DEPARTMENT OF WATER AFFAIRS & FORESTRY

GUIDELINE FOR

DISPOSAL OF SOLIDS FROM WATER AND WASTEWATER TREATMENT PROCESSES

Revision: 4

Date: July 2012

TABLE OF CONTENTS

DEFINITIONS

General:

brine:	Term commonly used to describe the waste water produced by reverse osmosis treatment processes. Substances removed by reverse osmosis from the feed stream are concentrated in a waste stream, referred to as brine;
dewatering:	Dewatering processes reduce the water content of sludge to minimise transport volumes and improve handling characteristics. Typically, dewatered sludge can be handled as a solid rather than as a liquid;
effluent:	liquid waste originating from domestic, industrial, agricultural or mining activities that has been treated in a wastewater treatment facility and released into the environment in a dam, an evaporation pond, an aquifer, a river, the sea or onto the surface of the ground;
groundwater:	Any water resource found under the surface of the ground;
land application:	Spraying or spreading of sludge or residue onto the land surface; the injection of sludge or residue below the land surface; or the incorporation of sludge or residue into the soil so that it can either condition the soil or fertilise crops or vegetation grown in the soil;
landfill:	Disposal of waste on land, whether by use of waste to fill in excavation or by creation of a landform above grade, where the term "fill" is used in the engineering sense;
leachate:	Aqueous solution with a high pollution potential, arising when water is permitted to percolate through decomposing waste;
liner:	Layer of impenetrable material/sheeting placed beneath a landfill and designed to direct leachate to a collection drain or sump. May be made of building construction materials, synthetic materials, or a combination thereof;
pathogen:	Disease-causing organism, such as certain bacteria, viruses and parasites;
residue:	Substance that is left over after a waste has been treated or destroyed;
sewer:	Pipe or conduit which is used for the conveyance of sewage or industrial effluents;
sludge:	Solid waste generated by wastewater treatment plants, predominantly biological processes;
vector:	Potential disease carrying organisms such as flies, mosquitoes, rodents, fleas and birds;
waste:	Includes any solid or material that is dissolved, suspended or transported in water, including sediment;
water resource:	Includes a watercourse, an aquifer, the sea and meteoric water;
water treatment residue	

(WTR):	Solid waste generated by potable water treatment plants, predominantly collected during physical-chemical removal processes such as coagulation, flocculation and sedimentation;

Abbreviations:

COD:	Chemical Oxygen Demand = measurement of the amount of oxidisable organic matter, *viz* the amount of oxygen required to convert all organic carbon constituents to CO_2 and H_2O.
DWAF:	Department of Water Affairs and Forestry = the responsible authority enforcing this regulation in Namibia
DLD:	Dedicated Land Disposal = Disposal site at which sludge is applied to the surface of the land on a routine basis but where the objective is sludge disposal and not sludge utilisation as in land application for agricultural purposes.
SOUR:	Specific Oxygen Uptake Rate = measurement of the mass of oxygen consumed per unit time per unit mass of total solids (dry-weight basis) in biosolids
WTR:	Water Treatment Residue

1. INTRODUCTION

This guideline addresses the use and disposal of solid waste generated during the treatment process by both drinking water and wastewater treatment plants. Due to the costs associated with landfill disposal options, environmental concerns and globally increasing awareness about waste reduction and recycling, the purpose of this guideline is to inform plant owners how to safely discard their solid waste and to promote the safe and feasible reuse of such waste.

When dealing with recovered wastewater sludge emphasis must be placed on the continuous monitoring and safe use thereof, especially where such sludge comes into direct contact with humans, or plants and animals consumed by humans. Possible risks and hazards related to sludge use include:

- water-borne diseases caused by helminth, bacterial, viral and/or protozoan infections;
- aesthetic issues like odor pollution or decreased product sales due to consumers not wanting to buy products that were produced using wastewater;
- environmental issues including groundwater contamination, endangering of marine life and pollution of water bodies used for recreational purposes;

Clear distinction needs to be made between waste produced by sewage or wastewater treatment works and potable water treatment works, since the two waste types are fundamentally different and cannot be grouped together into one definition. The term “water treatment residue” is often freely interchanged with the term “water treatment sludge”. To avoid confusion, in this guideline the term “water treatment residue” (WTR) or just “residue” will be used to refer to waste produced by potable water treatment plants mainly during physical-chemical removal processes. The term “sludge” will be used to refer to waste produced by wastewater treatment plants and refers pre-dominantly to solid waste produced during biological processes.

<u>WTR</u> results from the removal of suspended solids and other contaminants by coagulation, flocculation and sedimentation of raw water. Chemical precipitants such as aluminum sulfates, ferric salts, lime and poly-electrolytes are added to the turbid raw water at the inflow of the treatment plant causing suspended solids to flocculate. The flocculated solids fraction is then filtered out and dewatered. This dewatered solid portion forms the WTR, which can be reused beneficially.

<u>Sludge</u> consists primarily of organic solids and is defined as a solid, semi-solid or liquid waste generated during the treatment of domestic sewage by primary, secondary or advanced wastewater treatment processes. Thus, it consists pre-dominantly of biological matter. Ash generated by incineration of sludge, as well as grit and screenings, are not included in the definition of sludge.

<u>Brine</u> is a very saline concentrate stream produced as a by-product of a reverse osmosis treatment process. This concentrated solution must be disposed of and is generally discharged into the ocean or evaporated in evaporation ponds leaving only the solid matter contained in the original brine.

Recognition of the beneficial properties inherently contained in sludge and WTR has lead to an increase in use of these wastes as a fertilizer for various vegetation growths as opposed to simply disposing of them without any further use. This document serves as a guideline for the use of sludge and WTR for land application as well as the disposal of sludge by on-site and off-site disposal.

SECTION A: DISPOSAL OF WASTEWATER TREATMENT SOLIDS

2. CLASSIFICATION OF SLUDGE

All sludge that is to be disposed of or used for agricultural purposes needs to be classified according to microbial, stability and pollution indicators. This needs to be done, since the safe application of wastewater sludge for various applications is determined according to these classifications. The Namibian Wastewater Sludge Classifications System, as further elaborated on hereinafter, must be applied to classify the sludge for its intended use:

Table 1 - Namibian Wastewater Sludge Classification System

Microbial Class	A	B	C
Stability Class	1	2	3
Pollution Class	a	b	c

The characterization and classification of sludge should be repeated whenever changes in the process or operation conditions occur that could affect the classification. This could include factors including operational changes or process adjustments made at the wastewater plant or changes in the influent raw water quality. Whenever any factors that could possibly alter the sludge quality occur, the sludge needs to be re-classified.

2.1 Microbiological Classification

Microbiological analyses of sludge samples can be used to determine the microbiological class, as in Table 2. The microbiological classification indicates to what degree the sludge is contaminated with potentially hazardous pathogenic organisms.

