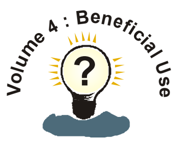
SLUDGE GUIDELINE VOLUMES

These Guidelines were developed to encourage the implementation of beneficial use of sludge. Rather than attempting to develop a single guideline to address all the management options, separate Guideline Volumes deal with each of the possible management options. This also simplifies the document(s) for the users, as each Guideline Volume is dedicated to the management, technical and legislative aspects associated with a particular option, as well as the sludge characterisation requirements for that option.

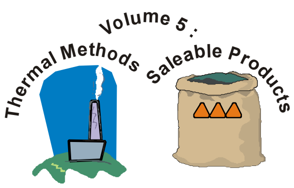
Volume 1: Selection of management options

Volume 2: Requirements for the agricultural use of sludge

Volume 3: Requirements for the on-site and off-site disposal of sludge



Volume 4: Requirements for the beneficial use of sludge



Volume 5: Requirements for thermal sludge management practices and for commercial products containing sludge

THESE VOLUMES ARE AVAILABLE FROM:

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Guidelines for the Utilisation and Disposal of Wastewater Sludge

Volume 1: Selection of Management options

Prepared for the
Water Research Commission
by

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WRC Report No. TT 261/06

March 2006

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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

Most of the South African laws and regulations pertaining to environmental, waste and water have either been replaced or updated in the last decade. These Sludge Guidelines have been developed taking the updated regulatory framework into consideration, as well as international trends and local knowledge gathered over the last 5 years. For example, these Guidelines adopt the principle of sustainability by offering different options for sludge handling. The agricultural use of sludge is presented as the preferred management option. However, it is recognised that not all the sludge generated in South Africa can be used in agricultural practices. For this reason, guidelines have also been developed for other management options such as disposal in landfill facility.

The Guidelines are now aligned with international best practice with the introduction of a new sludge classification system. At the same time, local contributions, including research findings from the Water Research Commission (WRC) were used to develop guidelines that suit South African environmental and socio-economic challenges.

The Guidelines were developed so that regulatory authorities, managers, practitioners and operators responsible for sludge management can easily understand them. At the same time, in the interest of transparency, the scientific basis, assumptions, thought processes and the extensive consultation process were also documented as separate documents that are available from the 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 Senior Manager: Resource Protection and Waste, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001.

Ms Buyelwa Patience Sonjica (MP)

MINISTER OF WATER AFFAIRS AND FORESTRY

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"PERMISSIBLE UTILISATION AND DISPOSAL OF SEWAGE SLUDGE, EDITION 2"

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The financing of the project by the Water Research Commission and the contribution of the members of the Reference Group are gratefully acknowledged.

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INTRODUCTION

PURPOSE OF THE SLUDGE GUIDELINES

These Guidelines deal with the requirements of different options for managing sludge.

The purpose of the Guideline Volumes is to assist the reader to:

- Select appropriate management options for the specific sludge streams under consideration;
- Implement the requirements pertaining to the specific management option(s) selected. These include the operational and legal requirements; and,
- Implement the monitoring requirements for the selected option(s).

Definition: Wastewater sludge

The term "wastewater sludge" (hereafter referred to as "sludge") refers to the material removed from wastewater treatment plants designed to treat predominately domestic wastewater and includes the following products:

- Raw or primary sludge from a primary clarifier
- Primary sludge from an elutriation process
- Anaerobically digested sludge, both heated and cold digestion
- Oxidation pond sludge
- Septic tank sludge and other sludge from on-site sanitation units
- Surplus or waste activated sludge
- Humus sludge
- Pasteurised sludge
- Heat-treated sludge
- Lime-stabilised sludge
- Composted sludge

Note that these guidelines can also be applied for the management of sludges from biological treatment plants designed to treat high COD effluents from industrial operations.

These Guidelines **do not** apply to:

- Screenings and grit removed in the preliminary treatment processes of wastewater treatment plants
- Solids removed from on-site sanitation systems which are mixed or blended with domestic refuse and solid waste
- Inorganic sludge produced by potable water treatment plants
- Inorganic brine and sludge produced by the treatment of industrial effluents or mine water
- Sludge and solids removed from a treatment plant that treats hazardous waste and effluents

WHO SHOULD USE THESE GUIDELINES?

These Guidelines were developed to ensure the safe use and disposal of sludge. Any person who effectively applies the Guidelines will comply with environmental, social and regulatory requirements. The Guidelines were developed for:

- **Wastewater treatment plant operators** – to understand the requirements for managing sludge generated at the plant.
- **Wastewater treatment service providers** – to implement and manage an appropriate sludge management strategy.
- **Local authorities and town/city councils that own and operate wastewater treatment plants** – to understand what is required to effectively operate and monitor a selected sludge management strategy.
- **Wastewater plant planners** – to design a scheme that complies with the requirements stipulated in the Guidelines, while understanding the long term operational and maintenance requirements.
- **Wastewater engineers/scientists** – to serve as baseline for the development of improved treatment methods, disposal options and monitoring protocols that will assist the water industry to improve.
- **Regulatory authorities** – to assess compliance in applicable cases.
- **Educators** – to use as training material to build capacity.

OVERVIEW OF VOLUME 1:

SELECTION OF MANAGEMENT OPTIONS

This section gives an overview of the structure and content of Volume 1 of the Sludge Guidelines and its linkage to the other volumes that comprise the Guidelines.

Volume 1: Selection of Management options

Part 1

Background
Approach followed
Motivation

Part 2

Structure of the Sludge Guidelines
Provides a quick overview of what is contained in each volume (1 - 5)

Part 3

Good sludge management practices
This section contains notes and guidance on :
- Sludge types and stability
- Best management practices

Part 4

Legal framework for Sludge use and Disposal
Use this section to familiarise yourself with the relevant sections of the National Water Act and related environmental legislation

Part 5

Comprehensive characterisation of sludge
Use this section to ensure that appropriate sampling and analysis is done to gather sufficient information to do a preliminary classification

Part 6

Determine a Preliminary classification of sludge
Use the results obtained in Part 5 to do a preliminary classification of the sludge.
Assign a - Microbiological class;
- Stability class; and
- Pollutant class

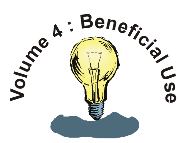
Part 7

Selecting an appropriate management option
Determine which management options are appropriate for a specific sludge.

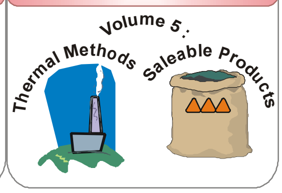
VOLUME 2

VOLUME 3

VOLUME 4



VOLUME 5



PART 1:

BACKGROUND

PREVIOUS GUIDELINES

These Guidelines replace the following documents:

- Water Research Commission. 1997. Permissible Utilisation and Disposal of Sewage Sludge. 1st ed. WRC, Pretoria TT85/97. ISBN 1-86845-281-6.

- Water Research Commission. 2002. Addendum 1 to Edition 1 (1997) of Guide: Permissible Utilisation and Disposal of Sewage Sludge. WRC, Pretoria TT154/02. ISBN 1-86845-798-2.

Note that previous versions of South African Sludge Guidelines such as the ones published by the Department of Health in 1991[1] and contained in the Water Institute of Southern Africa's publication on sewage sludge utilisation and disposal[2] are also replaced by these guidelines.

THESE GUIDELINES LOOK SUBSTANTIALLY DIFFERENT FROM THE PREVIOUS SLUDGE GUIDELINES. WHY IS THIS?

There are several reasons why the previous guidelines had to be updated, the main reason being the significant change in the regulatory environment during the last decade. Most of the South African laws and regulation documents pertaining to the environment, waste and water have either been replaced or updated in the last decade. These Guidelines have been developed taking the updated regulatory framework into consideration.

Other reasons for updating the sludge guidelines include:

- **The principle of sustainability**

  These Guidelines support the principle of appropriate/sustainable use of resources. Sludge management options should not harm the environment by either the inefficient use of non-renewable resources or the accumulation of a substance/compound in the environment to harmful levels. This is in line with the resolution of the World Summit on Sustainable Development held in South Africa in 2003.

- **Choice of different options**

  The 1997 sludge guidelines focussed on the use of sludge as a soil conditioner, but were not clear on the requirements for other options such as disposal to a landfill facility. The addendum that followed in 2002 identified different management options based on the characteristics of the sludge. However, the addendum[3] was intended to clarify the

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[1] Department of Health. 1991. Guide: Permissible Utilisation and Disposal of Sewage Sludge. Health Act (Draft 2, A11/2/5/4, Dec. 1991). Department of Health. Pretoria.

[2] Ekama, G. A. 1993. Sewage Sludge Utilisation and Disposal. Water Institute of Southern Africa, Midrand.

[3] Water Research Commission. 2002. Addendum 1 to Edition 1 (1997) of Guide: Permissible Utilisation and Disposal of Sewage Sludge. Water Research Commission, Pretoria.

ambiguities of the 1997 guidelines in the interim, until the second edition of the guidelines (Volume 1-5) could be published. This, the 2nd Edition of sludge guidelines, clearly differentiates between the different management options in a series of guideline volumes.

- **Aligning South African guidelines with international trends**

  These sludge guidelines introduce a new sludge classification system, which is more in line with international trends and best practices.

- **Local research findings**

  The previous sludge guidelines were largely based on international research results and guidelines. The WRC initiated a research programme to further develop the knowledge base for the management of sludge in the South African context. These research projects addressed the following aspects:

  - Quality of South African sludge (WRC Reports 1283/1/04 and 1339/1/05).
  - Agricultural use of sewage sludge (WRC Report 1210/1/04).
  - Dedicated land disposal (WRC Report 1209/1/04).
  - Sludge treatment technologies (WRC Report 1240/1/04).

