attraction reduction options at any stage during operation. The different vector attraction reduction options are listed in Table 3 and described in detail in Appendix 2.

It is more important to consistently comply with a vector attraction reduction option, than the actual initial Stability classification. Confirm the Stability class of the sludge by selecting at least one of the vector attraction reduction options in Table 3.

TABLE 3: STABILITY CLASS AND VECTOR ATTRACTION REDUCTION OPTIONS

Stability class	1	2	3
	Plan/design to comply with one of the options listed below on a 90 percentile basis.	Plan/design to comply with one of the options listed below on a 75 percentile basis.	No stabilisation or vector attraction reduction options required.
Vector attraction reduction options (Applicable to Stability class 1 and 2 only)			
Option 1	Reduce the mass of volatile solids by a minimum of 38 percent		
Option 2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit		
Option 3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit		
Option 4	Meet a specific oxygen uptake rate for aerobically treated sludge		
Option 5	Use aerobic processes at a temperature greater than 40°C (average temperature 45°C) for 14 days or longer (eg during sludge composting)		
Option 6	Add alkaline material to raise the pH under specific conditions		
Option 7	Reduce moisture content of sludge that do not contain unstabilised solids (from treatment processes other than primary treatment) to at least 75 percent solids		
Option 8	Reduce moisture content of sludge with unstabilised solids to at least 90 percent solids		
Option 9	Inject sludge beneath the soil surface within a specified time, depending on the level of pathogen treatment		
Option 10	Incorporate sludge applied to or placed on the surface of the land within specified time periods after application to or placement on the surface of the land		

Pollutant classification

The Pollutant class determination of sludge in Volumes 1 and 2 was based on the total metal content (*aqua regia* digestion) of the sludge and in Volume 3 the Pollutant class was based on the Toxicity Characteristic Leaching Procedure (TCLP) test (Appendix 1). The beneficial use option selected in this Volume will establish the Pollutant class determination. For the high rate application of sludge to land (both once-off and continuous), the total metal content will apply (Table 4) while the TCLP test will apply for the use of sludge as landfill cover material (Table 5).

TABLE 4: DETERMINING THE POLLUTANT CLASS FOR HIGH RATE SLUDGE APPLICATION TO LAND

***Aqua regia* extractable metals (mg/kg)**	**Pollutant class**		
	a	**b**	**c**
Arsenic (As)	<40	40 - 75	>75
Cadmium (Cd)	<40	40 - 85	>85
Chromium (Cr)	<1 200	1 200 - 3 000	>3 000
Copper (Cu)	<1 500	1 500 - 4 300	>4 300
Lead (Pb)	<300	300 - 840	>840
Mercury (Hg)	<15	15 - 55	>55
Nickel (Ni)	<420	420	>420
Zinc (Zn)	<2 800	2 800 - 7 500	>7 500

TABLE 5: DETERMINING THE POLLUTANT CLASS FOR USING SLUDGE AS LANDFILL COVER

TCLP extractable metals	**Pollutant class**		
	a	**b**	**c**
	<AE mg/l	**≥AE and ≤ 10*AE mg/l**	**>10*AE mg/l**
Arsenic (As)	<0.38	0.38 - 3.8	>3.8
Cadmium (Cd)	<0.031	0.031 - 0.31	>0.31
Chromium (Cr III))	<4.7	4.7 - 47	>47
Chromium (Cr VI)	<0.02	0.02 - 0.2	>0.2
Copper (Cu)	<0.13	0.13 - 1.3	>1.3
Lead (Pb)	<0.12	0.12 - 1.2	>1.2
Mercury (Hg)	<0.022	0.022 - 0.22	>0.22
Nickel (Ni)	<0.75	0.75 - 7.5	>7.5
Zinc (Zn)	<0.7	0.7 - 7	>7

AE : Acceptable exposure

Note: Table 4 and 5 require the analyses of eight (8) potentially toxic metals and elements. These were specifically chosen as they are typically the elements that might be of concern. However, the sludge produced at a specific wastewater treatment plant could be compromised by other elements due to unique circumstances. A full total elemental analysis including a number of other trace metals and elements is required for the preliminary classification as detailed in Volume 1. The results of those analyses need to be consulted to determine if any other element is of concern. In cases where additional element(s) are identified, these also need to be included in the analyses for classification and monitoring purposes for beneficial use.

Sludge producers are encouraged to increase the sludge quality to protect the receiving environment during application. Sludge classified as Pollutant class **a** could be used beneficially on land and as cover material on landfill with minimal restrictions. Pollutant class **b** sludge could also be used beneficially on land at high application rates, although the restrictions and requirements (especially for monitoring) will be more onerous while land application of Pollutant class **c** sludge will only be allowed with very strict restrictions and monitoring requirements.

Since sludge is classified as a hazardous waste in the Minimum Requirements (latest edition), it would have to meet the delisting requirements if it is intended for landfill cover material. For Pollutant class **b** sludge this includes liming of the sludge (CaO) at a recommended dosage of 25 kg_{lime}/ton_{sludge}. The TCLP test should be repeated on the sludge after liming. If the new results indicate Pollutant class **a** sludge, the sludge could be used as landfill cover as normal Pollutant class **a** sludge. In cases where the analytical results after liming still indicate Pollutant class **b** or **c** sludge, the TCLP concentration will be used to calculate the maximum mixing ratio. DWAF/DEAT need to be informed of the situation and the landfill site owner/operator should provide the authority with the analytical results. For detailed discussion on the Minimum Requirements for the Handling and Disposal of Hazardous Waste and the delisting process, refer to Part 6 of this document and Part 5 of Volume 3 of the Sludge Guidelines.

Ideal sludge classes applicable for different beneficial use options

Table 6 shows the colour coded index that can be used to assess the appropriateness of a beneficial use option based on the Microbiological class, Stability class and Pollutant class of a specific sludge as discussed in Volume 1 of the Sludge Guidelines. The potential for beneficial use based on sludge classification is presented in Table 7. The restrictions and management requirements become more onerous with deteriorating sludge quality. For example, due to the presence of pathogens in Microbiological class C, public access to a site receiving the sludge should be restricted to protect the public.

TABLE 6: COLOUR CODED INDEX TO ASSESS APPROPRIATENESS OF SELECTED BENEFICIAL USE OPTIONS

(i)	Yes	Recognising that no management option can ever truly be applied without any restrictions, these options only have minor restrictions.
(ii)	Qualified yes	The restrictions that apply do not have major complications and can be managed using good management practices.
(iii)	Maybe	This can only be effectively applied under strict conditions and major management and cost implications apply.
(iv)	Qualified no	Only under unique conditions can this management option be applied for this class of sludge
(v)	No	This management option should not be considered for this class of sludge.

TABLE 7: PERMISSIBLE BENEFICIAL USE OPTIONS BASED ON SLUDGE QUALITY

South African Sludge Classification		Is beneficial use an option?	Notes
Microbiological Class	A	Yes (i)	Could potentially be used as a commercial product.
	B	Maybe (iii)	Restrictions and requirements apply.
	C	Qualified no (iv)	Only permissible if Stability class 1 or 2 is achieved. Restrictions and requirements apply.
Stability Class	1	Qualified yes (ii)	Could potentially be used as a commercial product.
	2	Maybe (iii)	Restrictions and requirements apply.
	3	No (v)	Unstable sludge may not be used beneficially.
Pollutant Class	a	Yes (i)	Could potentially be used as a commercial product.
	b	Maybe (iii)	Will depend on soil quality and land-use.
	c	Qualified no (iv)	Will depend on soil quality and land-use.

Note: Sludge that complies with all the requirements of class A1a may be sold or alienated to the public for unrestricted use.

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PART 3:

LEGAL REQUIREMENTS FOR BENEFICIAL USE OF SLUDGE

The South African environmental legislation is complex and authorisation by more than one Government Department needs to be considered. The Department of Water Affairs and Forestry (DWAF), Department of Environmental Affairs and Tourism (DEAT), Department of Health (DoH) and the Department of Agriculture (DoA) have a regulatory role to play in the beneficial use of sludge. A summary of the relevant legislation governing practice that are applicable to beneficial use of sludge are listed in Table 8. The Department of Water Affairs and Forestry will, typically, be the lead agent and will consult with the other departments. The different departments have committed to co-operative governance and to improve inter-departmental communication, which should simplify the regulatory process.

AUTHORISATIONS REQUIRED FOR THE BENEFICIAL USE OF SLUDGE

On-site land application is the beneficial use of sludge within the boundaries of the wastewater treatment plant (WWTP).

Off-site land application is the beneficial use of sludge outside the boundaries of the WWTP.

The authorisation/s required for the beneficial use of sludge is dependent on whether the sludge has been delisted or not, and is/are as follows:

DELISTED SLUDGE

- **On-site land application of sludge** – General Authorisation [in terms of the National Water Act, (Act No. 36 of 1998)], if sludge is applied to a maximum load of 150 tons per day, and/or full capacity is not exceeded. However authorisation for this may be included as part of the water use licence for the WWTP.

- **Off-site land application of dewatered sludge** – Comply with Directions in terms of Section 20 (5)(b) of the Environment Conservation Act (Act No. 73 of 1989) for general small and general communal waste disposal sites ($G:S:B^-$; $G:C:B^-$ and $G:C:B^+$) (maximum load of 150 tons/per day) and any additional conditions that may apply.

- **Use as landfill cover** – Comply with Directions in terms of Section 20 (5) (b) of the Environment Conservation Act (Act No. 73 of 1989) for general small and general communal waste disposal sites and any additional conditions that may apply. A permit amendment may be needed.

NON-DELISTED SLUDGE

- **Off-site land application of dewatered sludge:** Section 20 permits exemption in terms of the Environment Conservation Act (Act No. 73 of 1989). This however will require that DWAF dispenses with any licence requirement in term of Section 22 (3), or combine the Section 20 permit with the authorisation requirements in terms of Section 22 (4) of the National Water Act (Act No. 36 of 1998).

- **On-site land application of sludge:** Included as part of the water use authorisation obtained for the WWTP.

IRRIGATION OF SLUDGE

Water Use Authorisation in terms of Section 40 of the National Water Act (Act No. 36 of 1998). This could be in the form of a general authorisation, water use license or existing lawful water use.

REGULATORY REQUIREMENTS

The relevant regulatory requirements applicable to the on-site and off-site land application of sludge are listed in Table 8.