Table 2 - Microbiological Classification

Microbiological Class	Unrestricted Use Quality		General Use Quality		Limited Use Quality
	A		B		C
	Target Value	Maximum Permissible Value (MPV)	Target Value	Maximum Permissible Value (MPV)	
Faecal coliform (CFU/g_{dry})	< 1 000 (5 log reduction)	10 000 (4 log reduction)	< $1x10^6$ (2 log reduction)	$1x10^7$ (1 log reduction)	> $1x10^7$ (no reduction)
Helminth ova (viable ova/g_{dry})	< 0.25 (one ova/4g)	1	< 1	4	> 4
Compliance Requirements					
Requirements for classification purposes (minimum 3 samples)	100% of samples must comply	Not applicable	66% of samples must comply	Samples that failed must not exceed MPV	Not applicable
Requirements for monitoring	90% of samples must	Samples that failed must not	90% of samples must	Samples that failed must not	Not applicable

purposes	comply	exceed MPV	comply	exceed MPV	

2.2 Stability Classification

The stability classification indicates the potential of the sludge to attract vectors and generate odours. This classification can be determined analytically and/or by complying with at least one of the vector attraction reduction (VAR) requirements as listed in Table 3 and described in detail in Appendix 2.

Table 3 - Stability Classification

Stability Class	**1**	**2**	**3**
Percentile compliance with one of the VAR options	90%	75%	No stabilisation or VAR options required
VAR Option	**Description**		
1) Reduction in volatile solids content	Meet 38 percent reduction in volatile solids content		
2) Additional digestion of anaerobically digested sludge	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit		
3) Additional digestion of aerobically digested sludge	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit		
4) Specific Oxygen Uptake Rate (SOUR) for aerobically digested sludge	Meet a specific oxygen uptake rate for aerobically digested sludge		
5) Aerobic processes at greater than 40°C	Use aerobic processes at greater than 40°C for 14 days or longer		
6) Addition of alkaline material	Alkali addition under specified conditions		
7) Moisture reduction of sludge containing no unstabilised solids	Dry sludge with no unstabilised solids to at least 75 percent solids		
8) Moisture reduction of sludge containing unstabilised solids	Dry sludge with unstabilised solids to at least 90 percent solids		
9) Sludge injection	Inject sludge beneath the soil surface		
10) Incorporation of sludge into soil	Incorporate sludge into the soil within 6 hours of application on the land		
11) Covering sludge	Cover sludge placed on a surface disposal site with soil or other material at the end of each operating day (Note: only for surface disposal)		
12) Alkaline treatment for domestic septage	Alkaline treatment of domestic septage to pH 12 or higher for 30 minutes without adding more alkaline material		

2.3 Pollutant Classification

The pollutant classification indicates to what degree the sludge is contaminated with potentially toxic metals and elements. The sludge analyses results can be used to determine this classification. Note that 90% compliance is required to comply with the requirements of a pollutant class. Therefore, compliance can only be shown after 10 sample results are known. The *aqua regia* extraction method [ISO 11466: 1995(E). *Soil quality: extraction of trace elements soluble in aqua*] is to be used.

Table 4 - Pollutant Classification

***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)	<1200	1200 - 3000	>3000
Copper (Cu)	<1500	1500 - 4300	>4300
Cyanide (CN)	<50		≥50
Lead (Pb)	<300	300 - 840	>840
Mercury (Hg)	<15	15 - 55	>55
Nickel (Ni)	<420	420	>420
Zinc (Zn)	<2800	2800 - 7500	>7500
Radioactivity			
Radioactivity (gross alpha activity)	<0.5 Bq/L	<0.5 Bq/L	<0.5 Bq/L
Radioactivity (gross beta activity)	<1.0 Bq/L	<1.0 Bq/L	<1.0 Bq/L

The general pollutant class determination is thus based on the above eight potentially toxic metals. However, the sludge at a wastewater treatment plant could be contaminated by other metals or elements unique to that specific plant. It is therefore necessary to initially perform a full elemental analysis including trace elements, for each treatment plant to determine if any elements other than those in Table 4 are of concern. In cases where additional elements of concern are identified, these need to be included in the analysis for classification and monitoring. Where radioactivity exceeds the above limits, the sludge may not be re-used under any circumstances, regardless of the microbial and the stability classification or the envisaged application of the sludge.

3. LAND APPLICATION OF SLUDGE

The use of sludge produced during wastewater treatment for agricultural use is encouraged due to the high levels of nutrients inherently contained therein. However, such use must be strictly controlled and monitored with restrictions on specific uses in order to ensure the health and safety of both the producers and the consumers of agricultural products to which sludge has been applied. It should be noted that all three sludge classifications need to be considered simultaneously. For example, even if sludge is of an acceptable standard in two of the classifications, it might not be suitable for a specific application due to a poor third classification. Table 5 summarises the permissible utilisation of sludge for agricultural purposes according to the sludge classification. The use of a specific class of sludge is only permitted if the restrictions and requirements in the right hand column of Table 5 are met.

Table 5 - Land Application Restrictions According to Sludge Classification

Sludge Classification		Agricultural Use an Option?*	*Restrictions and Requirements
Microbiological Class	A	Yes	None
	B	Yes	Restrictions and requirements apply (3.1.2)
	C	Yes	Only permissible if Stability Class 1 or 2 is achieved. Restrictions and requirements apply (3.1.3)
Stability Class	1	Yes	None
	2	Yes	Additional management actions to encourage compliance with Class 1
	3	No	May not be used for agricultural purposes
Pollutant Class	a	Yes	None
	b	Yes	If soil analysis is acceptable (3.3.2)
	c	No	May not be used for agricultural purposes

3.1 Restrictions Based on Microbiological Classification

Crops to which wastewater sludge is to be applied are divided into different categories, according to the risk of direct contact of the edible part of the crop with the applied sludge. The three crop categories along with several examples are given below, according to harvested or edible parts that:

- **Usually do not touch the soil/sludge mixture:** includes grains and trees such as wheat, barley, corn, soy beans, oats, cotton, apples, bananas, citrus, peaches, pineapples, grapes and avocados.
- **Usually touch the soil/sludge mixture:** includes fruit and vegetables grown above the ground such as cucumbers, tomatoes, spinach, lettuce, cabbage, celery, melons, strawberries, eggplant and squash.
- **Usually are within the soil/sludge mixture:** includes fruit and vegetables grown below the ground such as potatoes, sweet potatoes, onions, beetroot, peanuts, leeks, turnips and radishes.

3.1.1 Microbiological Class A: Restrictions for Agricultural Use

No restrictions and requirements apply. Sludge in this class can therefore be safely applied to any type of crop providing the Stability and Pollutant Classifications are acceptable for that application.