  Although the results of these research projects do not provide all the answers, these guidelines now combine the knowledge gained during the development of the addendum and research findings related to metals, nutrients and organic pollutants to ensure credibility.

- **Ease of use and understanding**

  Users of the 1st Edition of the sludge guidelines (1997) and the addendum (2002) required the assistance of experts, or an in depth understanding of the basis of the guidelines, to apply the principles correctly. The previous documents could therefore be misinterpreted. The 2nd Edition has been developed to explain the principles and concepts in a more user-friendly manner.

MOTIVATION FOR DEVELOPING THE SLUDGE GUIDELINES

The concept of sustainability was adopted as the ideal during the development of the 2nd edition of the Sludge Guidelines. Sustainable management options include options that do not harm the environment by either the use of a non-renewable resource or a build-up of substances in the environment to the extent that the assimilative capacity of the receiving environment has been exceeded. Unsustainable management options include disposal practices such as stockpiles, certain landfill and dedicated land disposal practices.

With current knowledge, there are three ways in which sludge management can contribute to sustainable development:

- Utilising the calorific energy value of the sludge (example: generating heat); or
- Utilising useful constituents such as carbon and nutrients (example: agricultural use); or

- Extracting useful constituents from the sludge (example: extraction of phosphorus).

Most agree that the second option *i.e.*, utilising the useful constituents such as carbon and nutrients in the sludge, particularly in support of agricultural practices, is the most viable management option for South Africa.

However, one also needs to be realistic and recognise that not all sludge generated in South Africa is suitable for agricultural use. For these sludges, the other two sustainable options may be considered. Factors that could exclude sludge from agricultural utilisation include:

- Sludge that is compromised by the contaminants such as heavy metals or organic contaminants;
- Lack of agricultural land that is available within a viable distance; and/or
- Community resistance against such practices.

It was therefore necessary to develop guidelines for other management options such as disposal and incineration and also provide opportunity for innovation. Each sludge management option was developed as a separate guideline volume. This simplifies the Guidelines for users, as each guideline focus on the management, technical and legislative aspects associated with a particular option. Each of the management options has different regulatory requirements and the sludge classification requirements for each option vary.

PROCESS FOLLOWED IN DEVELOPING THE SLUDGE GUIDELINES

Figure 1 details the process followed to develop the Sludge Guidelines. The aim has been to develop the Guidelines so that they are easily understood by regulatory authorities, managers, practitioners and operators responsible for sludge management. The scientific basis, the thought process and the consultation process were recorded in separate documents which are available from the WRC[4].

Literature survey

The literature survey provides details of the regulatory frameworks for sludge management in the United States, Canada, Mexico, Europe, Australia and New Zealand in terms of:

- Sludge classification systems.
- Inorganic constituents.
- Organic constituents.
- Pathogenic organisms.
- Vector attraction and odour reduction.
- Management requirements.

[4] Snyman, H.G. and Herselman, J.E. 2005. Guidelines for the utilisation and disposal of wastewater sludge: Literature review of South African and international guidelines and legislation and Scientific premise for Volumes 1 and 2. WRC Report 1453/1/05.

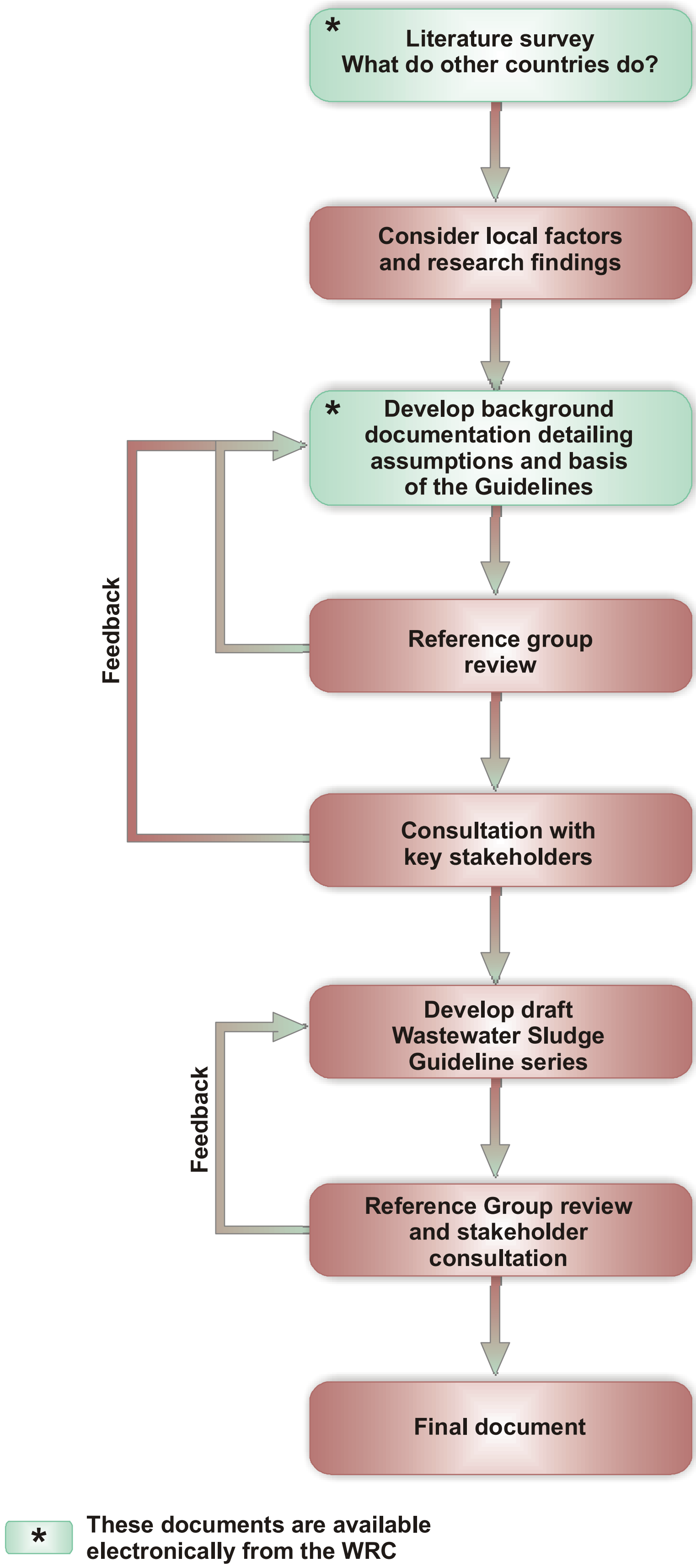

Figure 1: Process followed during the development of the Sludge Guidelines

These countries' sludge legislation and guidelines were evaluated based on the:

- International standing of the country in environmental terms.
- Amount and quality of the research and development supporting their guidelines.
- Climate and socio-economic indicators.
- Availability of the regulations and guidelines in English.
- The amount of sludge applied to land.

Based on the findings of the literature survey, recommendations were made regarding the South African Sludge Guidelines. For example, the survey showed that the South African sludge classification system was not in line with the classification systems used in other countries.

Consideration of local factors and research findings

As mentioned before, several South African research projects were completed during the last five years. These findings were used to develop the guideline limits and management requirements as described in these Guidelines. All the assumptions and the summary of the research findings were documented in a document which is available from the WRC[5].

Development of background documentation

A background document was developed and presented to the Reference Group. The concept and basis of the guidelines were then communicated to an open workshop at the WISA conference in May 2004 to invite comments from key stakeholders. The outcomes of the workshop were documented and comments incorporated into the Guidelines. The workshop attendees agreed with the proposed concept and basis of development. This enabled the project team to continue with the development of draft Guidelines.

Reference Group review and stakeholder consultation

The draft sludge guidelines were again presented to the Reference Group and their review comments were incorporated. The final draft was presented at eight workshops hosted across the country.

At each of the workshops, a register of the issues raised was documented. The participants also completed workshop feedback forms where issues were raised and comments made. Each of these contributions was considered and where possible addressed in the finalisation of the Guidelines.

Final document

The final draft document was again reviewed by the Reference Group to ensure that the scientific integrity of the document was retained throughout the consultation process.

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[5] Snyman, H.G. and Herselman, J.E. 2005. Guidelines for the utilisation and disposal of wastewater sludge: Literature review of South African and international guidelines and legislation and Scientific premise for Volumes 1 and 2. WRC Report 1453/1/05.

PART 2:

STRUCTURE OF THE SLUDGE GUIDELINES

Volume 1 forms part of a series of Sludge Guideline Volumes developed to address the major application and disposal options for sludge. Volume 1 helps to select the appropriate management options for the sludge streams generated by a specific wastewater treatment plant. Once a suitable management option has been selected, the user is referred to the relevant volume that deals with the selected management option (Figure 2).