TABLE 8: REGULATORY REQUIREMENTS APPLICABLE FOR THE BENEFICIAL USE OF SLUDGE

Disposal Option	On-site land application of sludge	Continuous off-site land application of liquid sludge	Continuous off-site land application dewatered sludge	Once-off high rate sludge application	Use as landfill cover
Applicable Act Governing Practice	National Water Act (Act No. 36 of 1998)	National Water Act (Act No. 36 of 1998)) Environment Conservation Act (Act No. 73 of 1989) National Environmental Management: Waste Management Act	Environment Conservation Act (Act No. 73 of 1989) National Environmental Management: Waste Management Act	Environment Conservation Act (Act No. 73 of 1989) National Water Act (Act No. 36 of 1998)	Environment Conservation Act (Act No. 73 of 1989) National Environmental Management: Waste Management Act
Authorisation Required	**Water Use Authorisation**	**Water Use Authorisation**	**Disposal site Permit**	**None** However permission may be required from DWAF and/or DEAT and the onus is upon the sludge user/producer to consult the regulators	S20 Directions (registration with DEAT is required) S20 Permit amendment
Lead Authority	**DWAF**	**DWAF**	**DEAT**	**DEAT** (*for irrigation of sludge* **DWAF**)	**DEAT**
Regulatory Instrument	**Water Use licence** (or general authorisation or existing lawful water use)	**Water Use licence** (or general authorisation or existing lawful water use)	**Disposal site Permit**	**None**	S20 Directions (registration with DEAT is required) S20 Permit amendment
Regulatory Guidelines	**Sludge Guidelines (Volume 4)** and/or **Minimum Requirements (latest edition)** and if applicable, **Regulation 1048** in terms of section 29 of the Conservation of Agricultural Resources Act (Act No. 43 of 1983) related to the control measures for the restoration and reclamation of eroded land and of disturbed or denuded land.				

Further Regulatory Requirements that may apply

	Storage	Transportation
Once-off (up to 90 days)	Requirements as per: 'Once-off high rate sludge application'	Must comply with the National Road Traffic Act (Act No. 93 of 1996) and the Hazardous Substance Act (Act No. 15 of 1973) for the transportation of hazardous wastes.
Continuous Storage (Exceeds 90 days or sludge is always present on surface)	Requirements as per: 'Off-site land application of dewatered sludge' OR Section 20 Directions (may include additional conditions) **NB**: Authorisation is related to the Facility (legal requirements and control of issues)	

PART 3: LEGAL REQUIREMENTS FOR BENEFICIAL USE OF SLUDGE

While the regulatory instrument may be either a waste permit or water use authorisation, DWAF or DEAT as the supporting authority to the lead authority will however still have to approve the activity and/or impacts before either authorisation is issued. For example, DWAF may require a positive Record of Decision (RoD) for an EIA from DEAT in order to issue a water use licence. Similarly DEAT will require a RoD from DWAF to approve water use impact aspects before a waste permit is issued. The different departments have committed to co-operative governance and to improve inter-departmental communication, which should simplify the regulatory process. Similarly, the lead authority will also consult with the other national and provincial departments that could have regulatory requirements that must be taken into consideration. The DWAF and DEAT have indicated the minimum legal requirements for sludge producers and users as follows:

Legal requirements for sludge producers (individual/entity producing sludge)

- The producer **must** have a legal agreement / contract with the user for all beneficial use options if the sludge is utilised by a third party;
- For once-off high rate sludge application:
  - Comply with Volume 4 of the Sludge Guidelines.
- For continuous high rate application of sludge (on-site and off-site):
  - The producer must comply with Volume 4 of the Sludge Guidelines;
  - The producer must have authorisation for such a water use (Existing Lawful Use, General Authorisation or licence or Disposal site Permit). This will be included in the Authorisation of the WWTP.
- For utilization of sludge as landfill cover:
  - The producer must comply with Volume 4 of the Sludge Guidelines.

Legal requirements for sludge users (individual/entity using sludge)

- The user **must** have a legal agreement / contract with the producer for all beneficial use options;
- For once-off high rate sludge application:
  - Comply with Volume 4 of the Sludge Guidelines.
- For continuous high rate application of sludge (on-site and off-site):
  - The user must comply with Volume 4 of the Sludge Guidelines;
  - The user must have authorisation for such a use (Existing Lawful Use, General Authorisation or licence or disposal site permit).
- For utilization of sludge as landfill cover:
  - The landfill owner/operator must comply with Volume 4 of the Sludge Guidelines and the Minimum Requirements (Latest edition);
  - The landfill operator must have a Disposal site Permit that specifies that sludge may be used as cover material.

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Classification of Sludge intended for beneficial use at high loading rates

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Legal requirements for the beneficial use of sludge at high loading rates

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Restrictions and requirements for once-off high rate sludge application

- Site considerations for once-off application
- Management requirements for once-off high rate sludge application
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Restrictions and requirements for continuous high rate sludge application

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Restrictions and requirements for using sludge as landfill cover material

PART 4:

RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

Part 4 deals with the restrictions and requirements specifically applicable to **once-off high rate** application of sludge to land. This beneficial use option includes, but is not limited to:

- Rehabilitation of disturbed/degraded soils due to nutrient depletion, erosion, acidity and salinity, poor physical properties and reduced biological activity. Rehabilitation may be necessary after mining activities, intensive farming and industrial activities. These are generally sites with limited public access or private land;

- Establishment of golf courses, race courses, vineyards, road embankments, public parks etc. The quality of the applied sludge may be restricted at public access sites (i.e. where the general public have unrestricted access to the sites).

Sludge can be added once-off to soil at high rate (higher than agronomic rates) to improve its chemical and physical characteristics to enable it to sustain vegetation. In some instances once-off application may not be enough to improve the soil's capacity to sustain vegetative growth and additional application may be required. However, if sludge is applied to the same piece of land more than three times at rates higher than agronomic rates in a 5 year period, it will classify as continuous sludge application which is discussed in Part 5.

SITE CONSIDERATIONS FOR ONCE-OFF HIGH RATE SLUDGE APPLICATION

The sludge user should consider the following aspects when an application site is selected:

Sensitive areas:

- Areas below the 1 in 100 year flood line (wetlands, vleis, pans and flood plains) are sensitive to water pollution;

- Avoid areas characterised by steep gradients where slope stability could be a problem and soil erosion would be prevalent;

- Avoid areas immediately upwind of a residential area in the prevailing wind direction(s).

Note: Sludge application in these sensitive areas might be considered if the user can prove that adequate mitigation measures are implemented to alleviate potential negative effects.

Buffer zones:

- Depth to aquifer – >5 m (dewatered sludge application) and >10 m (liquid sludge application)

- Distance from surface water/borehole – >200 m

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

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

Topography:

The slope of the land application site should be considered to minimise run-off, erosion and ponding. If vegetation is established on a steep slope the vegetation will minimize run-off and erosion and the slope consideration can be relaxed.

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.
- The soil pH will indicate whether acidic conditions could cause metals to leach through the soil profile.
- The concentration of nutrients, trace elements and metals will give baseline concentrations to determine whether the soil will be able to attenuate the additional metal load added during sludge application.

MANAGEMENT REQUIREMENTS FOR ONCE-OFF HIGH RATE SLUDGE APPLICATION

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.

Soil quality

The total metal concentration of the soil must be determined before high rate sludge application to determine whether additional metals can be added to the soil without negative effects on surface and groundwater. Limits have been set for metals in the receiving soil. These limits will depend on the present and future land-use of the site (agricultural or industrial) and are more stringent if the end land-use is agriculture (edible crops).

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 9) 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.

When the total metal content (*aqua regia* digestion) of the soil exceeds the TMT, sludge application on land where edible crops will be grown and/or where public access is unlimited is not permissible. In cases where the land is used to cultivate industrial crops, sites with limited public access and industrial areas (mine rehabilitation and forests) sludge may be applied. When the soil metal concentrations are higher than the MPL, sludge application is not permissible.

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

TABLE 9: 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

Sludge application rate

The sludge application rate at once-off 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. 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 300 mm

Example: A land developer wants to use sludge at high application rate to establish a golf course. The sludge classification is B1b (1800 mg/kg Cu). The analytical results of the soil samples indicate that the metal content of the soil is well below the TMT except for the Cu concentration of 110 mg/kg which is close to the TMT for soil.

The permissible application rate for this sludge on this soil is:

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

$$PAR = \frac{120mg/kg - 110mg/kg}{1800mg/kg_{conc}} * 3900$$

$$PAR = 21ton_{\ dry\, sludge}/ha$$

At an application rate of 21 ton_{sludge}/ha the Cu application will be 10 mg_{Cu}/kg_{soil} and the TMT of the soil will not be exceeded.

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 once-off and continuous high rate application sites based on site specific data (soil properties, depth to aquifer, type of aquifer, 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.

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

The storage of sludge in an open area for extended periods before application may result in leachate or highly contaminated seepage being generated and any area where sludge is stored for a period exceeding 90 days is considered a disposal area and should be operated as such. Therefore, it is recommended that sludge storage before once-off application not exceed 90 days. However, where sludge intended for once-off application in different areas are stored in the same dedicated area before application, this storage area will probably have sludge for more than 90 days and will not classify for exemption from a disposal site permit.

MANAGEMENT REQUIREMENTS FOR HIGH RATE SLUDGE APPLICATION IN MINE REHABILITATION

Although mine rehabilitation with sludge application to establish vegetation can be regarded as once-off high rate sludge application there are certain specific considerations for mine rehabilitation that are different from that of other beneficial uses, including acid mine drainage and high baseline metal concentrations in the tailings or soil to be rehabilitated. Due to the specific properties of mining sites, the management requirements discussed in the sections above might not all be applicable to mine rehabilitation while other additional requirements might be relevant. Therefore, the most important properties to consider during mine rehabilitation will be discussed in this section.

Site considerations

The location of the site to be rehabilitated will be on land owned by the Mining Company (private land) zoned as an industrial area. The potential for sludge application to cause further environmental deterioration is limited. The user must however consider the pollution potential and apply the sludge in a responsible manner.

Buffer zones

The buffer zones applicable to other once-off beneficial uses may be relaxed based on site specific investigations and practical considerations. The user will have to prove that an adverse impact on the receiving environment will be mitigated and that groundwater and surface water resources will be protected.

Topography

The slope of the facility to be rehabilitated might be too steep for other once-off application options, but the vegetation of the slopes will minimise run-off and erosion. However, additional management requirements to limit erosion will be needed while the vegetation is being established.

Soil / Tailings properties and quality

Due to the high probability of the presence of pollutants, most tailings will require either physical changes or chemical changes or both in order to sustain a satisfactory plant growth. The physical and chemical properties of the material to be rehabilitated have to be determined to assess:

- Permeability and water retention – these parameters will indicate the potential for leaching of water and soluble pollutants in the profile. If the permeability and water retention is high it will be the ideal condition for vegetation growth. However, due to the low organic matter content of the tailings, the water retention is likely to be low and water will leach easily. Sludge application will increase the organic material with an increase in permeability and water retention.

- pH and salinity – The generation and management of acid mine drainage (AMD), resulting in low pH values is the single biggest concern during mine rehabilitation. There are a limited number of plants that will survive in a soil that has a pH of 4.5 or less and the pH of the soil/tailings will have to be raised to above 5. The most cost effective method for raising the pH is by the use of lime. The acid to base condition of the tailings will determine the amount of lime required. Lime is added to sludge at many WWTP to stabilise sludge and will also benefit the rehabilitation process if the pH of the sludge is >7.5.