3.1.2 Microbiological Class B: Restrictions for Agricultural Use

Sludge producers are encouraged to achieve Microbiological Class A classification so that no restrictions and requirements for the sludge application apply. For Microbiological Class B sludge, the following restrictions apply:

Table 6 - Restrictions of Microbiological Class B Sludge for Agricultural Use

Sludge Application	Site Restrictions
1) Food crops with harvested parts that touch the sludge	Food crops with harvested parts that touch the sludge/soil mixture and are totally above the land surface shall not be harvested for 14 months after application of sludge
2) Food crops with harvested parts below the land surface	• When the sludge remains on the land surface for 4 months or longer prior to incorporation into the soil, food crops with harvested parts below the surface of the land shall not be harvested for 20 months after application of the sludge • When the sludge remains on the land surface for less than 4 months prior to incorporation into the soil, food crops with harvested parts below the surface of the land shall not be harvested for 38 months after application of the sludge
3) Food crops with harvested parts that do not touch the sludge, feed crops and fibre crops	Food crops with harvested parts that do not touch the sludge/soil mixture, feed crops and fibre crops shall not be harvested for 30 days after application of sludge
4) Animal grazing	Animals shall not be grazed on the land for 30 days after application of sludge
5) Turf growing	Turf grown on land where sludge is applied shall not be harvested for 1 year after application of the biosolids. This applies to lawns and land with high potential for public exposure.
6) Public Access	• Public access to land with a high potential for public exposure shall be restricted for 1 year after application of sludge • Public access to land with a low potential for public exposure shall be restricted for 30 days after application of sludge

3.1.3 Microbiological Class C: Restrictions for Agricultural Use

Microbiological Class C sludge is only suitable for use if Stability Class 1 or 2 (section 3.2) is achieved. In such cases the following restrictions apply:

Table 7 - Restrictions of Microbiological Class C Sludge for Agricultural Use

Sludge Application	Site Restrictions
1) Food crops with harvested parts that touch the sludge	Use of Microbiological Class C sludge is not permitted
2) Food crops with harvested parts below the land surface	Use of Microbiological Class C sludge is not permitted
3) Food crops with harvested parts that do not touch the sludge, feed crops and fibre crops	Food crops with harvested parts that do not touch the sludge/soil mixture, feed crops and fibre crops shall not be harvested for 90 days after application of sludge
4) Animal grazing	Animals shall not be grazed on the land for 90 days after application of sludge
5) Turf growing	Turf grown on land where sludge is applied shall not be harvested for 1 year after application of the sludge. This applies to lawns and land with high potential for public exposure.
6) Public Access	• Public access to land with a high potential for public exposure shall be restricted for 1 year after application of sludge • Public access to land with a low potential for public exposure shall be restricted for 90 days after application of sludge

3.2 Restrictions Based on Stability Classification

3.2.1 Stability Class 1

No restrictions or requirements apply. Sludge in this class can therefore be safely applied to any type of crop providing the Microbiological and Pollutant Classifications are acceptable for that application.

3.2.2 Stability Class 2

Odours and vector attraction are important aspects that affect public perception of sludge application to agricultural land. In addition to implementing a reliable vector attraction reduction (VAR) option, additional management systems may thus be required. VAR options are described in Appendix 3.

3.2.3 Stability Class 3

Not suitable for agricultural use. At least one VAR option needs to be successfully implemented before any land application can be considered.

3.3 Restrictions Based on Pollutant Classification

3.3.1 Pollutant Class a

No restrictions or requirements apply. Sludge in this class can therefore be safely applied to any type of crop providing the Microbiological and Stability Classifications are acceptable for that application.

3.3.2 Pollutant Class b

Sludge that is classified as Pollutant Class b can still be used for agricultural purposes, provided that it is shown that the receiving soil can accommodate the pollutant load. This is done by taking samples of the soil <u>before</u> application of sludge and determining the metal content using the *aqua regia* extraction method (ISO 11466: 1995(E)). These results must then be compared to the values in Table 8.

Table 8 - Metal Pollutant Concentrations in the soil <u>before</u> sludge application using *aqua regia* method

Metal Elements	Target Value (*aqua regia* method) mg/kg	Maximum Permissible Value (*aqua regia* method) mg/kg	Maximum Permissible Available Metal Content (NH_4NO_3 method) mg/kg
Arsenic (Ar)	2	2	0.014
Cadmium (Cd)	2	3	0.1
Chromium (Cr)	80	350	0.1
Copper (Cu)	100	120	1.2
Cyanide (Total CN^-)	< 5	100	N/A
Lead (Pb)	56	100	3.5
Mercury (Hg)	0.5	1	0.007
Nickel (Ni)	50	150	1.2
Zinc (Zn)	185	200	5.0

Note that the soil (before or after sludge application) must also meet the following requirements in terms of radioactivity parameters:

- Radioactivity (gross alpha activity) must be less than 0.5 Bq/L
- Radioactivity (gross beta activity) must be less than 0.5 Bq/L

The following scenarios resulting from the soil sample analysis are possible:

- If the analysis shows that the soil achieves the target values for all metal elements, as set out in Table 8, then Pollutant Class b sludge may be applied to this soil. The situation must be re-assessed after five (5) years.
- If the metal concentrations in the soil lie between the target value and the maximum permissible value (Table 8), then the available metal content of the soil shall be determined using the NH_4NO_3 extraction method (Appendix 5).
    - If the available metal content is less than the maximum permissible available metal content, then Pollutant Class b sludge may be applied to this soil. The situation must be re-assessed after two (2) years.
    - If the available metal content is more than the maximum permissible available metal content, then Pollutant Class b sludge may not be applied to this soil.
- If the available metal content exceeds the maximum permissible available metal content, then Pollutant Class b sludge may not be applied to this soil.
- If the soil samples exceed the maximum permissible values (Table 8), then Pollutant Class b sludge may not be applied to this soil.

3.3.3 Pollutant Class c

Not suitable for agricultural use. Source control should be implemented to reduce the metal content in the sludge.

3.4 General Restrictions and Requirements

Irrespective of the classification, general restrictions apply for the agricultural use of sludge.

3.4.1 Sludge Storage

Sludge that is not utilised immediately after production must be stored in adequate storage facilities that minimise the impact on the environment. Storage facilities must be designed to shield off wind, minimise odour production and vector attraction, and prevent leachate run-off.

3.4.2 Sludge Application Rates

Sludge should not be applied in excess of the agronomic rate for the specific crop type concerned. The agronomic rate is a measure of the nitrogen requirement of the plant. This rate should not be exceeded to prevent nitrogen from passing through the root zone of the crop and entering the groundwater. The nitrogen content of the sludge must be confirmed before each major planting season and the application rate determined according to the specific crop's agronomic rate. Note that only 30 to 50% of nitrogen becomes available after the first year of sludge application. However, the maximum application rate of 10 tons dry mass sludge per hectare per year may not be exceeded unless special permission is obtained from the Department of Water Affairs and Forestry (DWAF).