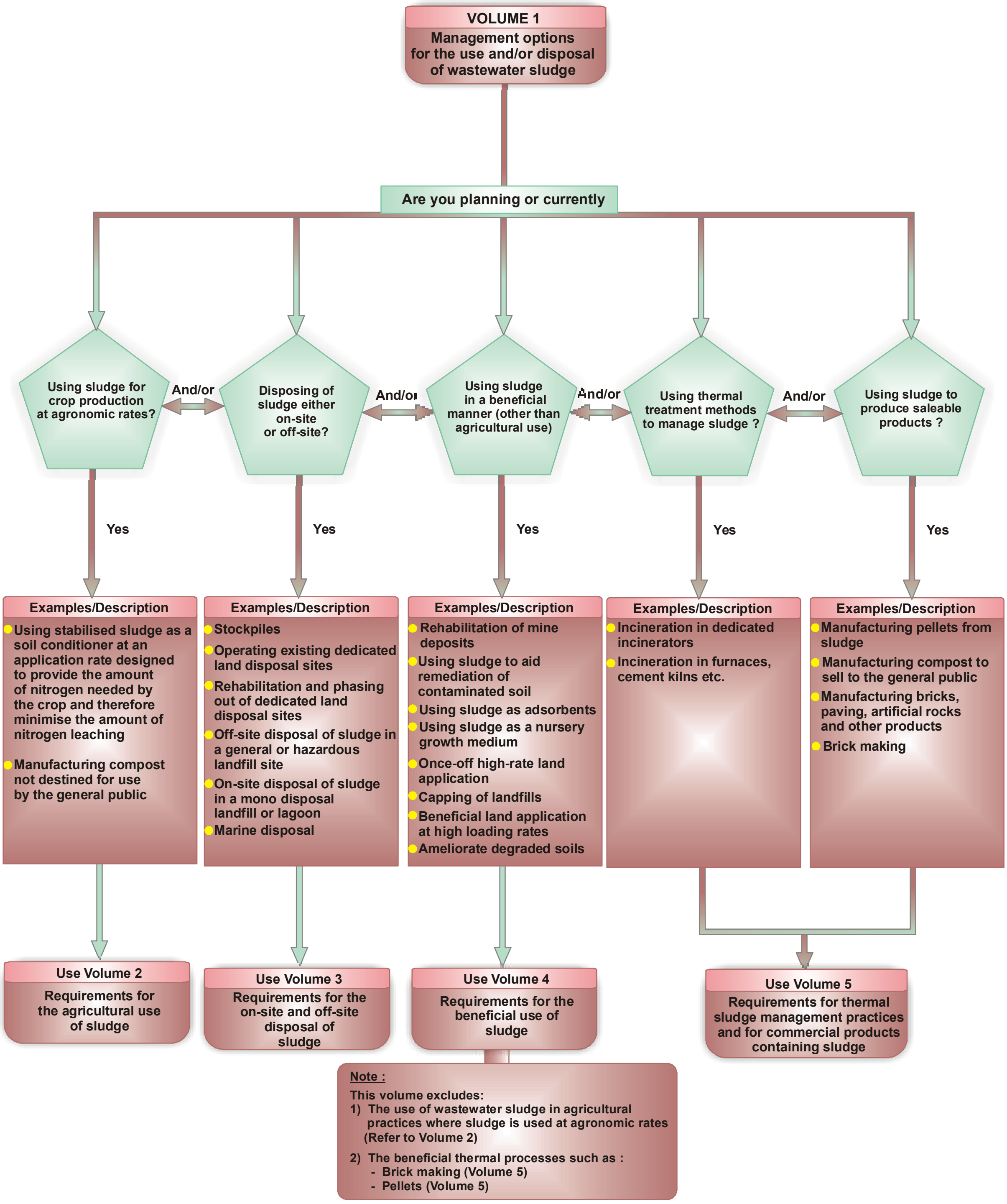

Figure 2: Decision-making process to identify the most suitable management option

Volume 1: Selection of management options

Volume 1 describes the initial comprehensive characterisation of the sludge. Based on the results of the characterisation, appropriate management options can be selected for a particular case. The document directs the reader to the appropriate Guideline volume to use.

Volume 2: Requirements for the agricultural use of sludge

Volume 2 describes the requirements and restrictions related to the safe use of sludge for the production of crops.

This Volume should be used:

- When stabilised sludge is used as a **nutrient source** and/or **soil conditioner** at an application rate designed to supply a crop's nitrogen needs, while at the same time minimising the risk of nutrient leaching. This applies to both commercial as well as to small scale and subsistence farming practices.
- To manage **compost** containing sludge that is not sold or distributed to the general public for use. Compost that is of such a high quality that it can be distributed to the general public is viewed as "a saleable product", the requirements of which are detailed in Volume 5 of the Sludge Guidelines.
- When sludge is used for municipal parks. If these parks are used by the public, additional pathogen management strategies will apply.

Volume 3: Requirements for the on-site and off- site disposal of sludge

Volume 3 describes the requirements and restrictions related to the on-site and off-site disposal of sludge. The Volume gives detailed requirements and guidance on:

- Managing the phasing out of unlined sludge stockpile facilities;
- Operating existing dedicated land disposal sites; and,
- The rehabilitation and phasing out of dedicated land disposal sites.

Other disposal options, such as:

- Off-site disposal of sludge in a general or hazardous landfill site;
- On-site disposal of sludge in a mono disposal landfill or lagoon; and,
- Disposal of sludge to the marine environment,

are addressed in other guidelines and policies published by the Department of Water Affairs and Forestry and the reader is guided to the relevant sections. The Volume also mentions some waste specific details that should simplify the process.

This Volume should be used for:

- **Managing the phasing out of uncontrolled stockpile facilities**. The Department of Water Affairs and Forestry will no longer accept the indefinite storage of sludge in uncontrolled stockpiles. This practice thus needs to be phased out over time. This Volume assists with the selection of alternative management options and rehabilitating the footprint of the stockpile (if required).

- **Operating existing dedicated land disposal sites**. This Volume assists the reader to determine what the environmental impacts of the current practices are and how to manage an existing dedicated land disposal site to minimise negative environmental impacts.

- **Rehabilitation and phasing out of dedicated land disposal sites.** If a dedicated land disposal site proves to have an unacceptable impact, it will have to be phased out in a responsible manner. This Volume details the steps to be taken to phase out an operating dedicated land disposal site in a responsible manner.

- **Off-site disposal of sludge in a general or hazardous landfill site**. This Volume addresses the co-disposal of sludge in municipal or commercial landfill facilities (both general and hazardous landfill facilities). Sludge disposal in a landfill should adhere to the Waste Management Series[6]. These documents are currently being revised and the user should adhere to the latest edition. This Volume assists the reader to understand the requirements stipulated in the Minimum Requirements by explaining the relevant sections that pertain to the management of sludge in landfill operations. The volume details the process of delisting, dewatering and co-disposal ratio requirements.

- **On-site disposal of sludge in a mono disposal landfill or lagoon**. This Volume addresses the disposal of sludge in dedicated disposal facilities and sludge lagoons. These practices need to comply with the latest edition of the Waste Management Series[6]. This Volume assists the reader to understand the requirements stipulated in the Minimum Requirements by explaining the relevant sections that pertain to the management of sludge in mono-disposal facilities and sludge lagoons. The Volume details the process of delisting, dewatering, liner and closure requirements.

- **Disposal of sludge to the marine environment**. It is unclear whether sludge disposal to the marine environment would be permissible in future. This Volume refers to the latest information on the interpretation of the "Operational Policy for the Disposal of Land-derived Water Containing Waste to the Marine Environment"[7].

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[6] Department of Water Affairs and Forestry, 1998. Waste Management Series. Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste. Minimum Requirements for Waste Disposal by Landfill. Minimum Requirements for the Monitoring of Water Quality at Waste Management Facilities.

[7] Operational Policy for the Disposal of Land-derived Water Containing Waste to the Marine Environment of South Africa - Edition 1, 2004. (Department of Water Affairs and Forestry, Water Quality Management Series, Sub-Series No. MS 13).

Volume 4: Requirements for the beneficial use of sludge

This Volume describes the requirements and restrictions pertaining to the beneficial use of sludge. Note that Volume 2 should be used for the agricultural use of sludge at agronomic rates and not Volume 4.

Volume 4 should be used for guidance on the:

- **Rehabilitation of mining waste deposits**. Inorganic waste material such as mine tailings could in some cases benefit from the addition of organically rich material. However, in some cases, the addition of organic material can cause environmental problems. This application must therefore be done responsibly. This volume details the process to follow to use sludge in the treatment of organically poor material such as mine tailings.

- **Using sludge to aid remediation of contaminated soil**. It has been proven that the micro-organisms and the organic material in sludge can enhance the process of bioremediation of contaminated soil. Sludge can be used for both the remediation of hydrocarbon-contaminated soils as well as for the remediation of soils that have been contaminated with inorganic pollutants such as metals. The sludge can also be used as an **adsorbent** by incorporating it into oil contaminated soil. The sludge will absorb the free oil, which increases the ability of micro-organisms to degrade the contaminant. This Volume gives some guidelines on how to apply sludge for the remediation of contaminated soil.

- **Using sludge as a nursery growth medium**. When preparing nursery growth media, the sludge component may exceed the agronomic rate. This will not cause any detrimental environmental effects as the seedlings and pot-plants are distributed and planted in natural soils. Care should be taken not to expose the public to high levels of pathogens. This Volume gives guidance on the use of sludge a nursery growth medium.

- **Once-off high rate application**. An example of once-off high rate application of sludge is during the construction of golf courses, establishment of vineyards or fruit orchards. This Volume gives guidance on these practices.

- **Covering of landfills**. Sludge could be used as part of the capping material for landfills or as daily cover. This volume gives guidance on these practices.

- **Beneficial land application at high loading rates**. Some crops such as instant lawn can be cultivated using sludge applications much higher than the recommended agronomic rates. The lawn is removed with the sludge attached to the root zone. This means that the topsoil is not removed as the sludge serves as the root support structure. However, these practices must be managed to avoid nitrate leaching and other negative environmental effects. This volume details the requirements for the beneficial agricultural use of sludge at high loading rates.

  Several beneficial thermal processes such as brick making or pellet manufacturing also exist. However, the manufacturing of these products includes at least one high temperature step and the product often has a commercial value. For this reason, these processes and products are addressed in **Volume 5**.

Volume 5: Requirements for thermal sludge management practices and for commercial products containing sludge

Volume 5 is divided in two parts. The first part addresses the use of thermal methods to manage sludge. The second part addresses the use of sludge to manufacture saleable products. These aspects were combined in one volume, as many of the saleable products include a thermal process in their manufacturing process. For example, the use of sludge in brick manufacturing could be seen as both a thermal process and producing a saleable product.