- Metal content – The metal content of the tailings or soil to be rehabilitated is likely to be higher than the MPL set for soils. Under normal conditions additional sludge application would not be allowed, especially if the sludge also contains elevated metal concentrations. However, sludge application can be beneficial in reducing the mobility of metals in the soil or tailings material, resulting in an increase in leachate quality. Once-off sludge application to aid in revegetation of mine tailings can therefore be considered a viable option even when the metal content of the material exceed the MPL. The user will have to prove that further negative impact on the receiving environment due to sludge application is limited.

Sludge application rate

The PAR will in most cases not be applicable to rehabilitation sites due to the potential elevated metal content of the material to be rehabilitated. If however the metal content of the soil / tailings are below the MPL, it is recommended that the PAR be calculated. The recommended MAR for rehabilitation sites is 120 ton $_{dry\ sludge}$/ha/year.

RESTRICTIONS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

Although the environmental and human health impact of once-off high rate sludge application will be limited, certain restrictions will apply to protect the receptors.

Sludge quality restrictions

Due to the potential of public exposure to constituents present in sludge when applied to beneficial use sites, especially public access sites, the use of certain quality sludge will not be permissible (Table 10). The beneficial use of unstable sludge will not be allowed. At least one vector attraction reduction option should be implemented.

The restrictions that will be applicable include public access and grazing animal restrictions as well as crop restrictions which will be discussed in the sections that follow.

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

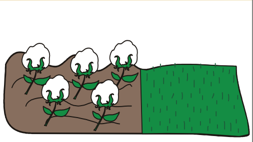
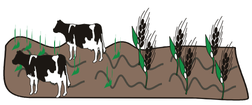
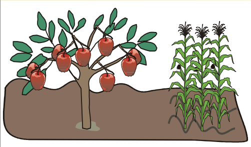
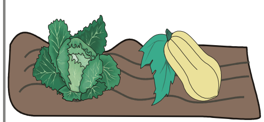
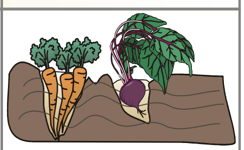
TABLE 10: SLUDGE QUALITY RESTRICTIONS FOR ONCE-OFF HIGH RATE SLUDGE APPLICATION ON PUBLIC AND PRIVATE LAND

Sludge Quality		Public access sites	Private land
Microbiological Class	A	✓	✓
	B	!	!
	C	X	!
Stability Class	1	✓	✓
	2	!	!
	3	X	X
Pollutant Class	a	✓	✓
	b	!	!
	c	X	!
Legend:			
✓ = permissible		! = permissible with restriction	X = not permissible

Restrictions on crop production

Crop restrictions are implemented to prevent food-chain contamination. Table 11 lists different types of crops and indicate which have restrictions applicable to them. The specific restrictions are based on the quality of the applied sludge which is detailed in Table 12.

TABLE 11: CROPS TO CONSIDER FOR 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)

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

TABLE 12: SPECIFIC RESTRICTIONS APPLICABLE TO CROPS RECEIVING ONCE-OFF 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	

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 13.

TABLE 13: RESTRICTIONS ON ANIMAL GRAZING APPLICABLE TO ONCE-OFF 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 14).

TABLE 14: PUBLIC ACCESS RESTRICTIONS APPLICABLE TO ONCE-OFF 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	Sludge must be incorporated into soil

MONITORING REQUIREMENTS FOR ONCE-OFF HIGH RATE APPLICATION

No monitoring is necessary for once-off high rate sludge application unless specifically requested by DWAF/DEAT. However, the user is advised to monitor soil quality to ensure the PAR is adhered to.

CLOSURE PLANS FOR ONCE-OFF HIGH RATE SLUDGE APPLICATION

No closure plan will be required for once-off high rate sludge application sites unless specifically requested by DWAF/DEAT.

RECORD KEEPING REQUIREMENTS FOR ONCE-OFF 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. Table 15 summarises the record keeping requirements for the producer supplying sludge to users for once-off high rate sludge application (irrespective of the class of sludge produced). Since the sludge producer remains ultimately responsible for sludge application, it is the responsibility of the producer to obtain data from the sludge user as per their agreement (see Appendix 3).

PART 4: RESTRICTIONS AND REQUIREMENTS APPLICABLE TO ONCE-OFF HIGH RATE APPLICATION

TABLE 15: SPECIFIC RECORD KEEPING REQUIREMENTS FOR ONCE-OFF HIGH RATE SLUDGE APPLICATION

Description of records to be kept by the sludge producer	
Sludge records	
1	Classification of sludge used for once-off high rate application 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 between the sludge producer and the sludge user (if applicable)
Initial site investigation records	
4	Proof that application site is not located in a sensitive area
5	Concentration of trace elements and metals (total) in the receiving soil
Record of sludge application	
6	Location of site (map or co-ordinates)
7	Sludge application rate (ton/ha)
8	Date/s of application. Only 3 applications allowed in a 5 year period

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Classification of Sludge intended for beneficial use at high loading rates

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Legal requirements for the beneficial use of sludge at high loading rates

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Restrictions and requirements for continuous high rate sludge application

- Site selection requirements
- Initial site investigation requirements
- Management requirements
- Restrictions applicable to continuous high rate application
- Monitoring requirements
- Remediation plans
- Closure plans
- Record keeping requirements

PART 6

Restrictions and requirements for using sludge as landfill cover material

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

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 200 m 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.

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

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

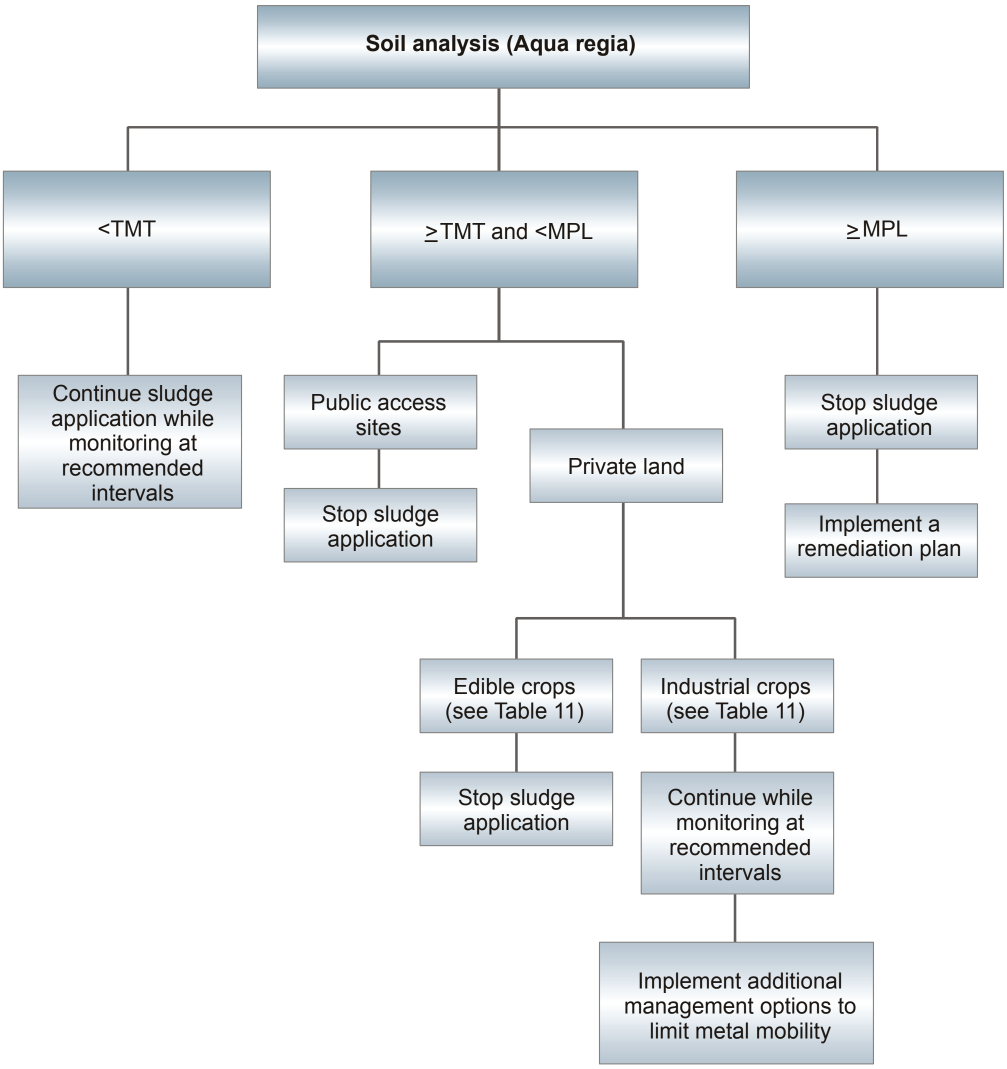


Figure 4: Influence of soil quality on beneficial use options

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 300 mm

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:

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

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

$$PAR = 22ton_{\ dry\,sludge} / ha$$

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:

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

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

$$PAR = 580ton_{dry\,sludge}/ha$$

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

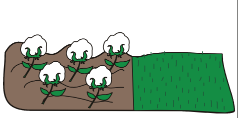
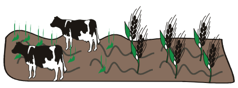
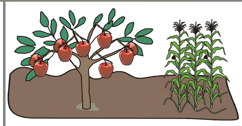
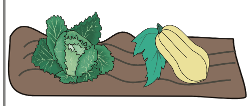
Industrial crops	Animal feed	Crops with harvested / edible parts that :		
		Usually do not touch the soil/sludge mixture	Usually touch the soil/sludge mixture	Are within soil/sludge mixture
				
Allowed with restrictions	Allowed with restrictions	Allowed with restrictions	Not allowed (Refer to Volume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

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

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

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

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 <5 m 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

What should be monitored ?	Chemistry - pH, EC PO_4, NH_4, NO_3, COD Microbiology - Faecal coliforms and *E.coli* depending on sludge quality		
How often should samples be collected and analysed?		**Dewatered sludge**	**Irrigated sludge**
	Chemistry	Biannually / quarterly*	Quarterly / monthly*
	Microbiology	Biannually / quarterly**	Quarterly / monthly**
	* - existing sites with water table <5m (dewatered sludge) or < 10m (liquid sludge) ** - Microbiological class B / Microbiological class C		
What sampling equipment should be used?	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		
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)		

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

- Water table >10 m (dewatered sludge application) or >20 m (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, 20-50 m 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)	

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

- The distance to the nearest surface water resource or borehole is > 1 km;
- 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 100 mm depth increments up to 500 mm.
- 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).