3.4.3 Buffer Zones for Groundwater and Surface Water

Areas to which sludge is applied for agricultural purposes must meet the following requirements:

- Distance to surface water or borehole > 500 m
- Depth to aquifer > 10 m

The above requirements can be relaxed by the DWAF for specific cases if it can be shown that groundwater and surface water is adequately protected.

3.4.4 Buffer Zones for Urban Areas and Settlements

Sludge is not to be applied to areas that lie within 500 m from inhabited dwellings, in order to protect the community against unpleasant odours and vectors. This requirement can be relaxed by the DWAF for specific cases if it can be shown that odour control and vector attraction reduction is successfully implemented.

3.4.5 Monitoring Programmes

3.4.5.1 Sludge Monitoring Programme

Sludge quality should be carefully monitored to ensure that informed decisions can be made regarding the safe application of such sludge. Physical and chemical properties, as well as microbiological quality need to be monitored by collecting and analysing at least three composite samples with a dry mass of at least 500 g for each sludge stream. The frequency of sampling depends on the sludge production rate of the plant, as set out in Table 9:

Table 9 - Sludge Sampling Frequency

Amount of sludge produced ($t_{\text{dry weight}}$)		Monitoring frequency
Daily average	**Yearly average**	
< 1	< 365	Every 12 months
1 - 5	365 - 1825	Every 3 months
5 - 45	1825 - 16500	Every 2 months
> 45	>16500	Every month

Sludge should be sampled at each of the process intervals, as set out in Table 10:

Table 10 - Sludge Sampling Locations

Sludge Processing Progress	Sampling Point
Anaerobically digested	Sampling valves on the discharge side of sludge pumps
Aerobically digested	Sampling valves on the discharge side of sludge pumps
Thickened	Sampling valves on the discharge side of pumps

Heat treated	Sampling valves on the discharge side of pumps after decanting
Dewatered, dried, composted	Collection conveyors or bulk containers
Dewatered by belt filter press, centrifuge	Discharge chute
Dewatered in drying beds	Divide bed into quarters, sample from each quarter and combine samples
Compost piles	Product

3.4.5.2 Soil Monitoring Programme

As mentioned in section 3.3.2, soil to which Pollutant Class b sludge is to be applied needs to be sampled in order to monitor whether the soil can continue receiving such sludge. The sampling and testing procedure is described in section 3.3.2.

In addition, the nutrient requirements for the particular crop to be grown are to be determined before each planting season in order to ensure that the sludge application does not exceed the agronomic rates. Samples should consist of mixed samples from various regions of the application area and contain at least 1 kg dry mass.

3.4.5.3 Record Keeping

When the permits and licenses for sludge production and usage have been granted it is up to the producer and the user to keep certain sludge records, irrespective of the class of sludge. These records need to be accessible by DWAF at all times. It is the responsibility of the producer to obtain data from the user, as per their contract, where applicable (Appendix 1). The following records need to be kept:

1) Mass, solids content and volume of each sludge stream produced as well as supporting wastewater treatment plant mass balance;
2) Detailed description of sludge management process;
3) Classification of each sludge stream that leaves the plant;
4) Results supporting initial classification in terms of the:
    a. Microbiological class
    b. Stability class
    c. Pollution class
5) The original or certified copy of the contract between the sludge producer and user (if applicable);
6) Copies of applicable permits and licenses;
7) Monitoring data pertaining to the:
    a. Microbiological class
    b. Stability class
    c. Pollution class
8) It is recognised that plants will experience problems from time to time. Document any operational problems that could affect the sludge management by detailing:
    a. Nature of the problem

   b. Duration of the problem
   c. What was done with off-spec sludge
   d. How the problem was rectified
9) Complaints register (includes complaints by users, the public or other interested and affected parties):
   a. Date, time of complaint
   b. Nature of complaint
   c. Description of actions taken to address the complaint
10) Monitoring data pertaining to the:
   a. Nutrient status of the soil
   b. Metal content of the soil (total and/or NH_4NO_3 extractable)

4 DISPOSAL OF SLUDGE

In this section, disposal of sludge at different waste treatment facilities is discussed. It should be noted that this section only serves an informative purpose. Where sludge is to be disposed of, all applicable local laws and regulations regarding solid waste management should be adhered to.

In cases where sludge cannot be used beneficially and all reasonable alternatives have been exhausted, incineration and/or disposal to a hazardous waste site can be considered. Sludge disposal options include the following:

- **Mono-fill**: Landfill where only sludge is disposed of, usually in the form of dewatered sludge deposited in depressions in the land or on the land surface in a regulated manner with containment of the contents.
- **Waste piles**: Final disposal of dewatered sludge in the form of stockpiles or mounds without daily or final cover. These are on-site disposal options and can be lined or unlined facilities.
- **Lagoon:** Disposal site where sludge with a high water content is placed in an open excavated area. These facilities should be lined with an appropriate leachate collection system.
- **Dedicated land disposal (DLD):** Disposal site at which sludge is applied to the surface of the land on a routine basis but where the objective is sludge disposal and not sludge utilisation as in land application for agricultural purposes.

It should be noted that where any of the above sludge disposal options are to be used, all requirements contained in the guideline for “Disposal of Solid Waste by Landfill” need to be adhered to.

4.1 General Restrictions

4.1.1 Site Selection

It is generally preferable to establish the disposal site as close as possible to the generation site as to minimise transport costs. It is recognised that existing sludge disposal sites were not necessarily placed in the most suitable areas for waste disposal. A review of such sites is recommended to ensure that:

- The sludge disposal site is not situated in a sensitive area where disposal is not permitted (see section 4.1.2);
- The sludge disposal site is distinctly separated from the treated wastewater disposal site, to prevent possible contamination of the treated water;

For new disposal sites an Environmental Impact Assessment (EIA) is to be performed to ensure that the site is suitable for sludge disposal. As part of the EIA an initial site investigation needs to be performed to assess the impact of the disposal practices over time. This investigation needs to include (as a minimum):

- **Topography:** The slope of the disposal site should be considered to minimise run-off, erosion and ponding. The site should not be within the 1:100 year flood line.
- **Soil properties:** Soil with clay content <50% needs to be lined if it is to be used as a sludge disposal site. The soil pH should be higher than 6.5 at all times to ensure that metals do not leach through the soil profile.
- **Surface water:** Where surface water resource is a possibility, background water quality sampling is required to determine the baseline values which can be used for comparative purposes in the future. If contamination is expected, water samples should be taken and compared to these baseline values as well as to relevant standards.
- **Groundwater:** Sludge disposal will not be permitted within 500 m of the recharge zone of major aquifers, sole-source aquifers or other strategic aquifers. In addition, the hydraulic gradient of the area surrounding a sludge disposal site should be determined to assess the most suitable positions for monitoring boreholes, which must be used to obtain water samples up gradient and down gradient from the sites. As with surface water, baseline values need to be determined for groundwater quality and compared to values obtained after operation of the sludge disposal site to determine possible contamination and non-compliance with relevant standards. Only a suitably qualified specialist should confirm cases where groundwater contamination is unlikely, due to depth of water table or other circumstances.