Volume 5 should be used for guidance on the:

- **Use of thermal methods to manage sludge**
  - **Incineration in dedicated incinerators.** This Volume addresses the requirements for the incineration of sludge with specific reference to the operational requirements and management of the air emissions and the ash residues.
  - **Incineration in furnaces, cement kilns, etc.** Sludge can also be co-incinerated in industrial processes such as industrial furnaces and cement kilns. This volume addresses the requirements for these practices. This will include the use of sludge in the manufacturing of bricks.

- **Use of sludge to produce saleable products**

  The requirements for a saleable product are understandably much stricter than the controlled use of sludge products. Saleable products should be adequately disinfected. For this reason, composting is addressed in both Volumes 2 and 5. Some plants in South Africa, generate compost that is not completely disinfected. For this type of compost, restrictions apply as addressed in Volume 2. For high quality compost destined for the general public, the process requirements and quality criteria are high, but few restrictions apply after the product leaves the manufacturing process. The same principles apply to:

  - **Manufacturing pellets from sludge.** The pellets, which resemble commercial fertilisers, could be enriched with additional plant nutrients.
  - **Manufacturing bricks, paving, artificial rocks and other products.** Many innovative product applications have emerged internationally. Many of these applications are not financially viable in South Africa. However, this volume gives guidance on how to implement such a process in the South African legislative environment.

PART 3:

GOOD SLUDGE MANAGEMENT PRACTICES

SLUDGE TYPES AND STABILITY

It is important to be familiar with different sludge generation and use/disposal options. Figures 3 and 4 illustrate just two examples of how different sludge types are generated and the relative stability of the sludge. Many other processes and process configurations exist. For example, in Figure 3, primary sludge is stabilised by anaerobic digestion, followed by another disinfection step. Primary sludge can also be stabilised and disinfected by lime treatment in one step. Note that less sophisticated processes can also be used to stabilise sludge. For example, the sludge from an oxidation pond, if left for a long time could be adequately stabilised.

In the past confusion and misconceptions existed regarding the concept of a "stable" sludge. It is important to clearly distinguish between "stable", "disinfected" and/or "dewatered" sludge.

Stable sludge: The sludge has been treated to reduce volatile organic matter, vector attraction and to reduce the potential for putrefaction and offensive odours.

Disinfected sludge: The sludge has been subjected to a process that destroys, inactivates or reduces pathogenic micro-organisms.

Dewatered sludge: The sludge has been subjected to a process that reduces 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.

Note that separate processes are not necessarily required to achieve a stable, disinfected and dewatered sludge. For example, if you dewater sludge to levels above 90% solids content, you have both a stable and dewatered sludge.

BEST MANAGEMENT PRACTICES

Irrespective of the management option adopted, good sludge management practices will be required. This includes understanding and managing the full life cycle of the sludge streams generated at a wastewater treatment plant to ensure appropriate use and disposal.

Figure 5 illustrates conceptually how a life cycle assessment can be used to manage sludge. It is particularly important to understand the source of possible pollutants that might restrict the use and disposal of the sludge. Equally important is the management and operation of the wastewater treatment plant to generate a stable sludge which does not generate any odours or attract disease vectors. If the resulting sludge does not meet the required standards, this information should feed back to the operation of the plant and wastewater source control. Managing the full life cycle of the sludge generation, handling, use and disposal will ensure continuous improvement.

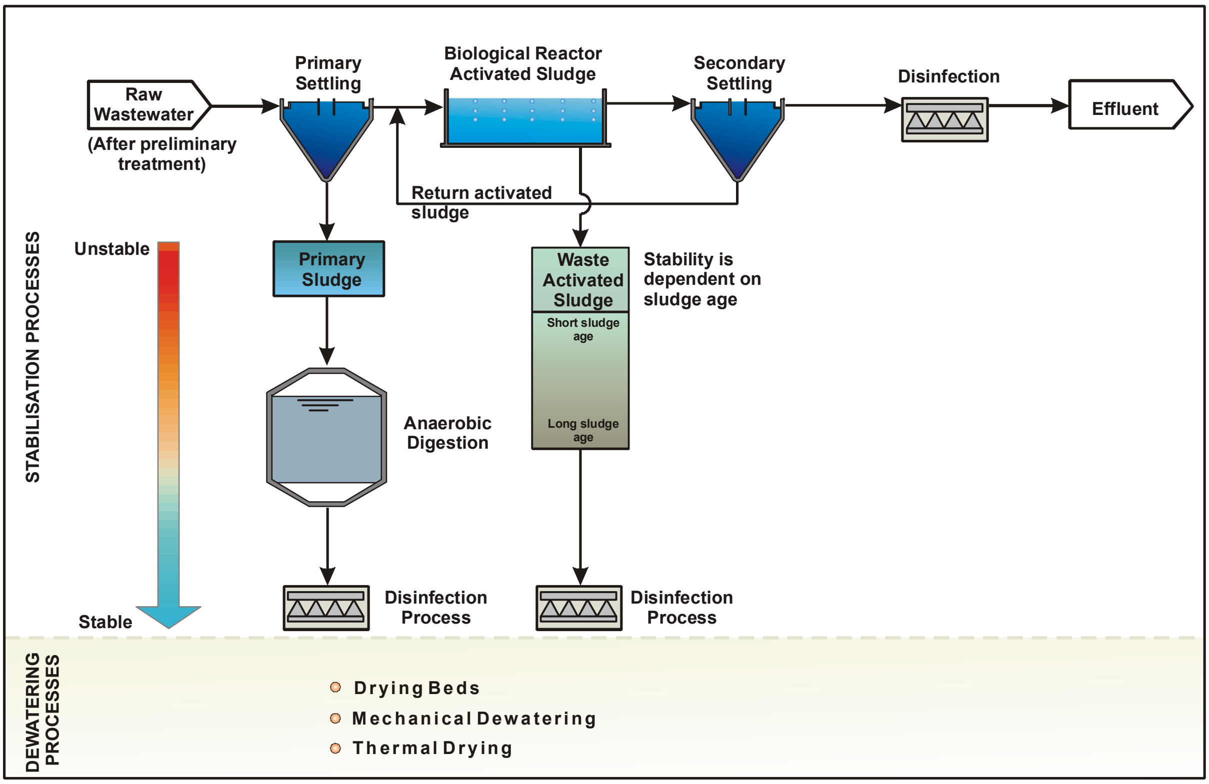

Figure 3: An example of an Activated Sludge wastewater treatment plant showing sludge stabilisation and dewatering options

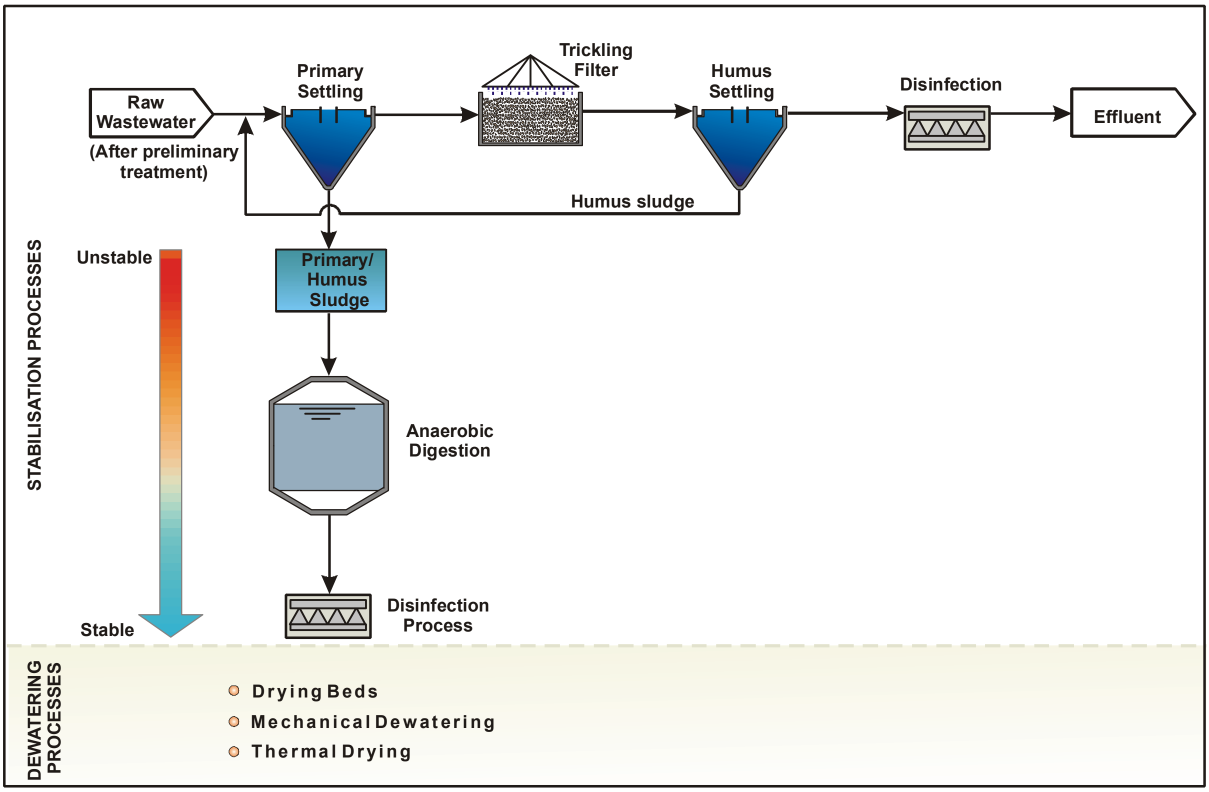

Figure 4: An example of a Trickling Filter wastewater treatment plant showing sludge stabilisation and dewatering options