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 1
Background

PART 2
Classification of Sludge intended for beneficial use at high loading rates

PART 3
Legal requirements for the beneficial use of sludge at high loading rates

PART 4
Restrictions and requirements for once-off high rate sludge application

PART 5
Restrictions and requirements for continuous high rate sludge application

PART 6
Restrictions and requirements for using sludge as landfill cover material

- Background information
- Sludge quality restrictions
- Specific restrictions and requirements pertaining to the sludge producer
- Specific restrictions and requirements pertaining to the landfill operator
- Monitoring requirements for landfill sites receiving sludge
- Closure and remediation plans for landfill sites

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.

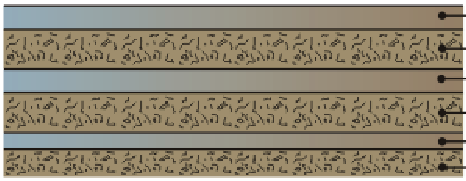


Figure 5: Use of sludge as daily cover

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 100 mm of soil.

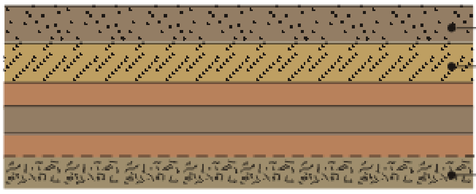


Figure 6: Use of sludge as final cover

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** Hazardous waste - **H**	Communal (**C**) - <25 t/day Small (**S**) - 25-150 t/day Medium (**M**) - 150-500 t/day Large (**L**) - >500 t/day	$\mathbf{B^+}$ - precipitation exceeds evaporation $\mathbf{B^-}$ - evaporation exceeds precipitation

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.

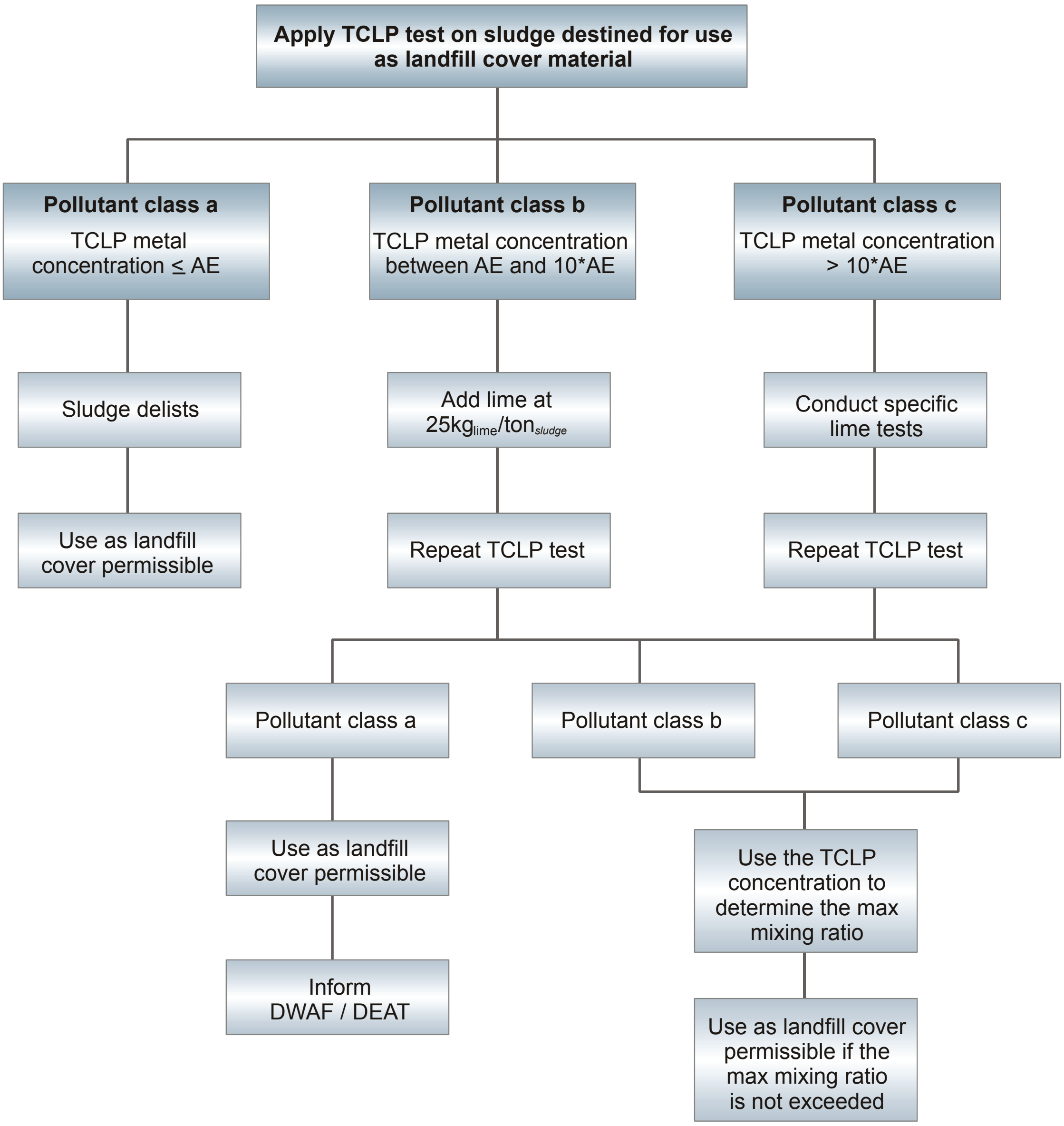


Figure 7: Schematic presentation of sludge delisting process

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.

APPENDIX 1: PARAMETERS AND ANALYTICAL METHODS REQUIRED FOR CLASSIFICATION OF SLUDGE AND MONITORING OF SLUDGE, WATER AND SOIL SAMPLES

Appendix 1.1: Analyses required for classification and characterization of sludge

Characteristic	Parameter	Guidance on methodology and/or recommended extraction method
Physical characteristics	pH	Direct measurement pH on saturated paste or solution
	Total solids (TS)	Standard method 2540B[1]
	Volatile suspended solids (VSS)	Standard method 2540E[2]
	Volatile Fatty Acids (VFA)	Adapted from Standard methods. The full method is detailed in Volume 1, Appendix 2.
Nutrients	Total Kjeldahl Nitrogen (TKN)	The suggested method description has been attached in Volume 1, Appendix 2.
	Total Phosphorus (TP)	The suggested method description has been attached in Volume 1, Appendix 2.
	Potassium (K)	The suggested method description has been attached in Volume 1, Appendix 2.
Metals and micro-elements	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc (Any other metal or element identified during the comprehensive characterisation detailed in Volume 1)	For beneficial use land the extraction of trace elements with *aqua regia* solution is recommended. International Standard ISO 11466 (Ref number: ISO11466:1995(E)) For use as landfill cover the TCLP test is recommended. US EPA Method 1311, 1992 Note: A semi-quantitative ICP scan would give concentrations for all mentioned metals. Remind the laboratory to manage the interferences on the ICP appropriately, especially for compounds such as Arsenic.
Microbiological quality	Faecal coliforms	m-FC medium
	Total viable Helminth ova	See recommended new method further on in this Appendix
[1,2] Standard Methods for the Examination of Water and Wastewater, 20th edition (1998) or latest, by Leonore S. Clesceri, Arnold E. Greenbert and R. Rhodes Trussell.		

Appendix 1.2: Sludge analyses required for monitoring purposes

Characteristic		Parameter	Guidance on methodology and/or recommended extraction method
Physical characteristics		pH	Direct measurement pH on saturated paste or solution
		Total solids (TS)	Standard method 2540B[1]
		Volatile suspended solids (VSS)	Standard method 2540E[2]
		Volatile Fatty Acids (VFA)	Adapted from Standard methods. The full method is detailed in Volume 1, Appendix 2.
Chemical characteristics	Nutrients	Total Kjeldahl Nitrogen (TKN)	The suggested method description has been attached in Volume 1, Appendix 2.
		Total Phosphorus (TP)	The suggested method description has been attached in Volume 1, Appendix 2.
		Potassium (K)	The suggested method description has been attached in Volume 1, Appendix 2.
	Metals and micro-elements	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc (Any other metal or element identified during the comprehensive characterisation detailed in Volume 1)	For beneficial use land the extraction of trace elements with *aqua regia* solution is recommended. International Standard ISO 11466 (Ref number: ISO11466:1995(E)) For use as landfill cover the TCLP test is recommended. US EPA Method 1311, 1992 Note: A semi-quantitative ICP scan would give concentrations for all mentioned metals. Remind the laboratory to manage the interferences on the ICP appropriately.
Microbiological quality		Faecal coliforms	m-FC medium
		Total viable Helminth ova	See recommended new method further on in this Appendix
[1,2] Standard Methods for the Examination of Water and Wastewater, 20th edition (1998) or latest, by Leonore S. Clesceri, Arnold E. Greenbert and R. Rhodes Trussell.			

Appendix 1.3: Surface and groundwater analyses required for monitoring purposes

Characteristic	Parameter	Guidance on methodology and/or recommended extraction method
Water chemistry	pH	Direct measurement
	EC	Direct measurement
	PO_4	Standard method 4500-P[1]
	NH_4	Standard method 4500-NH_4[1]
	NO_3	Standard method 4500-NO_3[1]
	COD	Standard method 5220D[1]
Water microbiology	Faecal coliforms	Membrane filter/ m-FC medium[1]
	E coli	Standard method 9221B[1]

[1] Standard Methods for the Examination of Water and Wastewater, 20th edition (1998) or latest, by Leonore S. Clesceri, Arnold E. Greenbert and R. Rhodes Trussell

Appendix 1.4: Soil analyses required for monitoring purposes

Characteristic	Parameter	Guidance on methodology and/or recommended extraction method
Nutrients	Total Kjeldahl Nitrogen (TKN)	The suggested method description has been attached in Volume 1, Appendix 2.
	Total Phosphorus (TP)	The suggested method description has been attached in Volume 1, Appendix 2.
Metals to assess compliance in terms of the TMT and MPL	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc (Any other metal or element identified during the comprehensive characterisation detailed in Volume 1)	Extraction of trace elements soluble in *aqua regia* solution. International Standard ISO 11466 Method Reference number: ISO 11466:1995 (E) Note: A semi-quantitative ICP scan would give concentrations for all mentioned metals. Remind the laboratory to manage the interferences on the ICP appropriately.

Appendix 1.5: Recommended new procedure to determine Helminth ova in wastewater sludge

Note: This is a new method which was developed after Volume 1 of the New Sludge Guidelines has been published and differs from the method published in Volume 1.

<u>Method for analyses of sludge</u>

Note: It is always preferable to work with small sub-samples as eggs may not be as easily released from a large sample to float out of the sludge when doing the $ZnSO_4$ flotation technique. Rather increase the number of sub-samples than overload each test-tube in order to keep the number of tubes down.