4.1.2 Prohibited Areas

Areas where the disposal of sludge is not permitted are as follows:

- Areas within the 1:100 year flood line including wetlands, vleis, pans and flood plains, so that water contamination is minimised;
- Unstable areas where sinkholes and subsidence are likely including fault zones, seismic zones and dolomitic or karst areas;
- Areas with steep gradients where slope stability, soil erosion and leachate run-off could be a problem;
- Areas where groundwater is recharged and the topography or soil permeability could lead to groundwater pollution;
- Areas immediately upwind of residential areas in the prevailing wind direction;
- Areas that form part of the natural habitat of endangered plant and/or animal species;

4.1.2 Buffer Zones

The following buffer zones must be adhered to when establishing sludge disposal sites:

- Depth to aquifer:
    - Dewatered sludge application must be >10 m (mono-fills, waste piles and dewatered designated land disposal)
    - Liquid sludge application must be >15 m (lagoons and liquid designated land disposal)
- Distance from surface water or borehole water must be >500 m

The above requirements can be relaxed by the DWAF for specific cases if it can be shown that groundwater and surface water is adequately protected.

4.2 Management of Sludge Disposal

Where sludge disposal is done on land disposal sites, stringent management and monitoring practices need to be adhered to in order to ensure that safety and environmental concerns are properly addressed. Records of any data collected by sludge producers and users should be kept, irrespective of the nature of the data, so that proper analyses of the sludge disposal process can be made.

4.2.1 Vector Attraction Reduction (VAR)

One of the VAR options described in Appendix 2 must be performed to minimise vector attraction and odour production.

4.2.2 Sludge Solids Content

To ensure sludge pile stability, sludge should be dewatered to at least 20% solids before it can be disposed of on mono-fill, waste piles or landfill facilities.

4.2.3 Run-off and Leachate Collection

Run-off is rainwater that drains over the land and runs off the land surface, while leachate is liquid originating from excess moisture in the sludge or rainwater percolating through the disposal site. Run-off needs to be collected and disposed off according to the license agreement. Leachate needs to be collected to prevent possible contamination of surface water and groundwater. If the disposal site has a liner and a leachate collection system, such a system must be properly maintained and inspected on a regular basis. Collected leachate should be recycled back to the wastewater treatment plant or alternative appropriate treatment system.

4.2.4 Surface Water Protection

Surface water resources near the disposal site need to be protected by contamination of sludge disposed at the site. This can be achieved by:

- Constructing bunded walls or trenches down-gradient from the disposal site to intercept and collect run-off;
- Planting non-edible plants with a high water demand between the water resource and the disposal site to intercept run-off;

- Increasing the distance between the disposal site and the water resource so that run-off cannot reach the resource;

4.2.5 Groundwater Protection

Chemicals present in the sludge could leach through the soil profile and cause contamination of aquifers. The groundwater must therefore be tested for nitrate contamination at regular intervals (at least every 3 years). The maximum permissible level of NO_3-N in the groundwater is 10 mg/l. For example, if the initial background concentration of NO_3-N in the water exceeds 20 mg/l, specialist studies should be conducted to determine whether sludge disposal will further contaminate the groundwater.

4.2.6 Liner Requirements

A liner is an impermeable layer placed beneath a land disposal site to contain and collect leachate. It may comprise natural, building or synthetic materials, or a combination thereof. Sites with soil clay content <50% and sites receiving Pollutant Class c sludge must be handled as per solid waste handling procedure.

4.2.7 Soil Quality

Action trigger values and maximum values for metal content in the soil of unlined facilities have been set to ensure that the soil does not degrade to such an extent that major intervention is required to restore the soil functionality. Once an action trigger value has been exceeded, the producer should be aware that the capacity of the soil to receive sludge is reaching its limit and that additional management requirements need to be implemented. Such management requirements could include additional liming to ensure immobility of metals in the soil profile and/or source control to improve sludge quality.

Table 11 - Boundary Metal Concentrations in Soil

Element	Action Trigger Value (mg/kg)	Maximum Value (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

It should again that both the alpha and beta gross radioactivity should be less than 0.5 Bq/L.

4.2.8 Methane Gas

Methane is an odourless and highly combustible gas generated at disposal sites when sludge is covered by soil or other material. At these sites air quality must be continuously monitored for methane gas and must meet the limits on the concentration of methane in the air as presented in Table 12.

Table 12 - Methane Gas Requirements

	Methane Level	Mitigation Required
Inside buildings	0.1% - 1% in air (2% - 20% of LEL)	Regular monitoring must be implemented
	>1% in air (20% of LEL)	Building must be evacuated and trained personnel consulted
Disposal site property boundary	0.5% - 5% in air (10% of LEL)	Regular monitoring of the boundary must be implemented
	>5% in air (at LEL)	Monitoring should be initiated and an investigation to determine lateral mitigation
LEL = Lower Explosive Limit - the lowest % (by volume) of methane gas in air that supports a flame at 25°C and atmospheric pressure		

4.2.9 Crop Production and Animal Grazing

No edible crops may be grown on sludge disposal sites unless the owner/operator can prove to the permitting authority that the crops are protected from adverse effects of pathogens and pollutants present in the sludge. Grazing animals are also not allowed at disposal sites unless it can be proven that the public health, health of the animals and the environment is protected and not adversely affected by the sludge.

4.2.10 Public Access

Public access must be restricted by at least a 2,2 m high diamond mesh fence with barbed wire on top, at all disposal sites while the site is in operation and 3 years after closure. Large, clear warning notices indicating that the area is a disposal site and off-limits to the public, must be mounted on the fence. This management practice minimises public contact with pollutants, including pathogens that may be present in the sludge.

4.3 Monitoring of Sludge Disposal

4.3.1 Sludge Monitoring

Sludge monitoring is recommended to determine whether sludge quality has increased or decreased with time. The sludge monitoring process was described in section 3.4.5.1.

4.3.2 Groundwater Monitoring & Sampling

As mentioned in section 4.1.1, groundwater needs to be sampled regularly and the results of the analyses compared to previously obtained background values in order to detect any significant changes or trends. The following table can be used as a guideline for groundwater monitoring.