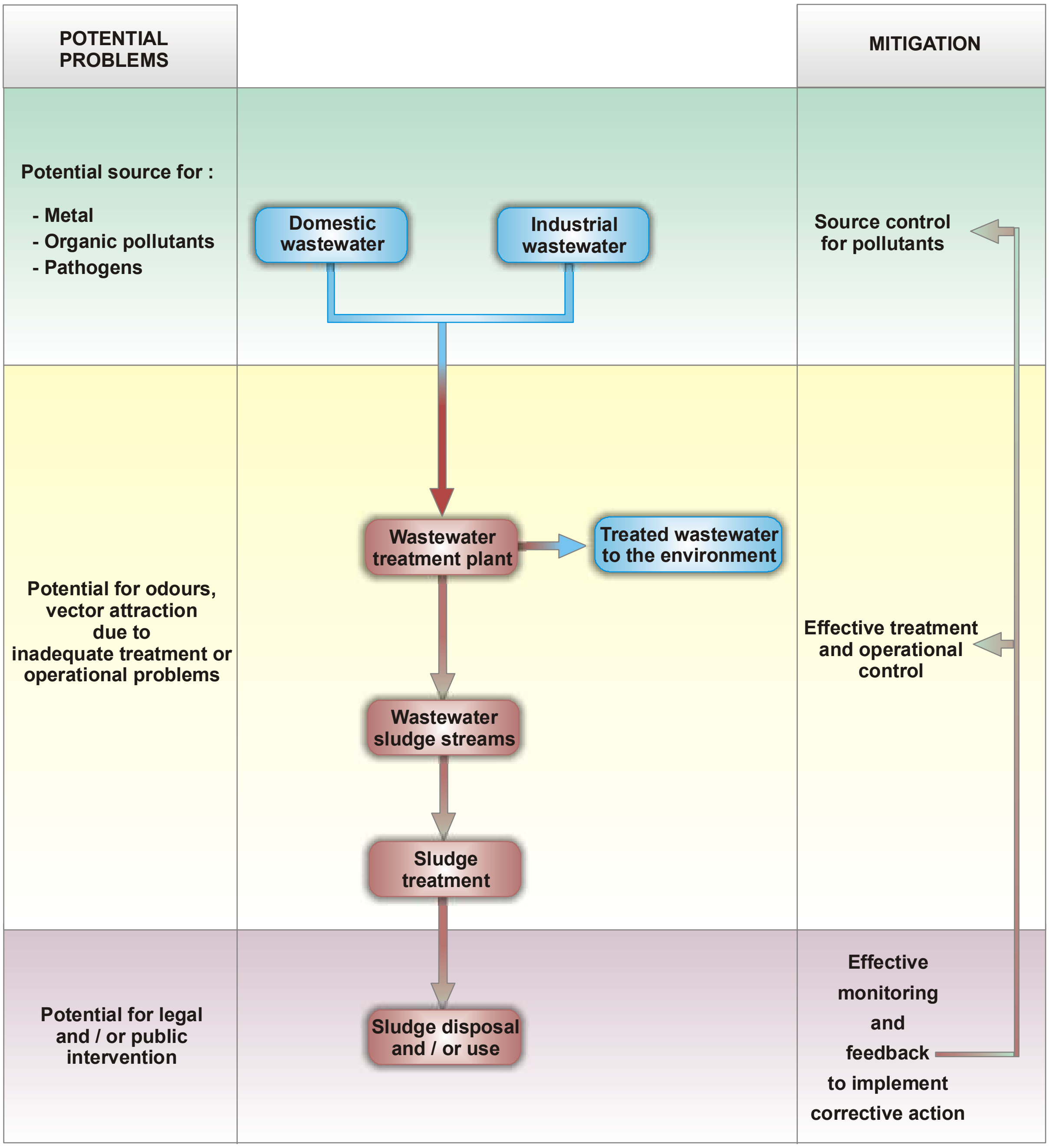

Figure 5: Life-cycle assessment to manage sludge quality

PART 4:

LEGAL FRAMEWORK FOR SLUDGE USE AND DISPOSAL

These Guidelines aim to simplify the legal complexities related to sludge use and disposal.

The use and disposal of wastewater sludge are influenced by, amongst others, the following Acts and guidelines:

- The National Water Act (Act 36 of 1998) (NWA)
- The Water Act (Act 54 of 1956) (WA)
- The Environment Conservation Act (Act 73 of 1989) (ECA)
- The Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act 36 of 1947)
- The Conservation of Agricultural Resources Act (Act 43 of 1983) (CARA)
- The National Health Act (Act 61 of 2003) (HA)
- The Water Services Act (Act 108 of 1997) (WSA)
- The National Environmental Management Act (Act 107 of 1998) (NEMA)
- Minimum Requirements: (Second Edition) 1998

This refers to the Waste Management Series published by Department of Water Affairs and Forestry, which establishes a reference framework of standards for waste management in South Africa in terms of Section 20 of the ECA. This trilogy consists of:

  - Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste
  - Minimum Requirements for Waste Disposal by Landfill
  - Minimum Requirements for Water Monitoring at Waste Management Facilities

- Water Use Authorisation and Registration Management System (WARMS). This is a registration system used by DWAF for water uses

It is important to note that not all the Acts, regulations and guidelines (as mentioned in the box above) are applicable to all the uses. For example, the Minimum Requirements need to be consulted for the disposal of sludge in a landfill, but do not have to be considered if sludge is to be used beneficially as a soil amendment.

For this reason, the regulatory requirements and relevant "legal" instruments will be detailed for each management option in the relevant Volume that deals with that particular option.

However, irrespective of the management option selected, the Department of Water Affairs and Forestry will remain the lead regulatory agent and will manage the sludge management options using the NWA. The insert below shows the relevant section at the NWA that the Department uses to regulate sludge management.

National Water Act: Act No. 36 1998

Definition of "waste" according to the National Water Act

"(xxiii) "waste" includes any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted."

Prevention and remedying effects of pollution (Part 4)

Part 4 deals with pollution prevention, and in particular the situation where pollution of a water resource occurs or might occur as a result of activities on land. The person who owns, controls, occupies or uses the land in question is responsible for taking measures to prevent pollution of water resources. If these measures are not taken, the catchment management agency concerned may itself do whatever is necessary to prevent the pollution or to remedy its effects, and to recover all reasonable costs from the persons responsible for the pollution.

Section 19 of the National Water Act

19. (1) An owner of land, a person in control of land or a person who occupies or uses the land on which -

(a) any activity or process is or was performed or undertaken; or

(b) any other situation exists,

which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.

(2) The measures referred to in subsection (1) may include measures to -

(a) cease, modify or control any act or process causing the pollution;

(b) comply with any prescribed waste standard or management practice;

(c) contain or prevent the movement of pollutants;

(d) eliminate any source of the pollution;

(e) remedy the effects of the pollution; and

(f) Remedy the effects of any disturbance to the bed and banks of a watercourse.

(3) A catchment management agency may direct any person who fails to take the measures required under subsection (1) to

(a) commence taking specific measures before a given date;

(b) diligently continue with those measures; and

(c) complete them before a given date.

(4) Should a person fail to comply, or comply inadequately with a directive given under subsection (3), the catchment management agency may take the measures it considers necessary to remedy the situation.

(5) Subject to subsection (6), a catchment management agency may recover all costs incurred as a result of it acting under subsection (4) jointly and severally from the following persons:

(a) any person who is or was responsible for, or who directly or indirectly contributed to, the pollution or the potential pollution;

(b) the owner of the land at the time when the pollution or the potential for pollution occurred, or that owner's successor-in-title;

(c) the person in control of the land or any person who has a right to use the land at the time when -

(i) the activity or the process is or was performed or undertaken; or

(ii) the situation came about; or

(d) any person who negligently failed to prevent -

(i) the activity or the process being performed or undertaken; or

(ii) the situation from coming about.

(6) The catchment management agency may in respect of the recovery of costs under subsection (5), claim from any other persons who, in the opinion of the catchment management agency, benefited from the measures undertaken under subsection (4), to the extent of such benefit.

(7) The costs claimed under subsection (5) must be reasonable and may include, without being limited to, labour, administrative and overhead costs.

(8) If more than one person is liable in terms of subsection (5) , the catchment management agency must, at the request of any of those persons, and after giving the others an opportunity to be heard, apportion the liability, but such apportionment does not relieve any of them of their joint and several liability for the full amount of the costs.

PART 5:

COMPREHENSIVE CHARACTERISATION OF SLUDGE

WHY SLUDGE NEEDS TO BE CHARACTERISED

To establish which management options are suitable for the type and quality of sludge generated at a particular wastewater treatment plant, the different sludge streams need to be characterised. Note that this characterisation should be done at the following stages of a wastewater treatment plant's life:

- During the planning and development stages
- When major extensions are implemented
- When major operational changes are made
- When the raw wastewater quality of the wastewater treatment plant changes in such a way that the sludge quantity and quality could be affected
- When an alternative sludge management option is considered.

In other words, the comprehensive characterisation required in Volume 1 should only be done once and will only be required again if the characteristics of sludge is likely to change due to treatment plant extensions or change in the raw wastewater.

The required characterisation and monitoring programme could differ for a particular management option and once a particular management option has been selected, the characterisation and monitoring requirements pertaining to that particular management option should be followed.

Initial characterisation of all sludge streams destined for storage, further processing and disposal is required.

At least three composite sludge samples from each sludge stream considered for use/disposal should be collected for analyses (Figure 6). Plants that employ sludge disinfection are required to collect grab samples for microbiological analyses.

Notes on the collection of sludge samples, sample size and appropriate sampling containers have been included in Appendix 1.