The number of sub-samples will also be dependent on the helminth ova load expected. This will require knowledge of the epidemiology of helminths in the particular area in South Africa. Consequently, more sub-samples must be done in an area of low endemicity and less in a highly endemic area.

1. Mix the sludge sample well by swirling and stirring with a plastic rod. From the total sample take 4 x 15 mℓ sub-samples and place them into 4 x 50 mℓ test tubes. (If the solid content is high this should be sufficient sample. If it is low, take more 15 mℓ sub-samples).
2. Add either a few millilitres of 0.1% Tween80 or AmBic solution to the samples, vortex and add more wash solution. Repeat this procedure until the tubes are filled to approximately a centimetre from the top.
3. Place the 150 µm sieve in a funnel in a retort stand with a plastic beaker underneath to catch the filtrate. Filter the well-mixed contents of the tubes one at a time, rinsing out each tube and washing this water through the sieve as well.
4. Pour the filtrate into test tubes and centrifuge at 1389 g (±3000 rpm) for 3 minutes. Suction off the supernatant fluids and discard. Combine the deposits into a suitable number of tubes so that there is not more than 1 mℓ in a 15 mℓ tube or 5 mℓ in a 50 mℓ tube
5. Re-suspend each of these deposits in a few millilitres of ZnSO and vortex well to mix. Keep adding more $ZnSO_4$ and mixing until the tube is almost full.
6. Centrifuge the tubes at 617 g (±2000 rpm) for 3 minutes. Remove from the centrifuge and pour the supernatant fluids through the 20 µm filter, washing well with water.
7. Collect the matter retained on the sieve and wash it into test tubes.
8. Centrifuge the tubes at 964 g (±2500 rpm) for 3 minutes; remove & discard the supernatant fluid. Combine the deposits into one test tube, using water to recover all the eggs from the other tubes. Then centrifuge again at 964 g for 3 minutes to get one deposit.
9. Once there is one final deposit, remove all of it using a plastic Pasteur pipette and place it onto one or more microscope slides. Place a coverslip over each deposit and examine microscopically using the 10x objective and the 40x objective to confirm any unsure diagnoses.

10. Each species of helminth ova is enumerated separately and reported as eggs per gram of sludge.

Note: Samples may be examined slightly differently from that described in step No. 10 above by doing the following:

The deposits are filtered through a 12 µm ISOPORE membrane, which is then rinsed with distilled water. The membrane is air-dried, cut in half and placed on a microscope slide. Immersion oil is used to clear the membrane before examining under the microscope.

To test for viability:

Perform steps 1 to 8 of the procedure above and continue as follows:

9. Once there is a final deposit in the test tube, re-suspend it in 4 mℓ of 0.1 H_2SO_4. Before incubating mark the test tube with the level of liquid and incubate at a temperature of 26°C for three to four weeks. Check the level of liquid in each one of the test tubes and add the reagent every time that is necessary, compensating for any evaporation that may occur.

10. Once the incubation time is over, homogenize the deposit and proceed to quantify the eggs. Remove all of the deposit using a plastic Pasteur pipette and place it onto one or more microscope slides. Place a coverslip over each deposit and examine microscopically using the 10x objective and the 40x objective to confirm any unsure diagnoses. Only those ova where the larva is observed are considered viable.

Equipment required and related information

1. A centrifuge with a swing-out rotor and buckets that can take 15 mℓ and/or 50 mℓ plastic conical test tubes.
2. Vortex mixer.
3. Retort Stand with at least 2 clamps on it.
4. Large plastic funnels to support the filters (±220 mm diameter).
5. Filters / Sieves: 1 x 150 µm; 1 x 100 µm; 1 x 20 µm.
6. Approx. 6 Plastic beakers (500 mℓ) & 3 Plastic wash bottles.
7. At least 4 glass "Schott" bottles (1ℓ, 2ℓ & 5ℓ sizes) for make-up and storage of the chemical solutions and de-ionized water.
8. Magnetic stirrer and stirring magnets.
9. 15 mℓ and 50 mℓ plastic conical test tubes.
10. 3 x Small glass beakers (100 mℓ).
11. Plastic Pasteur Pipettes & Plastic Stirring Rods.
12. Glass microscope slides (76 x 26 x 1,2 mm).
13. Square & Rectangular Cover-slips (22 x 22 mm & 22 x 40 mm).

14. A binocular compound microscope with 10x eyepieces, a 10x objective and a 40x objective.

Working out the g-force of your centrifuge

G-force (or g) = $(1{,}118 \times 10^{-5})\, r\, s^2 = 0{,}00001118 \times r \times s^2$

where: s = revolutions per minute (i.e. the speed you spin at)

r = the radius (the distance in centimetres from the centre of the rotor to the bottom of the bucket holding the tubes, when the bucket is in the swing-out position)

Reagents

Zinc Sulphate

- $ZnSO_4$ (heptahydrate) is made up by dissolving 500 g of the chemical in 880 mℓ de-ionised or distilled water.
- A hydrometer must be used to adjust the specific gravity (SG) to 1.3, using more chemical if the SG is too low or more water if it is >1,3.

This high specific gravity facilitates the floating of heavier ova such as *Taenia* sp. (SG = 1.27). It is not critical if the SG of the $ZnSO_4$ solution is just over 1.3 but it should **never** be below this value!

Ammonium Bicarbonate

The AMBIC solution is essentially a saturated ammonium bicarbonate solution. Ammonium bicarbonate can be obtained from Merck Chemicals and is made up by dissolving 119 g of the chemical in 1000 mℓ of de-ionised water.

0,1% Tween80

1 mℓ of Tween80 is measured out using a pipette and placed in 1000 mℓ of de-ionized or distilled water to give a 0,1% wash solution.

Note: Tween80 is extremely viscous and it is necessary to wash **all** of it out into the water in which it is made up, by alternately sucking up water and blowing it out using the same pipette.

References:

WRC Report number: TT 321/08. Standard methods for the recovery and enumeration of Helminth ova in wastewater, sludge, compost and urine diversion waste in South Africa.

Posters: Standard methods and photographs of Helminth ova.

Appendix 1.6: Toxicity Characteristic Leaching Procedure (TCLP) extraction for sludge destined for co-disposal (USEPA Method 1311)

Summary of method

- For liquid wastes (containing <0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 µm glass fiber filter, is defined as the TCLP extract.
- For wastes containing ≥ 0.5% solids, the liquid, if any, is separated from the solid phase and stored for later analyses.

Apparatus

- Agitation apparatus capable of rotating the extraction vessel in an end-over-end fashion at 30 ± 2 r.p.m.
- Extraction bottles for inorganics. These may be constructed from various materials. Borosilicate glass bottles are highly recommended. Polytetrafluoroethylene (PTFE), high density polyethylene (HDPE), polypropylene (PP), Polyvinyl chloride (PVC) and stainless steel bottles may also be used.

TCLP solution 1

- Add 5.7 mℓ glacial Acetic Acid to 500 mℓ of reagent quality water (double distilled water).
- Add 64.3 mℓ of 1N NaOH.
- Dilute to a volume of 1 litre.
- When correctly prepared, the pH of this solution will be 4.93 ± 0.05.

TCLP solution 2

- Dilute 5.7 mℓ glacial acetic acid with double distilled water to a volume of 1 litre.
- When correctly prepared, the pH of this solution will be 2.88 ± 0.05.

Samples

- The sample must be a minimum of 100 grams.
- The sample must be able to pass through a 9.5 mm sieve, i.e. particle size of the solid must be smaller than 10 mm.

TCLP extractions

Note that the TCLP test requires that a waste be pre-tested for its acid neutralization capacity. Those with low acid neutralization capacity are extracted with TCLP solution 1 (0.1 M Sodium Acetate Buffer, pH 4.93±0.05) and those with high acid neutralization capacity are extracted with TCLP solution 2 (0.1 M Acetic Acid, pH 2.88±0.05). Most sludges have a low acid neutralization capacity and will, therefore, be extracted with TCLP solution 1. After addition of lime, the acid neutralization capacity of the sludge is increased, but note that the treated sludge should be leached using the TCLP solution used for original sludge, i.e. in most cases TCLP solution 1, so that the results are directly comparable and one can evaluate the effect of the lime treatment. This is correct even though the pre-test used in the TCLP on the lime treated sludge may indicate that TCLP solution number 2 should be used.

A. Preliminary evaluation:

This part of the extraction procedure must be performed to determine which TCLP (No. 1 or 2) solution should be used (see extraction solutions).

1. Weigh out 5.0 grams of the dry waste into a 500 mℓ beaker or Erlenmeyer flask. (In this exercise the particle size of the 5 grams should be 1 mm or less).
2. Add 96.5 mℓ of double distilled water, cover with a watch glass and stir vigorously for 5 minutes with a magnetic stirrer.
3. Measure the pH.
4. If the pH is less than 5.0, then use TCLP solution – No 1.
5. If the pH is greater than 5.0, then proceed as follows:
    - 5.1 Add 3.5 mℓ 1N HCl and stir briefly.
    - 5.2 Cover with a watch glass, heat to 50°C and hold at 50°C for ten minutes.
    - 5.3 Let cool to room temperature and record the pH.
6. If the pH is less than 5.0, then use TCLP solution – No 1.
7. If the pH is more than 5.0, then use TCLP solution – No 2.

B. Extraction for analysis of contaminants:

1. Weigh out 100 gram of the dry waste, which passes through a 9.5 mm sieve, and quantitatively transfer it to the extraction bottle.

2. Add two litres (2l) of the appropriate TCLP solution (No. 1 or 2 as determined by preliminary evaluation) and close bottle tightly.

3. Rotate in agitation apparatus at 30 r.p.m. for 20 hours. Temperature of room in which extraction takes place should be maintained at 23 ± 2°C.

4. Filter through a glass fibre filter and collect filtrate. Record pH of filtrate.

5. Take aliquot samples from the filtrate for determination of metal concentrations.

6. Immediately acidify each aliquot sample with nitric acid to a pH just less than 2.

7. Analyse by AA or other sensitive and appropriate techniques for different metals.

8. If analysis cannot be performed immediately after extraction, then store the acidified aliquots at 4°C, until analysis (as soon as possible).

Reference: USEPA Test Methods SW-846 On-line
http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1311.pdf

APPENDIX 2: VECTOR ATTRACTION REDUCTION OPTIONS

The following options are available to reduce the vector attraction potential. These options have been adopted from the US EPA Part 503 Rule.

Option 1: Reduction in Volatile Solids Content

Vector attraction is reduced if the fraction of volatile solids in the primary sludge is reduced by at least 38 percent during the treatment of the sludge. This percentage is the amount of volatile solids reduction that is attained by anaerobic or aerobic digestion plus any additional volatile solids reduction that occurs before the sludge leaves the treatment works, such as through processing in drying beds or lagoons, or by composting.