Table 13 - Groundwater Monitoring Requirements

What should be monitored?	• pH, electrical conductivity, PO_4, NH_4, NO_3, COD • Faecal coliforms and/or *E-coli* depending on sludge quality

How often should samples be taken?	**Groundwater**	**Surface Water**
	• Mono-fills, waste piles and lagoons: Table 14 • Dedicated Land Disposal: Table 15	Monthly, 20-50 m upstream and downstream of disposal site
What sampling equipment should be used?	Plastic bottles with a plastic cap and no liner within the cap are required for most sampling procedures. Glass bottles are required if organic constituents are to be tested.	
How should samples be taken?	See Appendix 3	
How should samples be preserved?	**pH, EC, PO_4 analyses**	**NH_4, NO_3, COD analyses**
	No additives, refrigerate and analyse as soon as possible	Add H_2SO_4 to pH<2
How many samples should be taken?	At least 2 samples from each water course, 1 sample for pH, EC and PO_4 analyses and 1 sample for NH_4, NO_3 and COD analyses	
Sample sizes?	At least 1000 ml per sample	

4.3.3 Soil Monitoring

For sludge disposal, soil monitoring is extremely important. Soil needs to sampled and analysed regularly to determine that the receiving soil is capable of receiving more sludge without causing possible health and safety risks. The soil sampling procedure is described in detail in Appendix 4.

4.3.4 Monitoring Frequency

4.3.4.1 Mono-fills, waste piles and lagoons

Table 14 - Monitoring Frequency for Mono-fills, Waste Piles and Lagoons

	Mono-fill		**Waste pile**		**Lagoon**	
	L	**U**	**L**	**U**	**L**	**U**
Groundwater chemistry	y	6m/3m*	y	6m/3m*	6m	3m/3m*
Groundwater microbiology	NA	6m#/3m##	NA	6m#/3m##	NA	6m#/3m##
Surface water quality	m	m	m	m	m	m
Soil quality	NA	y/6m**	NA	y/6m**	NA	6m/3m**

Legend:

L = lined; U = unlined; NA = not applicable; y = yearly; m = monthly; 3m = quarterly; 6m = bi-annually

* For existing disposal sites where the water table is <5 m and lagoons where the water table is <10 m below the surface

** For existing sites with soil pH <6.5 and/or clay content <20%

Microbiological Class B

Microbiological Class C

4.3.4.2 DLD Sites

Table 15 - Monitoring Frequency for DLD Sites

	Dewatered Sludge	Liquid Sludge
Groundwater chemistry	6m/3m*	3m/3m*
Groundwater microbiology	6m#/3m##	6m#/3m##
Surface water quality	m	m
Soil quality	y/6m**	6m/3m**

Legend:

y = yearly; m = monthly; 3m = 3-monthly; 6m = 6-monthly

* For existing disposal sites where the water table is <5 m (dewatered) and <15 m (liquid) below the surface

** For existing sites with soil pH <6.5 and/or clay content <50%

Microbiological Class B

Microbiological Class C

SECTION B: DISPOSAL OF WATER TREATMENT SOLIDS

5 LAND APPLICATION OF WTR

As with sewage sludge (section 3), the use of water treatment residue (WTR) produced during potable water treatment can be used for agricultural purposes. However, such use must be strictly controlled to ensure the health and safety of both the producers and the consumers of agricultural products to which WTR is applied, in addition to ensuring that the environment is not adversely affected. Where WTR is to be disposed of by land filling, the same requirements as for disposal of sewage sludge apply (section 4).

The properties of WTR are influenced by the quality of the raw water that was treated as well as the coagulants used in the water treatment process. Therefore, three different types of WTRs are considered in this text:

1) Alum residue (resulting from aluminium sulfate use for coagulation)
2) Ferric residue (resulting from ferric chloride use for coagulation)
3) Lime residue (resulting from lime use for coagulation or softening)

It should be noted that for WTR usage, all the requirements for sewage sludge described in sections 2, 3 and 4 must also be adhered to. Thus, if WTR adheres to all the requirements in section 5 but fails to adhere to any of the requirements in section 2, 3 and 4, additional management or treatment options need to be considered before the WTR may be used for land application. Organic sludges from polyelectrolytes should be handled as per section A.

5.1 General Restrictions and Requirements

The following restrictions must be adhered to, regardless of the type of WTR that is to be applied.

- The WTR must not cause contamination of groundwater or surface water. Therefore, the buffer zones for groundwater and surface water protection described in section 3.4.3 must be adhered to. These buffer zone requirements can be relaxed if it can be proven by a suitably qualified specialist that the groundwater or surface water is not adversely affected by the WTR application. Groundwater and surface water quality monitoring (as described in section 4.3.2) will have to be performed to ensure this.
- The WTR must not be a hazardous waste;
- The WTR must not create a public nuisance, dust emissions or objectionable odours;

5.2 Restrictions for Land Application of Lime WTR

Lime WTR is not expected to have an adverse impact on public health or the environment and can thus be used for land application without additional restrictions. It should be noted, however, that the maximum WTR application rate should not exceed 10 tons per hectare per year, which is the same restriction applicable to sewage sludge (section 3.4.2). These are repeated here for convenience:

Areas to which sludge is applied for agricultural purposes must meet the following requirements:

- Distance to surface water or borehole > 500 m
- Depth to aquifer > 10 m

The above requirements can be relaxed by the DWAF for specific cases if it can be shown that groundwater and surface water is adequately protected.

In addition, the general restriction for WTR application (section 5.1) must be adhered to.

5.3 Restrictions for Land Application of Alum WTR

When alum sludge is used for land application, the concentrations of certain elements need to be carefully monitored, in order to ensure that there is no threat to public health or the environment. The elements of concern for alum WTR are aluminium, arsenic, barium, lead and manganese. Table 16 shows the maximum permissible element concentrations of the soil, after application of alum WTR.

Table 16 - Alum WTR Restrictions

Element	Maximum Permissible Concentration (mg/kg)
Aluminium (Al)	80 000
Arsenic (As)	20
Barium (Ba)	120
Lead (Pb)	150
Manganese (Mn)	3 500

The values given in Table 16 are the maximum permissible concentrations. If regular sampling and analysing shows an increasing trend in one or more of the elements of concern (even if still below the maximum), management procedures should be implemented well before the maximum concentrations are reached. The generator of alum WTR must keep the results of the laboratory analyses for a minimum of three years and make them available to the DWAF upon request.

5.4 Restrictions for Land Application of Ferric WTR

When ferric sludge is used for land application, the concentrations of certain elements need to be carefully monitored, in order to ensure that there is no threat to public health or the environment. The elements of concern for ferric WTR are aluminium, arsenic, copper, iron and manganese. Table 17 shows the maximum permissible element concentrations of the soil, after application of ferric WTR.