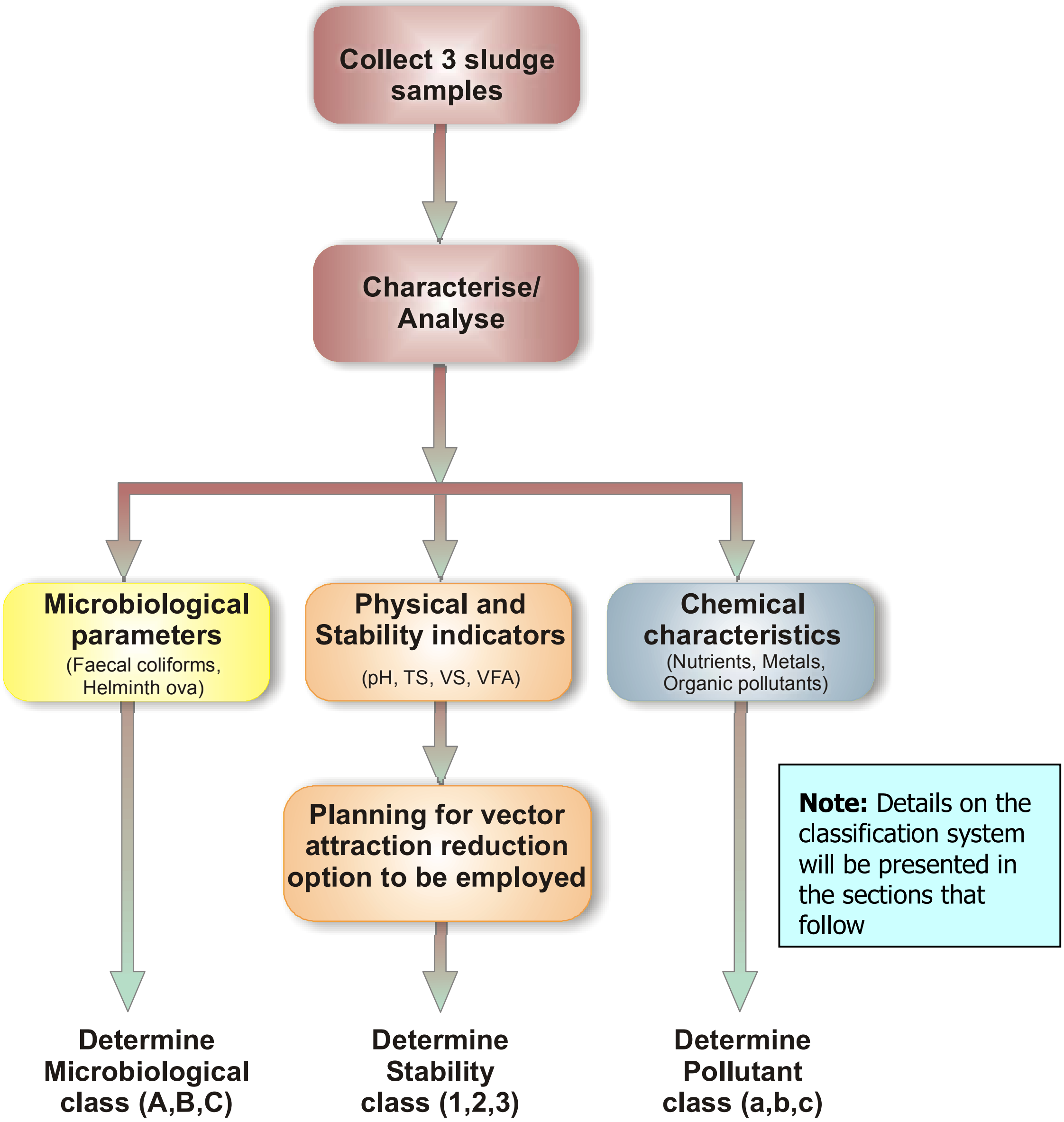

Figure 6: Initial characterisation and classification of sludge

ANALYSES REQUIRED

You are required to establish the:

- Physical characteristics of the sludge
- Chemical quality of the sludge
- Microbiological quality of the sludge.

Table 1 details the different constituents and parameters to be included in the characterisation of the sludge, as well as some guidelines on appropriate analytical methods.

TABLE 1: PARAMETERS TO BE INCLUDED IN THE COMPREHENSIVE CHARACTERISATION 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 solids (VS)		Standard Method 2540E[2]
	Volatile Fatty Acids (VFA)		Adapted from Standard Methods. The full method is detailed in Appendix 2.1
Nutrients	Total Kjeldahl Nitrogen (TKN)		The suggested method description is attached in Appendix 2.2
	Total Phosphorus (TP)		The suggested method description is attached in Appendix 2.2
	Potassium (K)		The suggested method description is attached in Appendix 2.2
Metals[3] and micro-elements	*Compulsory*	*Recommended*	*Compulsory method*
	Arsenic Cadmium Chromium Copper Lead Mercury Nickel Zinc	Aluminium Antimony Boron Barium Beryllium Cobalt Iron Manganese Molybdenum Selenium Silver Sodium Strontium Thallium Vanadium	The metal limits are based on *aqua regia* extraction. The full method is detailed in Appendix 2.3 International Standard ISO 11466 Method Reference number : ISO 11466:1995 (E)
Organic pollutants	Poly-aromatic hydrocarbons (PAH)[4]		EPA Methods 3510C (Liquid-liquid extraction) for liquid sludge, 3540C (Soxhlet extraction) for solid sludge and EPA Method 3660B for sulphur clean-up.
Microbiological quality	Faecal coliforms		Appropriate sample preparation based on moisture content and expected coliform count followed by incubation on selective growth media. Note: Determine moisture content on a sub-sample.
	Total viable Helminth ova		Filtration/flotation and also determine viability (Appendix 2.4) Note: Determine moisture content on a sub-sample.

[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 Trussel.

[3] A semi-quantitive ICP scan will give concentrations of all mentioned metals. Use the scan to identify the metals that are present in high concentrations. It is advisable to continue monitoring elevated metals even if they are not part of the "compulsory" list.
Note : Remind the laboratory to manage the interferences on the ICP appropriately, especially for compounds such as Arsenic.

[4] Acenaphthene, phenanthrene, fluorene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene.

The analytical methods detailed in Table 1 are recommended methods. Some laboratories use more sophisticated methods to measure the same parameter. It is not the intention to dictate to these laboratories to revert back to the older methods. Refer to the methods listed in Table 1 to assess whether similar fractions are extracted. For example, if the adopted method includes an acid extraction and ICP analyses instead of AA analyses, it will still be within the same standard for total metal analyses. If, for instance, the adopted method uses an EDTA extraction for chromium, it is not comparable with the chromium method listed in Table 1 and should therefore be changed. Note that the metal extraction method (*aqua regia*) is compulsory, as the metal limits are based on the acid extractable metal fraction.

ADDITIONAL ANALYSES

The Department of Water Affairs and Forestry and other authorities might require additional analyses, specifically with regard to additional organic pollutants such phenolic compounds, pesticides, polychlorinated biphenyls (PCBs), chlorinated hydrocarbons etc. It is also the sludge producer's responsibility to analyse for additional appropriate constituents if the sludge producer is aware of certain wastewater contributors that could influence the quality of the sludge. For example, if the producer is aware of an industry that discharges wastewater that contains aldehydes to the sewer, it is prudent to analyse for aldehydes in the sludge. Wastewater treatment plants that receive the leachate from landfills need to be specifically vigilant as the compounds dissolved in the leachate often end up in the sludge. If the additional analyses indicate elevated metal or other constituent concentrations, the Department of Water Affairs and Forestry should be informed and the additional risks should be investigated.

Based on the results of the analysis, the sludge can be classified and appropriate management options can be selected.

PART 6:

PRELIMINARY CLASSIFICATION OF SLUDGE

Use the results of the three samples collected for the comprehensive characterisation discussed in Part 5 to perform the preliminary classification. The preliminary classification can then be used to choose appropriate use and disposal methods or assess if the current practices are in line with the Sludge Guidelines.

Use the South African sludge classification system (Table 2) to classify the sludge in terms of its:

- Microbiological content
- Stability
- Organic and inorganic pollutants

TABLE 2: CLASSIFICATION SYSTEM FOR SLUDGE

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

MICROBIOLOGICAL CLASS

Use Table 3 to determine the preliminary microbiological class.

TABLE 3: PRELIMINARY CLASSIFICATION: MICROBIOLOGICAL CLASS

Microbiological class	**A**	**B**		**C**
	All three samples comply with the following standard	Two of the three samples comply with the following standard	The sample that failed does not exceed the following standard	One or more of the samples exceed the following concentration
Faecal coliforms (CFU/g_{dry})	< 1 000	< 1 x 10^6	1 x 10^7	> 1 x 10^7
Helminth ova (Total viable ova/g_{dry})	< 0.25 (or one viable ova/4g_{dry})	< 1	4	> 4

STABILITY CLASS

Since the beneficial use of sludge is promoted in the Guidelines, the stability of the sludge is of utmost importance. Odour is often the only factor that influence public perception of sludge reuse. Very seldom does a member of the public register a concern or complain about sludge due to a concern related to food safety. They usually complain due to odours from the sludge spreading activity. If sewage sludge did not smell, the public would probably not complain and the overall public perception of the reuse of sludge would improve. The increased stability of sludge with associated lower odour risk should enable more wastewater treatment facilities to dispose of sludge beneficially.

Use Table 4 to assign a preliminary stability class. Note that the stability class is based on what is planned for the future, or to classify according to the current sludge handling practice. It is possible to address stability issues at a later stage in a management practice. It is therefore recommend that a worst case stability class be assigned based on the current situation or management plan.

TABLE 4: PRELIMINARY CLASSIFICATION: STABILITY CLASS

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		

The different vector attraction reduction options listed in Table 4 are described in more detail in Appendix 3.

POLLUTANT CLASS

The organic and inorganic pollutant limits and load restrictions will vary for different applications. For example, the pollutant limits applicable for agricultural use of sludge will be completely different to those pertaining to landfill or incineration. The requirements for sampling and analysis would also be different for each option.