Digestion process efficiency can be measured by the reduction in the volatile solids content of the feed sludge to the digester and the sludge withdrawn from the digester. Anaerobic digestion of primary sludge generally results in a reduction of between 40 and 60% of the volatile solids.

O'Shaunessy's formula can be used to calculate the volatile solids (VS) reduction in a digester:

VS reduction (%) = $\{(V_i - V_o)/ V_i - (V_i \times V_o)\}$x100

Where V_i = volatile fraction in feed sludge

V_o = volatile fraction in digested sludge

Example of calculation of VS reduction

Assume volatile solids in feed sludge	=	84%		
Therefore volatile fraction of feed sludge	=	0.84	=	V_i
Assume volatile solids of digested sludge	=	68%		
Therefore volatile fraction of digested sludge	=	0.68	=	V_o

VS reduction (%) = $\{(0.84 - 0.68) / 0.84 - (0.84 \times 0.68)\} \times 100$

= 59%

Option 2: Additional Digestion of Anaerobically Digested Sludge

Frequently, primary sludge is recycled to generate fatty acids or the sludge is recycled through the biological wastewater treatment section of a treatment works or has resided for long periods of time in the wastewater collection system. During this time, the sludge undergoes substantial biological degradation. If the sludge is subsequently treated by anaerobic digestion for a period of time, it adequately reduces vector attraction. Because the sludge will have entered the digester already partially stabilized, the volatile solids reduction after treatment is frequently less than 38 percent.

Under these circumstances, the 38 percent reduction required by Option 1 may not be achievable. Option 2 allows the operator to demonstrate vector attraction reduction by testing a portion of the previously digested sludge in a **bench-scale unit** in the laboratory. Vector attraction reduction is demonstrated if, after anaerobic digestion of the sludge for an additional 40 days at a temperature between 30°C and 37°C, the volatile solids in the sludge are reduced by less than 17 percent from the beginning to the end of the bench test.

Option 3: Additional Digestion of Aerobically Digested Sludge

This option is appropriate for aerobically digested sludge that cannot meet the 38 percent volatile solids reduction required by Option 1. This includes activated sludge from extended aeration plants, where the minimum residence time of sludge leaving the wastewater treatment processes section generally exceeds 20 days. In these cases, the sludge will already have been substantially degraded biologically prior to aerobic digestion.

Under this option, aerobically digested sludge with 2 percent or less solids is considered to have achieved vector attraction reduction, if in the laboratory after 30 days of aerobic digestion in a batch test at 20°C, volatile solids are reduced by less than 15 percent. This test is only applicable to liquid aerobically digested sludge.

Option 4: Specific Oxygen Uptake Rate (SOUR) for Aerobically Digested Sludge

Frequently, aerobically digested sludge is circulated through the aerobic biological wastewater treatment process for as long as 30 days. In these cases, the sludge entering the aerobic digester is already partially digested, which makes it difficult to demonstrate the 38 percent reduction required by Option 1.

The specific oxygen uptake rate (SOUR) is the mass of oxygen consumed per unit time per unit mass of total solids (dry-weight basis) in the sludge. Reduction in vector attraction can be demonstrated if the SOUR of the sludge that is used or disposed, determined at 20°C, is equal to or less than 2 milligrams of oxygen per hour per gram of total sludge (dry-weight basis). This test is based on the fact that if the sludge consumes very little oxygen, its value as a food source for micro-organisms is very low and therefore micro-organisms are unlikely to be attracted to it. Other temperatures can be used for this test, provided the results are corrected to a 20°C basis. This test is only applicable to liquid aerobic sludge withdrawn from an aerobic treatment process.

Option 5: Aerobic Processes at Greater than 40°C

This option applies primarily to composted sludge that also contains partially decomposed organic bulking agents. The sludge must be aerobically treated for 14 days or longer, during which time the temperature must always be over 40°C and the average temperature must be higher than 45°C.

This option can be applied to other aerobic processes, such as aerobic digestion, but Options 3 and 4 are likely to be easier to meet than the other aerobic processes.

Option 6: Addition of Alkaline Material

Sludge is considered to be adequately reduced in vector attraction if sufficient alkaline material is added to achieve the following:

- Raise the pH to at least 12, measured at 25°C, and without the addition of more alkaline material, maintain a pH of 12 for at least 2 hours.

- Maintain a pH of at least 11.5 without addition of more alkaline material for an additional 22 hours.

The conditions required under this option are designed to ensure that the sludge can be stored for at least several days at the treatment works, transported, and then used or disposed without the pH falling to the point where putrefaction occurs and vectors are attracted.

Option 7: Moisture Reduction of Sludge Containing no Un-stabilised Solids

Under this option, vector attraction is considered to be reduced if the sludge does not contain unstabilised solids generated during primary treatment and if the solids content of the sludge is at least 75 percent before the sludge is mixed with other materials. Thus, the reduction must be achieved by removing water, not by adding inert materials.

It is important that the sludge does not contain un-stabilised solids because the partially degraded food scraps likely to be present in such sludge would attract birds, some mammals, and possibly insects, even if the solids content of the sludge exceeds 75 percent. In other words, simply dewatering primary sludge to a 75% solid is not adequate to comply with this option. Activated sludge, humus sludge and anaerobically digested sludge can, however be dewatered to 75% solids and comply with option 7.

Option 8: Moisture Reduction of Sludge Containing Unstabilised Solids

The ability of any sludge to attract vectors is considered to be adequately reduced if the solids content of the sludge is increased to 90 percent or greater, regardless of whether this contains primary sludge or raw unstabilised sludge. The solids increase should be achieved by removal of water and not by dilution with inert solids. Drying to this extent severely limits biological activity and strips off or decomposes the volatile compounds that attract vectors.

The way dried sludge is handled, including storage before use or disposal, can again create the opportunity for vector attraction. If dried sludge is exposed to high humidity, the outer surface of the sludge will increase in moisture content and possibly attract vectors. This should be properly guarded against.

Option 9: Sludge Injection

Vector attraction reduction can be demonstrated by injecting the sludge below the ground surface. Under this option, no significant amount of sludge can be present on the land surface within 1 hour of injection, and if the sludge is Microbiological Class A or B, it must be injected within 8 hours after discharge from the pathogen-reducing process.

The reason for this special consideration for Microbiological class A and B sludge (assuming vector attraction has not been reduced by some other means) is that pathogens could regrow and Microbiological class A and B sludge has no site restrictions to provide crop, animal grazing of access protection.

Note: Microbiological class A and B can be applied to soil much later than 8 hours after discharge from the pathogen-reducing process if another vector attraction reduction option such as dewatering and/or drying is applied. The time periods referred to in Option 9 are intended for liquid sludge application of Microbiological classes A and B.

Injection of sludge beneath the soil places a barrier of earth between the sludge and vectors. The soil removes water from the sludge, which reduces the mobility and odour of the sludge. Odour is usually present at the site during the injection process, but quickly dissipates once injection is complete. This option is applicable all land disposal options and co-disposal on landfill.

Option 10: Incorporation of Sludge into the Soil

Under this option, sludge must be incorporated into the soil within 6 hours of application to or placement on the land. Incorporation is accomplished by ploughing or by some other means of mixing the sludge into the soil. If the sludge is Microbiological class A or B with respect to pathogens, the time between processing and application or placement must not exceed 8 hours – the same as for injection under Option 9. See the note under Option 9. This option is applicable all land disposal options and co-disposal on landfill.

Note: Practical restrictions, such as the ability of the plough to function immediately after application, could cause delays in the incorporation of the sludge within the 6 hours. This could cause the development of odours and increase risk of vector attraction. In these cases the sludge producer needs to monitor the development of odours and manage the situation diligently.

APPENDIX 3: ESSENTIAL CONDITIONS TO BE INCLUDED IN A CONTRACTUAL AGREEMENT BETWEEN A SLUDGE PRODUCER AND SLUDGE USER

Producer

1. Name and address
2. Name and contact details of responsible person (signatory)
3. Classification of sludge
4. Statement on permissible beneficial use option based on sludge classification (Refer to Table 7 of this document)
5. Volume and type (liquid or dewatered) of sludge to be supplied
6. Notification of authorities involved where applicable

User

1. Name and address
2. Name and contact details of responsible person (signatory)
3. Name of transporter of sludge
4. Name and location of site where sludge will be used
5. Specification of beneficial use option
6. Previous sludge application – annual rate and frequency
7. Metal and inorganic content of soil. Soil to be analysed before commencing sludge application and monitored as described in this document where applicable

Agreement

1. Sludge to be used subject to Guideline Volume 4 (Site considerations, odour control, soil quality, sludge application rate, crop restrictions, monitoring requirements and record keeping requirements)
2. Inspection of user's activities by any appropriate authority
3. Breach of contract – termination of sludge supply and punitive measures

APPENDIX 4: SAMPLING METHODS AND PROCEDURES FOR WATER AND SOIL SAMPLES

WATER SAMPLING[4]

Sampling equipment needed

- Equipment to collect microbiological samples
  - Sterile sample bottles (see Table 25 and 26 for the type of sample bottle needed)
  - Sealed container or cool box which can be kept cool (preferably with ice)
- Equipment to collect chemical and physical samples
  - Correct sample bottles (see Table 25 and 26 for the different types of sample bottles required)
  - Cooler box with ice (if necessary)

Special precautions

- Microbiological water samples
  - Keep sample bottle closed and in a clean condition up to the point where it has to be filled with the water to be sampled.
  - Do not rinse bottle with any water prior to sampling.
  - When samples for chemical and microbiological analysis are to be collected from the same location, the microbiological sample should be collected first to avoid the danger of microbiological contamination of the sampling point.
  - The sampler (person taking the sample) should wear gloves (if possible) or wash his/her hands thoroughly before taking each sample. Avoid hand contact with the neck of the sampling bottle.
- Chemical water samples
  - Some plastic caps or cap liners may cause metal contamination of the water sample. Please consult with the laboratory on the correct use of bottle caps.
  - Keep sample bottle closed and in a clean condition up to the point where it has to be filled with the water to be analysed.
  - Never leave the sample bottles (empty or filled with the water sample) unprotected in the sun.
  - After the sample has been collected the sample bottle should be placed directly in a cooled container (e.g. portable cooler box). Try and keep cooled container dust-free.

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[4] For more detail on the water sampling procedure, consult the following documents:
Department of Water Affairs and Forestry. 1998. Waste Management Series. Minimum Requirements for Water Monitoring at Waste Management Facilities.
WRC. 2000. Quality of domestic water supplies. Volume 2: Sampling Guide. WRC no TT 117/99.