Table 17 - Ferric WTR Restrictions

Element	Maximum Permissible Concentration (mg/kg)
Aluminium (Al)	80 000
Arsenic (As)	20
Copper (Cu)	375
Iron (Fe)	53 000
Manganese (Mn)	3 500

The values given in Table 17 are the maximum permissible concentrations. If regular sampling and analysing shows an increasing trend in one or more of the elements of concern (even if still below the maximum), management procedures should be implemented well before the maximum concentrations are reached. The generator of ferric WTR must keep the results of the laboratory analyses for a minimum of three years and make them available to the DWAF upon request.

6 DISPOSAL OF BRINE

Brine is a very saline concentrate stream produced as a by-product of a reverse osmosis treatment process. This concentrated solution must be disposed of and is generally discharged into the ocean or evaporated in evaporation ponds leaving only the solid matter contained in the original brine. All requirements as per the Sea Fisheries Act need to be adhered to, regarding such discharge of brine.

Brine can only be discharged into the ocean after a full Environmental Impact Assessment (EIA) has been made by an independent marine specialist. Brine will have to be sufficiently dispersed over large areas by taking current patterns into account so that marine fauna and flora are not adversely affected. In cases where the EIA suggests that brine discharge into the ocean will have negative environmental impacts, such discharge will not be permitted. The brine will then have to be evaporated, as described below.

Brine can also be discharged into evaporation ponds, so that the water content in the brine can evaporate to leave only the solid matter removed during reverse osmosis. These ponds need to have a water-proof lining, so that brine cannot contaminate ground water supplies.

Once all of the water in a pond has been evaporated, the remaining solid matter needs to be treated at a municipal solid waste handling facility in accordance with applicable local laws and regulations.

REFERENCES

DIN [Deutsches Institut für Normung Hrsg.] 19730 (1997-06): *Extraction of trace elements in soils using ammonium nitrate solution* — Beuth Verlag, E DIN 19730: Berlin.

Department of Water Affairs and Forestry (South Africa): Guidelines for the Utilisation and Disposal of Wastewater Sludge: Vol 1: Selection of Management Options, March 2006.

Department of Water Affairs and Forestry (South Africa): Guidelines for the Utilisation and Disposal of Wastewater Sludge: Vol 2: Requirements for the agricultural use of sludge, March 2006.

Department of Water Affairs and Forestry (South Africa): Guidelines for the Utilisation and Disposal of Wastewater Sludge: Vol 3: Requirements for the on-site and off-site disposal of sludge of wastewater sludge, June 2009.

Department of Water Affairs and Forestry (South Africa): Guidelines for the Utilisation and Disposal of Wastewater Sludge: Vol 4: Requirements for the beneficial use of sludge at high loading rates, June 2009.

Department of Water Affairs and Forestry (South Africa): Guidelines for the Utilisation and Disposal of Wastewater Sludge: Vol 5: Requirements for thermal sludge management practices and for commercial products containing sludge, June 2009.

U.S. EPA, Office of Wastewater Enforcement and Compliance: *Land Application of Sewage Sludge: A guide for Land Appliers on the Record Keeping and Reporting Requirements of the Federal Standards for the Use or Disposal of Sewage Sludge, 40 CFR Part 503.* EPA/530/SW-91-010. December 1990.

U.S. EPA, Office of Wastewater Enforcement and Compliance: *Preparing Sewage Sludge for Land Application or Surface Disposal - A Guide for Preparers of Sewage Sludge on the Monitoring, Record Keeping, and Reporting Requirements of the Federal Standards for the Use or Disposal of Sewage Sludge, 40 CFR Part 503.* EPA/813-B-93-002a. September 1993.

ISO 11466: 1995(E). *Soil quality: extraction of trace elements soluble in aqua.*

Acts:

Sea Fisheries Act, 1992 (Act 29 of 1992) or subsequent revision

APPENDIX 1: ESSENTIAL CONDITIONS FOR A CONTRACTUAL AGREEMENT

The following essential conditions should be included in a contractual agreement between sludge producer and agricultural sludge user.

Producer:

1) Name and address
2) Classification of sludge
3) Quality
    a. Hygienic stability and micro-organisms
    b. Moisture content
    c. Nitrogen, phosphate and potassium content
    d. Maximum metal and inorganic content
4) Limiting metal and maximum application rate in t_{dry}/ha/year
5) Recommended maximum application rate in t/ha/yr in terms of nitrogen demand of crop
6) Notification of local authorities involved

User:

1) Name and address
2) Name of transporter of sludge
3) Name of farm or site where sludge will be stored and used
4) Size of sludge application area
5) Crops to be fertilised or alternative use
6) Previous sludge application - annual rate an frequency
7) Metal and inorganic content of soil. Soil to be analysed before commencing sludge application and monitored as described in this document
8) Details of sludge processing, addition of other materials or chemicals and quality of final product, if product is sold
9) Amount of sludge to be applied

Agreement:

1) Sludge to be used as described in this document
2) Inspection of user's activities by any appropriate local authority
3) Breach of contract - termination of sludge supply and punitive measures

APPENDIX 2: VECTOR ATTRACTION REDUCTION (VAR) OPTIONS

Vectors, which include flies, mosquitoes, fleas and birds, can transmit pathogens from sludge to human, animal or plant hosts. Such transmission of pathogens can pose a serious disease risk, either by direct transmission to humans or through indirect contamination of plant and animals consumed by humans. Reducing the attractiveness of sludge to vectors reduces the potential for transmitting diseases from pathogens in sludge. Any one of the following options can be used to successfully achieve VAR.

Option 1: Reduction in Volatile Solids Content

This option entails the reduction of the mass of volatile solids in the sludge by at least 38 percent during the treatment of the sludge. This percentage is the amount of solids reduction attained by anaerobic and aerobic digestion in addition to any additional volatile solids reduction that occurs before the sludge leaves the treatment plant. Such processing can occur in drying beds, lagoons or by composting. The volatile solids content of the feed sludge and the digested sludge can be measured to determine the percentage reduction.

Option 2: Additional Digestion of Anaerobically Digested Sludge

Sludge that is recycled through the biological wastewater treatment section of a plant for long periods of time are often biologically degraded by the time they finally exit the treatment plant. If subsequent anaerobic digestion of sludge occurs, the attraction of vectors to this sludge may have already been sufficiently reduced. However, in such cases the achievable reduction in volatile solids after treatment is frequently less than 38 percent.

Under such circumstances vector attraction reduction can be demonstrated by anaerobically digesting recycled sludge for an additional 40 days at a temperature between 30°C - 37°C in a bench-scale unit in a laboratory. If after such time the volatile solids in the sludge are reduced by less than 17 percent, then vector attraction reduction of sludge will have inherently occurred during the wastewater treatment process.