However, it is important to have an indication of the pollutant class for planning purposes. To do a preliminary classification, it is recommended that the metal limits designed for the agricultural use of sludge are used. Use Table 5 to assign a preliminary pollutant class for the eight (8) metals based on the results from the three sludge samples collected and analysed according to Table 1 in Part 5. The scientific basis for the development of the pollutant class limits is available from the WRC[8].

TABLE 5: PRELIMINARY CLASSIFICATION: POLLUTANT CLASS

Metal limits for South African Wastewater Sludges (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
Lead (Pb)	<300	300 - 840	>840
Mercury (Hg)	<15	15 - 55	>55
Nickel (Ni)	<420	420	>420
Zinc (Zn)	<2800	2800 - 7500	>7500
Benchmark Metal Values (mg/kg)			
Pollutant class	**a**	**b**	**c**
Antimony (Sb)	<1.1	1.1 - 7	>7
Boron (B)	<23	23 - 72	>72
Barium (Ba)	<108	108 - 250	>250
Beryllium (Be)	<0.8	0.8 - 7	>7
Cobalt (Co)	<5	5 - 38	>38
Manganese (Mn)	<260	260 - 1225	>1225
Molybdenum (Mo)	<4	4 - 12	>12
Selenium (Se)	<5	5 - 15	>15
Strontium (Sr)	<84	84 - 205	>205
Thallium (Tl)	<0.03	0.03 - 0.14	>0.14
Vanadium (V)	<85	85 - 430	>430

[8] Snyman, H.G. and Herselman, J.E. 2005. Guidelines for the utilisation and disposal of wastewater sludge: Literature review of South African and international guidelines and legislation and Scientific premise for Volumes 1 and 2. WRC Report 1453/1/05.

Several metals that are not included in the list of eight (8) metals also need to be determined. The guidelines for these additional metals in Table 5 are based on the benchmark values of typical South African sludge and samples. If the sludge has been assigned a Pollutant class a, the sludge quality falls in the top 20% in terms of South Africa metal quality. Similarly, if the sludge has been assigned a Pollutant class c, the sludge quality falls in the bottom 20% in terms of metal content of typical South African sludges. This means that, compared to the average metal content in South African sludges, the sludge samples show high metal content and should be investigated and monitored. The classification should be based on the average analytical result (*aqua regia* extraction) of the three samples collected and analysed according to Table 1 in Part 5.

Note that the routine analysis of organic pollutants in sludge is not required for **domestic sludge.** This decision was based on the fact that apart from one local research project, we do not have sufficient information to justify routine organic pollutant analyses that are often costly. However, in the interest of understanding the extent of the problem with regards to the organic pollutants of South African sludges, it is recommended that the poly-aromatic hydrocarbons (PAHs) be determined in the sludge samples suggested in Table 1 in Part 5.

Use this data and Table 6 to establish whether further action is required.

TABLE 6: DETERMINE THE ORGANIC POLLUTANT CONTENT

Poly-aromatic hydrocarbons (PAH)	No action required	Action required
Acenaphthene Phenanthrene Fluorene Fluoranthene Pyrene Benzo(b+j+k)fluoranthene Benzo(a)pyrene Benzo(ghi)perylene Indeno(1,2,3-cd)pyrene	The sum of the concentrations of these constituents is below 6mg/kg_{dry} solids	The sum of the concentrations of these constituents is above 6mg/kg_{dry} solids

In cases where the wastewater treatment plant receives industrial effluent that could influence the characteristics of the sludge in terms of organic pollutants, action is required.

PRELIMINARY CLASSIFICATION

Use the results obtained in Part 5 and the South African classification system to assign the preliminary classification based on all the parameters. For example, sludge that has a:

- Microbiological class: B (based on Table 3)
- Stability class: 1 (based on Table 4)
- Pollutant class: a (based on Table 5)

would have the following preliminary classification: B1a

PART 7:

SELECTING AN APPROPRIATE MANAGEMENT OPTION

Table 7 shows a colour coded index that can be used to assess the appropriateness of a management option based on the Microbiological class (Table 8), Stability class (Table 9) and Pollutant class (Table 10) of a specific sludge.

TABLE 7: COLOUR CODED INDEX TO ASSESS APPROPRIATENESS OF SELECTED MANAGEMENT OPTION

(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 implications and can be managed using good management practices.
(iii)	May be	This can only be effectively applied under strict conditions and major management and cost implications could 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 11 shows all the possible classification combinations of sludge and the coloured indicators of the appropriateness of a management option for a specific classification.

TABLE 8: USING THE PRELIMINARY MICROBIOLOGICAL CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Microbiological class?
Microbiological class A	Agricultural use at agronomic rates	Volume 2	**Yes (i)**	None.
	On-site or off-site disposal	Volume 3	**May be (iii)**	It is an inappropriate option for the disposal of a disinfected sludge. Disinfection technologies are costly and this management option therefore represents wasting of potential resource recovery.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Yes (i)**	None pertain to this Microbiological class.
	Thermal treatment methods	Volume 5	**No (v)**	It is not recommended to use thermal methods, such as incineration to manage a Microbiological class A sludge, as it was costly to achieve this classification in the first place.
	Produce saleable products	Volume 5	**Yes (i)**	Most saleable products will require disinfection process.
Microbiological class B	Agricultural use at agronomic rates	Volume 2	**Qualified yes (ii)**	May not be appropriate for some crops with edible parts below the soil surface.
	On-site or off-site disposal	Volume 3	**May be (iii)**	It could potentially be used beneficially, as this is a partially disinfected product.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**May be (iii)**	Due to the incomplete disinfection process it could affect the beneficial use depending on the application.
	Thermal treatment methods	Volume 5	**Qualified no (iv)**	It is not recommended to use thermal methods, such as incineration to manage a Microbiological class B sludge, as it was costly to achieve this classification.
	Produce saleable products	Volume 5	**Qualified no (iv)**	Due to the incomplete disinfection process it could influence the quality of the product.
Microbiological class C	Agricultural use at agronomic rates	Volume 2	**Qualified no (iv)**	Microbiological class C sludge can only be used if stability class 1 or 2 is achieved. Restrictions to crop types also apply.
	On-site or off-site disposal	Volume 3	**Yes (i)**	None.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Qualified no (iv)**	Care should be taken not to expose the public and workers to pathogens.
	Thermal treatment methods	Volume 5	**Yes (i)**	Thermal process is an appropriate technology for this microbiological class.
	Produce saleable products	Volume 5	**No (v)**	Risk of infection is unacceptable.

TABLE 9: USING THE PRELIMINARY STABILITY CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Stability class?
Stability class 1	Agricultural use at agronomic rates	Volume 2	**Yes (i)**	None.
	On-site or off-site disposal	Volume 3	**Yes (i)**	None. Note that vector attraction reduction options 9 and 10 do not apply.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Qualified yes (ii)**	Vector attraction reduction options 1 to 8 would be appropriate.
	Thermal treatment methods	Volume 5	**May be (iii)**	Vector attraction reduction options 7 and 8 or an appropriate dewatering step should be applied as a pre-treatment step before thermal treatment.
	Produce saleable products	Volume 5	**Yes (i)**	Long-term stability would be required for saleable products.
Stability class 2	Agricultural use at agronomic rates	Volume 2	**Qualified yes (ii)**	Due to the reliability of the vector attraction reduction measures implemented, additional management systems may be required.
	On-site or off-site disposal	Volume 3	**Qualified yes (ii)**	Vector attraction options 9 and 10 do not apply. Make sure that the vector reduction processes are reliable to prevent odours or other nuisances.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**May be (iii)**	This will depend on the beneficial use selected
	Thermal treatment methods	Volume 5	**Qualified yes (ii)**	Vector attraction reduction options 7 and 8 or an appropriate dewatering step should be applied as a pre-treatment step before thermal treatment.
	Produce saleable products	Volume 5	**Qualified no (iv)**	Long-term stability is required for saleable products and the reliability of this Stability class may not be appropriate.
Stability class 3	Agricultural use at agronomic rates	Volume 2	**No (v)**	At least one vector attraction reduction option should be implemented.
	On-site or off-site disposal	Volume 3	**Qualified no (iv)**	Unstable sludges such as raw/primary sludge may not be accepted at landfill sites.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Qualified no (iv)**	Care should be taken not to expose the public and workers to unstable sludge.
	Thermal treatment methods	Volume 5	**Yes (i)**	Vector attraction options 9 and 10 do not apply. Make sure that the vector reduction processes are reliable to prevent odours or other nuisances.
	Produce saleable products	Volume 5	**No (v)**	The product is not stable and the public will find this unacceptable.