Surface water sampling technique

The following procedures should be followed when taking water samples in rivers and streams:

- At the sampling point remove cap of sample bottle but do not contaminate inner surface of cap and neck of sample bottle with hands.
- Take samples by holding bottle with hand near base and plunge the sample bottle, neck downward, below the water surface (wear gloves to protect your hands from contact with the water).
- Turn bottle until neck points slightly upward and mouth is directed toward the current (can also be created artificially by pushing bottle forward horizontally in a direction away from the hand).
- Fill sample bottle without rinsing and replace cap immediately.
- Before closing the sample bottle, preserve the sample (if applicable, see Table 25) and leave ample air space in the bottle (at least 2.5 cm) to facilitate mixing by shaking before examination.
- Label the sample.
- Submit for analysis to a reputable analytical laboratory.

Composite Borehole Water Sampling

Composite water sampling is done by pumping water from a borehole. The recommended procedure for composite sampling is as follows:

- Activate the pump and remove (purge) at least three times the volume of water contained in the hole.
- Collect a water sample in a clean container (see Table 26).
- Filter and preserve the sample (if applicable, see Table 26) and submit for analysis to a reputable analytical laboratory.

Various types of pumps may be used. As a portable system, a submersible pump may be considered. Submersible pumps are generally available in South Africa. For sampling, a small submersible pump that yields 1 ℓ/sec would be sufficient for most sampling applications.

Where low-yielding monitoring boreholes are pumped, the borehole could temporarily run dry while being purged. In such instances, samples should be taken of the newly accumulated groundwater after recovery or partial recovery of the water level in the holes. It may be necessary to sample such boreholes a day or more after having purged the hole.

SOIL SAMPLING[5]

Sampling equipment needed

- Soil auger
- Plastic sheets
- Plastic or glass containers (bottles or bags) that can be closed tightly
- Tags and a permanent marker to label the samples

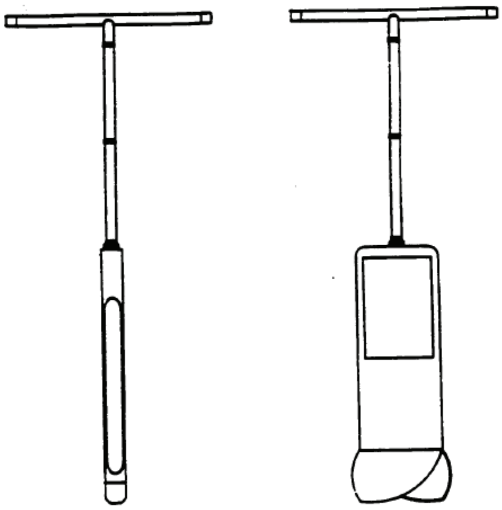

Figure A3: Soil augers

Number of samples

The number of samples will vary according to the size of the beneficial use site and different soil types present at the site. At least three composite samples for each depth increment for every hectare of the site are required.

Sampling procedure

The **soil auger** is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. The following procedure is recommended:

1. Clear the area to be sampled of any surface debris (e.g. twigs, rocks, litter).
2. Begin augering and after reaching the desired depth, slowly and carefully remove the auger from the hole. Deposit the soil onto a plastic sheet spread near the hole. For

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[5] For more information on soil sampling procedures, consult the following documents:
USEPA Environmental Response Team. 2000. Standard operating procedures: Soil sampling
USEPA 1989. Soil sampling quality assurance: User's Guide. EPA 600/8-89/046

soil monitoring at disposal sites these depths are 0-100 mm, 100-200 mm, 200-300 mm, 300-400 mm and 400-500 mm.

3. Place the samples into plastic or other appropriate containers, secure the caps tightly and label the sample.
4. If composite samples are to be collected, place a sample from another sampling site into the same container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
5. Preserve the samples as recommended in Table A4 and submit to a reputable laboratory.

TABLE A4: RECOMMENDED SOIL SAMPLE CONTAINERS, PRESERVATION AND HOLDING TIMES

Contaminant	Container	Preservation	Holding Time
Acidity	Plastic/Glass	Cool, 4°C	14 days
Ammonia	Plastic/Glass	Cool, 4°C	28 days
Sulfate	Plastic/Glass	Cool, 4°C	28 days
Nitrate	Plastic/Glass	Cool, 4°C	48 hours
Organic Carbon	Plastic/Glass	Cool, 4°C	28 days
Chromium VI	Plastic/Glass	Cool, 4°C	48 hours
Mercury	Plastic/Glass	Cool, 4°C	28 days
Other Metals	Plastic/Glass	Cool, 4°C	6 months

Soil samples can also be collected from a **test pit or trench excavation**. The following procedure is recommended:

1. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.
2. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling.
3. Place the samples into plastic or other appropriate containers, secure the caps tightly and label the sample.
4. If composite samples are to be collected, place a sample from another sampling site into the same container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
5. Preserve the samples as recommended in Table A4 and submit to a reputable laboratory.

APPENDIX 5: CALCULATING THE TOTAL LOAD / MAXIMUM MIXING RATIO FOR SLUDGE USED AS LANDFILL COVER

Example: Calculating the allowable mass of sludge with soil for use as a vegetative layer using the EEC principle.

A landfill with a surface area of 70 ha is to be covered. The 200 mm topsoil or vegetative layer is to contain sewage sludge as a soil conditioner.

Sludge properties:

Zn concentration from TCLP test	: 5.8 mg Zn/kg dry solids
Sludge moisture content	: 20% solids
Sludge density	: 600 kg/m^3

Solution: (following the procedure in Section 8.6 of the Minimum Requirements)

LC50 = 7 mg/ℓ

AE = 0.1 x LC_{50}

AE = 0.1 x 7 mg/ℓ

AE = 700 ppb

EEC = AE

g/ha/month x 0.66 = AE

= 700 / 0.66

= 1061 g/ha/month

but, this is a once-off application, therefore

EEC = 1061 g/ha

Mass of sludge (dry solids) = 1061 g/ha / 5.8 mg/kg

= 18.293 tonnes/ha

Mass of sludge (wet mass) = 18.293 / (20/100) tonnes/ha

= 91.465 tonnes/ha

Volume of sludge = 91.465 tonnes/ha / 600 kg/m^3

= 152.4 m^3/ha

Volume of vegetative layer/ha = 0.2 x 1000 x 1000 m^3/ha

= 200 000 m^3/ha (this is the final, compacted volume)

The moisture in the sludge impacts on the compaction density that can be achieved and in fact, on the optimum moisture content and density of the mixture. The actual mass of soil can therefore not be determined for this example since a series of compaction trails of soil and sludge mixtures should be undertaken. Once a suitable ratio is chosen, the maximum mass of sludge permitted in the compacted layer is 91.5 tonnes/ha. Despite the maximum permissible load in terms of the EEC procedure, the properties of the mixture must still be considered for construction of the cover.

DEFINITIONS AND DESCRIPTION OF KEY TERMS

Acceptable exposure: The concentration of a substance that will have minimal effect on the environment or human health.

Agricultural land: Land on which a food crop, a feed crop, or a fibre crop is grown. This includes grazing land and forestry.

Agronomic rate: The sludge application rate (dry-weight basis) designed (i) to provide the amount of nitrogen needed by the food crop, feed crop, fibre crop, cover crop, or vegetation grown on the land and (ii) to minimise the amount of nitrogen in the sewage sludge that passes below the root zone of the crop or vegetation grown on the land to the groundwater.

Agricultural use: The use of sludge to produce agricultural products. It excludes the use of sludge for aquaculture and as an animal feed.

Annual pollutant loading rate: The maximum amount of a pollutant that can be applied to an area of land during a 365-day period.

Assimilative capacity: This represents the ability of the receiving environment to accept a substance without risk.

Available metal content (Soil): Specific to Volume 2. Metal fraction extracted with ammonium nitrate in soil samples.

Beneficial uses: Use of sludge with a defined benefit, such as a soil amendment.

Bioavailability: Availability of a substance for uptake by a biological system.

Biosolids: Stabilised Sludge. Organic solids derived from biological wastewater treatment processes that are in a state that they can be managed to sustainably utilise the nutrient, soil conditioning, energy, or other value.

Bund wall: A properly engineered and constructed run-off interception device around a waste disposal site or down slope of a waste disposal site.

Co-disposal (liquid with dry waste): The mixing of high moisture content or liquid waste with dry waste. This affects the water balance and is an acceptable practice on a site equipped with leachate management measures.

Co-disposal (dewatered sludge with dry waste): The mixing of dewatered sludge with dry waste in a general landfill site or hazardous landfill site without affecting the water balance of the site.

Composting: The biological decomposition of the organic constituents of sludge and other organic products under controlled conditions.

Contaminate: The addition of foreign matter to a natural system. This does not necessarily result in pollution, unless the attenuation capacity of the natural system is exceeded.

Controlled access: Where public or livestock access to sludge application areas is restricted or controlled, such as via fences or signage, for a period of time stipulated by this guideline.

Cradle-to-grave: A policy of controlling a Hazardous Waste from its inception to its ultimate disposal.

Cumulative pollutant loading rate:	The maximum amount of a pollutant that can be applied to a unit area of land.
Cut-off trench:	A properly engineered and constructed trench to intercept and collect run-off.
Dedicated land disposal:	Sites that receive repeated applications of sludge for the sole purpose of final disposal.
Delisting:	If the estimated environmental concentration (EEC) is less than the Acceptable Exposure (AE) which is 10% of the LC_{50}, the waste can be delisted, i.e. be moved to a lower Hazard Rating or even disposed of at a General Waste landfill with a leachate collection system.
Dewatering:	Dewatering processes reduce the water content of sludge to minimise the volumes for transport and improve handling characteristics. Typically, dewatered sludge can be handled as a solid rather than as liquid matter.
Disinfection:	A process that destroys, inactivates or reduces pathogenic microorganisms.
Disposal:	The discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into the environment (land, surface water, ground water, and air).
Disposal site:	A site used for the accumulation of waste with the purpose of disposing or treatment of such waste. See also Waste Disposal Site.
Domestic sewage:	Waste and wastewater from humans or household operations that is discharged to, or otherwise enters a treatment works.
Dose:	In terms of monitoring exposure levels, the amount of a toxic substance taken into the body over a given period of time. See also LD_{50}
Domestic waste:	Waste emanating, typically, from homes and offices. Although classified as a General Waste, this waste contains organic substances and small volumes of hazardous substances.
Dose-response:	How an organism's response to a toxic substance changes as its overall exposure to the substance changes. For example, a small dose of carbon monoxide may cause drowsiness; a large dose can be fatal.
Drying:	A process to reduce the water content further than a dewatering process. The solids content after a drying process is typically > 75%.
Dry-weight (DW) basis:	The method of measuring weight where, prior to being weighed, the material is dried at 105ºC until reaching a constant mass (i.e. essentially 100% solids content).
Dump:	A land site where wastes are discarded in a disorderly or haphazard fashion without regard to protecting the environment. Uncontrolled dumping is an indiscriminate and illegal form of waste disposal. Problems associated with dumps include multiplication of disease-carrying organisms and pests, fires, air and water pollution, unsightliness, loss of habitat, and personal injury.