Option 3: Additional Digestion of Aerobically Digested Sludge

Similar to Option 2, the 38 percent volatile solids reduction required by section Option 1 can often not be achieved for sludge from extended aeration plants, where the minimum residence time of sludge usually exceeds 20 days. Sludge will thus have been biologically degraded during the treatment process, resulting in inherent vector attraction reduction.

To demonstrate effective vector attraction reduction, aerobically digested sludge with 2 percent or less solids shall be aerobically digested in a laboratory for an additional 30 days at 20°C. If volatile solids are reduced by less than 15 percent, vector attraction reduction will have inherently occurred during the water treatment process. Note that this test is only applicable to liquid aerobic sludge withdrawn from an aerobic process.

Option 4: SOUR for Aerobically Digested Sludge

For the same condition as mentioned in Option 3, another test can be performed to demonstrate whether vector attraction reduction has taken place during water treatment. 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. If, at 20°C, the SOUR of the sludge produced by extended aeration processes is equal to or less than 2 mg of oxygen per hour per gram of sludge (dry weight basis), then vector attraction reduction will have inherently occurred during the water treatment process. Note that this test is only applicable to liquid aerobic sludge withdrawn from an aerobic process.

Option 5: Aerobic Processes at Greater Than 40°C

As an alternative to the vector attraction reduction Options 3 and 4, sludge can be treated anaerobically for 14 days or longer at an average temperature of 45°C, with a minimum of 40°C. This option applies primarily to composted sludge that contains partially decomposed organic bulking agents.

Option 6: Addition of Alkaline Material

In order to ensure satisfactory reduction in vector attraction, alkaline material can be added to the sludge. Both of the following conditions need to be achieved:

- pH raised to at least 12 (at 25°C) and maintained above 12 for 2 hours, without addition of more alkaline material;
- pH of at least 11.5 maintained for an additional 22 hours, without addition of more alkaline material;

The above conditions need to be achieved to ensure that the sludge can be stored, transported and used without the pH decreasing to the point where vectors are attracted due to putrefaction.

Option 7: Moisture Reduction of Sludge Not Containing Unstabilised Solids

Under this option, vector attraction is considered to be reduced if both of the following two requirements are met:

- Sludge does not contain any unstabilised solids generated during primary treatment;
- Solids content of the sludge is at least 75%. The solids content of the sludge should be increased by removal of water and not by dilution with inert solids;

It is important that the sludge does not contain unstabilised solids since partially degraded food scraps likely to be present in such sludge would attract vectors even if the solids content of the sludge exceeded 75%.

Option 8: Moisture Reduction of Sludge Containing Unstabilised Solids

Under this option, the ability of any sludge to attract vectors is considered adequately reduced if the solids content of the sludge is increased to 90% or greater. The solids content of the sludge should be increased by removal of water and not by dilution with inert solids. Drying to this extent severely limits biological activity and decomposes volatile compounds that attract vectors.

Sludge that is stored or handled incorrectly after successful drying can again become attractive to vectors. If dried sludge is exposed to high humidity, the outer surface of the sludge will have increased moisture content and thus possibly attract vectors. Storage and handling should be performed in such a way as to prevent this.

Option 9: Sludge Injection

Under this option, liquid sludge is injected into the soil below the ground surface to achieve vector attraction reduction. To be successful, no significant amount of sludge can be present on the land surface within one hour of injection. If liquid sludge of Microbiological Class A or B is injected, it must be injected within 8 hours after discharge from a pathogen reducing process. If a vector attraction reduction process such as dewatering or drying is performed before sludge is injected, the 8 hour time constraint is not applicable.

Option 10: Incorporation of Sludge into the Soil

Under this option, dry sludge must be incorporated into the soil within 6 hours of application to the land, by means ploughing or some other form of mixing. As mentioned in Option 9 above, if liquid sludge is applied, it must be applied within 8 hours after discharge from a pathogen reducing process.

In cases where it is not possible to incorporate the sludge into the soil within 6 hours due to machinery failure or other unforeseen circumstances, the resultant vector attraction and odour production must be carefully monitored and managed.

APPENDIX 3: WATER SAMPLING

Equipment needed

- Equipment to collect microbiological samples
  - Sterile sample bottles (see Table 13 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 13 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.
  - Rinse sample bottle three times with the water to be sampled.
  - 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 to keep cooled container dust-free.

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 14) 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 15).
- Filter and preserve the sample (if applicable, see Table 15) 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.

APPENDIX 4: SOIL SAMPLING

Equipment needed

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

Number of samples

For mono-fills, waste piles and lagoons at least 4 composite samples of each disposal area at each depth will be required. For DLD sites the number of samples will vary according to the size of the disposal site and different soil types present at the disposal site. At least three composite samples for each depth increment for every hectare of the DLD 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 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 gathering of composite samples is complete, place the sample into appropriate, labelled containers and secure the caps tightly.
5) Preserve the samples as recommended in Table 18 and submit to an accredited laboratory.

Table 18 - Sample Preservation

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

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 composite sample is complete, place the sample into appropriate, labelled containers and secure the caps tightly.

5) Preserve the samples as recommended in Table 18 and submit to an accredited laboratory.

APPENDIX 5: AMMONIUM NITRATE EXTRACTION METHOD

This method can be used to determine the NH_4NO_3 extractable (available metal content of soil samples.

Place 20 g air dry soil in a shaking bottle (100-150 ml), add exactly 50 ml ammonium nitrate solution (1 mol/l) and shake for 2 hours at 20 rpm at room temperature. Then allow the solid particles to settle for 15 min. Decant the supernatant solution and filter (0,45 µm). Dispose the first 5 ml of the filtrate. Collect the remaining solution in a 50 ml bottle for analysis.

Minimum concentrations which have to be quantified accurately with the Ammonium Nitrate extraction method (DIN 19730) for good results in the field of soil protection:

Table 19 - Minimum Concentrations for Ammonium Nitrate Extraction Method

Element	1 mol/l Ammonium Nitrate Solution (µg/l)	Ammonium Nitrate extractable in the air (for dry soil) (µg/kg)
Ag (Silver)	<0.4	<1
As (Arsenic)	10	25
Be (Beryllium)	1	2.5
Bi (Bismuth)	<0.4	<1
Cd (Cadmium)	2	5
Co (Cobalt)	20	50
Cr (Chromium)	4	10
Cu (Copper)	100	250
Hg (Mercury)	<0.4	<1
Mn (Manganese)	2000	5000
Mo (Molybdenum)	10	25
Ni (Nickel)	100	250
Pb (Lead)	<8	<20
Sb (Antimony)	10	25
Tl (Thallium)	4	10
U (Uranium)	1	2.5
V (Vanadium)	10	25
Zn (Zinc)	100	250

Reference: DIN [Deutsches Institut für Normung Hrsg.] 19730 (1997-06): Extraction of trace elements in soils using ammonium nitrate solution — Beuth Verlag, E DIN 19730: Berlin.