E. coli: A group of bacteria normally found in the intestines of humans and animals. Most types of *e. coli* are harmless, but some active strains produce harmful toxins and can cause severe illness. In sanitary bacteriology, *Escherichia coli* is considered the primary indicator of recent faecal pollution.

Ecotoxicity: Ecotoxicity is the potential to harm animals, plants, ecosystems or environmental processes.

Emission: The release or discharge of a substance into the environment. Generally refers to the release of gases or particulates into the air.

Emission Standards: Government standards that establish limits on discharges of pollutants into the environment (usually in reference to air).

Environment: Associated cultural, social, soil, biotic, atmospheric, surface and groundwater aspects associated with the disposal site that could potentially be, impacted upon by the disposal.

Environmental Impact Assessment (EIA): An investigation to determine the potential detrimental or beneficial impact on the surrounding communities, fauna, flora, water, soil and air arising from the development or presence of a waste disposal site.

Estimated Environmental Concentration (EEC): The Estimated Environmental Concentration represents the concentration of a substance in the aquatic environment when introduced under worst case scenario conditions, i.e. directly into a body of water. It is used to indicate possible risk, by comparison with the minimum concentration estimated to adversely affect aquatic organisms or to produce unacceptable concentrations in biota, water or sediment.

Faecal coliform: *Faecal coliforms* are the most commonly used bacterial indicator of faecal pollution. *Faecal coliforms* are bacteria that inhabit the digestive system of all warm-blooded animals, including humans.

Hazard Rating: A system for classifying and ranking Hazardous waste according to the degree of hazard they present.

Hazardous waste: Waste that may, by circumstances of use, quantity, concentration or inherent physical, chemical or infectious characteristics, cause ill health or increase mortality in humans, fauna and flora, or adversely affect the environment when improperly treated, stored, transported and disposed of.

Helminth ova: The eggs of parasitic intestinal worms.

Incineration: Incineration is both a form of treatment and a form of disposal. It is simply the controlled combustion of waste materials to a non-combustible residue or ash and exhaust gases, such as carbon dioxide and water.

Integrated Environmental Management (IEM): A code of practice ensuring that environmental considerations are fully integrated into the management of all activities in order to achieve a desirable balance between conservation and development.

Land application: The spraying or spreading of wastewater sludge onto the land surface; the injection of wastewater sludge below the land surface; or the incorporation of wastewater sludge into the soil so that the wastewater sludge can either condition the soil or fertilise crops or vegetation grown in the soil.

Land disposal: Application of sludge where beneficial use is not an objective. Disposal will normally result in application rates that exceed agronomic nutrient requirements or cause significant contaminant accumulation in the soil.

Landfill: To dispose of waste on land, whether by use of waste to fill in excavation or by creation of a landform above ground, where the term "fill" is used in the engineering sense.

LC_{50}: The median lethal dose is a statistical estimate of the amount of chemical, which will kill 50% of a given population of aquatic organisms under standard control conditions. The LC_{50} is expressed in mg/ℓ.

LD_{50}: The median lethal dose is a statistical estimate of the amount of chemical, which will kill 50% of a given population of animals (e.g. rats) under standard control conditions.

Leachate: An aqueous solution with a high pollution potential, arising when water is permitted to percolate through decomposing waste.

Liner: A layer of low permeability placed beneath a landfill and designed to direct leachate to a collection drain or sump, or to contain leachate. It may comprise natural materials, synthetic materials, or a combination thereof.

Maximum available threshold (MAT): The maximum available (NH_4NO_3 extractable) metal concentration allowed for soils receiving sludge.

Maximum permissible level: The maximum total metal concentration allowed in soils at sludge disposal sites. Soil remediation would not be necessary except if this level is exceeded.

Minimum Requirement: A standard by means of which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices.

Monthly average: The arithmetic mean of all measurements taken during a given month.

Most probable number (MPN): A unit that expresses the amount of bacteria per gram of total dry solids in wastewater sludge.

Off-site: Sludge disposal site outside the boundaries of the wastewater treatment plant (WWTP).

On-site: Sludge disposal site within the boundaries of the wastewater treatment plant (WWTP).

Pathogenic organisms: Disease-causing organisms. This includes, but is not limited to, certain bacteria, protozoa, viruses, and viable helminth ova.

pH: The logarithm of the reciprocal of the hydrogen ion concentration. The pH measures acidity/alkalinity and ranges from 0 to 14. A pH of 7 indicates the material is neutral. Moving a pH of 7 to 0, the pH indicates progressively more acid conditions. Moving from a pH of 7 to 14, the pH indicates progressively more alkaline conditions.

Pollution: The direct or indirect alteration of the physical, chemical or biological properties of a (water) resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used; or harmful or potentially harmful to the welfare, health or safety of human beings; to any aquatic or non-aquatic organisms; to the resource quality; or to property.

Primary treatment: Treatment of wastewater prior to other forms of treatment and involving settling and removal of suspended solids.

Qualified person: A person is suitably qualified for a job as a result of one, or any combination of that person's formal qualifications, prior learning, relevant experience; or capacity to acquire, within a reasonable time, the ability to do the job.

Receptor: Sensitive component of the ecosystem that reacts to or is influenced by environmental stressors.

Recycle: The use, re-use, or reclamation of a material so that it re-enters the industrial process rather than becoming a waste.

Rehabilitation: Restoring a waste site for a new industrial function, recreational use, or to a natural state.

Remediation: The improvement of a contaminated site to prevent, minimize or mitigate damage to human health or the environment. Remediation involves the development and application of a planned approach that removes, destroys, contains or otherwise reduces the availability of contaminants to receptors of concern.

Residue: A substance that is left over after a waste has been treated or destroyed.

Responsible person: A person(s), who takes professional responsibility for ensuring that all or some of the facets of the handling and disposal of Hazardous Waste are properly directed, guided and executed, in a professionally justifiable manner.

Restricted agricultural use: Use of sludge in agriculture is permitted but restrictions apply (crop restrictions, access restrictions etc).

Risk: The scientific judgement of probability of harm. This basic and important concept has two dimensions: the consequences of an event or set of circumstances and the likelihood of particular consequences being realised. Both dimensions apply to environmental risk management with it generally being taken that only adverse consequences are relevant

Risk assessment: The evaluation of the results of risk analysis against criteria or objectives to determine acceptability or tolerability of residual risk levels, or to determine risk management priorities (or the effectiveness or cost-effectiveness of alternative risk management options and strategies).

Risk management: The systematic application of policies, procedures and practices to identify hazards, analysing the consequences and the likelihood associated with those hazards, estimating risk levels, assessing those risk levels against relevant criteria and objectives, and making decisions and acting to reduce risk levels to acceptable environmental and legal standards.

Secondary Treatment: Treatment of wastewater that typically follows primary treatment and involves biological processes and settling tanks to remove organic material.

Sludge-amended soil:	Soil to which sludge has been added.
Sludge:	Solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Wastewater sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and material derived from wastewater sludge in a wastewater sludge incinerator. It does not include the grit and screenings generated during preliminary treatment of domestic wastewater in a treatment works.
Soil organisms:	A broad range of organisms, including microorganisms and various invertebrates living in or on the soil.
Specific oxygen uptake rate (SOUR):	The mass of oxygen consumed per unit time per unit mass of total solids (dry-weight basis).
Stabilisation:	The processing of sludge to reduce volatile organic matter, vector attraction, and the potential for putrefaction and offensive odours.
Stabilised sludge:	Organic solids derived from biological wastewater treatment processes that are in a state that they can be managed to utilise the nutrient, soil conditioning, energy, or other value.
Sterilise:	Make free from microorganisms.
Supplier:	A person or organisation that produces and supplies sludge for use. This includes a water business producing and treating sludge and processors involved in further treatment.
Surface water interception mechanism:	A mechanism placed between the disposal site and the surface water body to intercept possible run-off from the disposal site before it can reach the water body.
Sustainability:	Being able to meet the needs of present and future generations by the responsible use of resources.
Sustainable use:	The use of nutrients in sludge at or below the agronomic loading rate and/or use of the soil conditioning properties of sludge. Sustainable use involves protection of human health, the environment and soil functionality.
Total investigative level (TIL):	The total metal concentration in agricultural soils where further investigation is necessary before sludge application can commence.
Total load capacity:	The capacity of a landfill site to accept a certain substance or the amount of a substance, which can be safely disposed of at a certain site. The total load capacity is influenced by the concentration levels and mobility of the waste, and by the landfill practice and design.
Total maximum threshold (TMT):	The maximum total metal concentration allowed in agricultural soils receiving sludge.
Total metal content:	Metal fraction extracted using an *aqua regia* solution (HCl/HNO_3 solution).
Total trigger value:	The total metal concentration in soils at disposal sites indicating that additional management options should be implemented to reduce the impact on the soil.

Toxic:	Poisonous.
Toxicity:	An intrinsic property of a substance which can cause harm or a particular adverse effect to humans, animals or plants at some dose.
Toxicity Characteristic Leaching Procedure (TCLP):	A test developed by the USA Environmental Protection Agency to measure the ability of a substance to leach from the waste into the environment. It thus measures the risk posed by a substance to groundwater.
Transporters:	A person, organisation, industry or enterprise engaged in or offering to engage in the transportation of waste.
Treatment:	Treatment is used to remove, separate, concentrate or recover a hazardous or toxic component of a waste or to destroy or, at least, to reduce its toxicity in order to minimise its impact on the environment.
Unrestricted agricultural use:	Sludge is of such good quality that it can be used in agricultural practices without any restrictions.
VAR:	Vector Attraction Reduction.
Vector attraction:	The characteristic of wastewater sludge that attracts rodents, flies, mosquitoes, or other organisms capable of transporting infectious agents.
Vectors:	Any living organisms that are capable of transmitting pathogens from one organism to another, either: (i) mechanically by transporting the pathogen or (ii) biologically by playing a role in the lifecycle of the pathogen. Vectors include flies, mosquitoes or other insects, birds, rats and other vermin.
Waste:	An undesirable or superfluous by-product, emission, or residue of any process or activity, which has been discarded, accumulated or stored for the purpose of discarding or processing. It may be gaseous, liquid or solid or any combination thereof and may originate from a residential, commercial or industrial area.
Waste disposal site:	Any place at which more than 100 kg of a Waste is stored for more than 90 days or a place at which a dedicated incinerator is located.
Wastewater Sludge:	The material recovered from predominantly domestic wastewater treatment plants. (Also see Sludge).
Wastewater Treatment Plant (WWTP):	Any device or system used to treat (including recycling and reclamation) either domestic wastewater or a combination of domestic wastewater and industrial waste of a liquid nature.
Wet weight:	Weight measured of material that has not been dried (see Dry-weight basis).