TABLE 10: USING THE PRELIMINARY POLLUTANT CLASSIFICATION TO ASSESS THE APPROPRIATENESS OF A MANAGEMENT OPTION

Class	Management option	Appropriate Sludge Guideline	Appropriateness of this option?	What are the major restrictions in terms of the Pollutant class?
Pollutant class a	Agricultural use at agronomic rates	Volume 2	**Yes (i)**	No limitations apart from the sludge application rate should not exceed agronomic rates.
	On-site or off-site disposal	Volume 3	**Qualified no (iv)**	This sludge should not be disposed off as it is a high quality product that should be used beneficially.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Yes (i)**	No limitations with regard to the pollutant class, for the beneficial uses identified in this Volume.
	Thermal treatment methods	Volume 5	**Yes (i)**	Thermal process will have limited environmental impacts in respect of the metals.
	Produce saleable products	Volume 5	**Yes (i)**	No limitations with regard to the Pollutant class. (This excludes the production of edible products from sludge).
Pollutant class b	Agricultural use at agronomic rates	Volume 2	**Qualified yes (ii)**	Additional analyses will be required to assess whether the receiving soil can accommodate the load.
	On-site or off-site disposal	Volume 3	**May be (iii)**	Delisting according to the Minimum Requirements will be required.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**May be (iii)**	High rate application of this sludge could cause long-term effects and source control should be implemented.
	Thermal treatment methods	Volume 5	**Qualified yes (ii)**	Emissions of gaseous contaminants and the ash should be monitored and managed.
	Produce saleable products	Volume 5	**May be (iii)**	This depends on the product.
Pollutant class c	Agricultural use at agronomic rates	Volume 2	**No (v)**	The sludge metal content is too high for agricultural use. Source control should be implemented.
	On-site or off-site disposal	Volume 3	**May be (iii)**	Delisting according to the Minimum Requirements will be required.
	Beneficial use (other than agricultural use at agronomic rates)	Volume 4	**Qualified no (iv)**	High rate application of this sludge could cause long-term effects and source control should be implemented.
	Thermal treatment methods	Volume 5	**Qualified yes (ii)**	Emissions of gaseous contaminants and the ash should be monitored and managed.
	Produce saleable products	Volume 5	**May be (iii)**	This depends on the product.

TABLE 11: AN OVERVIEW OF APPROPRIATE MANAGEMENT OPTIONS FOR EACH CLASSIFICATION

Sludge Classification	Available management options for each sludge classification														
	Agricultural use at agronomic rates			On-site or off-site disposal			Beneficial use (other than agricultural use at agronomic rates)			Thermal treatment methods			Produce saleable products		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
A1a	i	i	i	iii	i	iv	i	ii	i	v	iii	i	i	i	i
A1b	i	i	ii	iii	i	iii	i	ii	iii	v	iii	ii	i	i	iii
A1c	i	i	v	iii	i	iii	i	ii	iv	v	iii	ii	i	i	iii
A2a	i	ii	i	iii	ii	iv	i	iii	i	v	ii	i	i	iv	i
A2b	i	ii	ii	iii	ii	iii	i	iii	iii	v	ii	ii	i	iv	iii
A2c	i	ii	v	iii	ii	iii	i	iii	iv	v	ii	ii	i	iv	iii
A3a	i	v	i	iii	iv	iv	i	iv	i	v	i	i	i	v	i
A3b	i	v	ii	iii	iv	iii	i	iv	iii	v	i	ii	i	v	iii
A3c	i	v	v	iii	iv	iii	i	iv	iv	v	i	ii	i	v	iii
B1a	ii	i	i	iii	i	iv	iii	ii	i	iv	iii	i	iv	i	i
B1b	ii	i	ii	iii	i	iii	iii	ii	iii	iv	iii	ii	iv	i	iii
B1c	ii	i	v	iii	i	iii	iii	ii	iv	iv	iii	ii	iv	i	iii
B2a	ii	ii	i	iii	ii	iv	iii	iii	i	iv	ii	i	iv	iv	i
B2b	ii	ii	ii	iii	ii	iii	iii	iii	iii	iv	ii	ii	iv	iv	iii
B2c	ii	ii	v	iii	ii	iii	iii	iii	iv	iv	ii	ii	iv	iv	iii
B3a	ii	v	i	iii	iv	iv	iii	iv	i	iv	i	i	iv	v	i
B3b	ii	v	ii	iii	iv	iii	iii	iv	iii	iv	i	ii	iv	v	iii
B3c	ii	v	v	iii	iv	iii	iii	iv	iv	iv	i	ii	iv	v	iii
C1a	iv	i	i	i	i	iv	iv	ii	i	i	iii	i	v	i	i
C1b	iv	i	ii	i	i	iii	iv	ii	iii	i	iii	ii	v	i	iii
C1c	iv	i	v	i	i	iii	iv	ii	iv	i	iii	ii	v	i	iii
C2a	iv	ii	i	i	ii	iv	iv	iii	i	i	ii	i	v	iv	i
C2b	iv	ii	ii	i	ii	iii	iv	iii	iii	i	ii	ii	v	iv	iii
C2c	iv	ii	v	i	ii	iii	iv	iii	iv	i	ii	ii	v	iv	iii
C3a	iv	v	i	i	iv	iv	iv	iv	i	i	i	i	v	v	i
C3b	iv	v	ii	i	iv	iii	iv	iv	iii	i	i	ii	v	v	iii
C3c	iv	v	v	i	iv	iii	iv	iv	iv	i	i	ii	v	v	iii

1 = Microbiological class   2 = Stability class   3 = Pollution class

EXAMPLES OF HOW TO SELECT APPROPRIATE MANAGEMENT OPTION/S FROM PRELIMINARY CLASSIFICATION

Table 12 provides typical data for five wastewater treatment plants (WWTP) followed by examples of the classification process in the pages that follow.

TABLE 12: CHARACTERISATION AND PRELIMINARY CLASSIFICATION OF 5 SOUTH AFRICAN WASTEWATER TREATMENT PLANTS

		WWTP 1	WWTP 2	WWTP 3	WWTP 4	WWTP 5
Sludge type		Anaerobic digested	Anaerobic digested	Waste Activated Sludge	Waste Activated Sludge	Primary Sludge
Sampling point		Wet sludge	Compost	Wet sludge	Belt press	Compost
Microbiological parameters	Viable Helminth ova/g_{dw}	5.7	0	0	0.25	0.25
	Faecal Coliform/g_{dw}	1.79E+06	0.00E+00	3.66E+08	5.1E+04	0.9E+05
Metals *(Aqua regia)*	Arsenic (As)	35	10	23	12	20
	Cadmium (Cd) (mg/kg)	70.9	25.3	5.6	10.2	4.77
	Chromium (Cr) (mg/kg)	2791	1109	125	113	133
	Copper (Cu) (mg/kg)	2920	810	260	343	269
	Lead (Pb) (mg/kg)	3758	838	150	100	78.1
	Mercury (Hg) (mg/kg)	7.7	3.9	8.2	2.1	2.7
	Nickel (Ni) (mg/kg)	600	381	141	188	171
	Zinc (Zn) (mg/kg)	20533	5058	2157	1010	856.6
Vector attraction reduction options applied		- Anaerobic digestion with VS reduction of 40% - Dewatered on drying beds	- Reduce moisture content to 75% solids - Make compost	- None	- Add lime in rainy season ±20 days/ anum - Reduce moisture content to 20% solids	- Reduce moisture content to 75% solids - Make compost
Classification		C1c	A1b	C3a	B3a	B1a

Wastewater Treatment Plant 1

This Plant produces waste activated sludge (WAS) and primary sludge that is anaerobically digested. The WAS and primary sludge is pumped to a heated anaerobic digester. The anaerobic digester has a sludge retention time of 19 days and a volatile solids (VS) reduction of 40% is achieved (95% of the time). The resulting anaerobic digested sludge (AD) is dried on drying beds (typically 40% dry solids). The analyses data of 3 grab samples (average) from the digester is shown in Table 12.

The microbiological parameters in the sludge are high and therefore it is classified as Microbiological class C. The Stability class classification is 1 since the Plant complies with at least one vector attraction reduction options (Option 1) > 90% of the time. The Ni, Pb and Zn content of the sludge is high (Pollutant class c).

This sludge is thus a Type=C1c and the applicability of the management options is as follows:

- Agricultural use at agronomic rates – Not allowed due to Pollutant class
- On-site or off-site disposal – Allowed with restrictions
- Beneficial use (not agriculture) – Allowed with restrictions
- Thermal treatment – Allowed with restrictions
- Saleable products – Not allowed due to Microbiological class

The plant operator should consider source control to eliminate the high Ni, Pb and Zn concentrations.

Wastewater Treatment Plant 2

Plant 2 produces compost from organic waste materials and anaerobically digested sludge (heated digester) which is dried on drying beds. The average analyses of three (3) compost samples (average) are detailed in Table 12. The microbiological quality of the sludge falls in Microbiological class A. The Stability class is 1 since the moisture of the anaerobic digested sludge is reduced to 75% (Option 7) and the sludge is composted (Option 5). The Pb and Zn concentrations of the sludge are too high for unrestricted use, but still in Pollutant class b.

The sludge produced at this Plant is Type=A1b. The applicability of the management options is as follows:

- Agricultural use at agronomic rates – Allowed with restrictions due to Pollutant class (can be used if metal content of the soil is low)
- On-site or off-site disposal – Allowed, but should rather be used beneficially
- Beneficial use (not agriculture) – Allowed with restrictions
- Thermal treatment – Allowed, but should rather be used beneficially

- Saleable products – Allowed with significant restrictions due to Pollutant class

Wastewater Treatment Plant 3

Plant 3 is an activated sludge plant with nitrification, denitrification and biological phosphorus removal. There is no reduction in moisture content and currently the sludge is disposed on-site to dedicated land. Laboratory aerobic digestion tests (bench scale) at 20^{o}C have shown volatile solids (VS) reduction of 17% after 30 days. The average analyses of three (3) grab samples of the WAS is presented in Table 12.

The faecal coliform count of the sludge is high and therefore it is classified as Microbiological class C. The Stability class is 3, since tests done to proof compliance to vector attraction reduction option 3 was not acheived. The metal concentration of the sludge is low and the Pollutant class is a.

Thus, the sludge is Type=C3a and the applicability of the management options is as follows:

- Agricultural use at agronomic rates – Not allowed due to Microbiological and Stability classes. If a vector attraction reduction option is implemented, agricultural application can be allowed with restrictions due to the Microbiological class.
- On-site or off-site disposal – Not permissible without a vector attraction reduction option
- Beneficial use (not agriculture) – Allowed with major restrictions on some options
- Thermal treatment – Allowed, but dewatering will be required
- Saleable products – Not allowed due to Microbiological and Stability classes.

Wastewater Treatment Plant 4

This is an activated sludge plant with a sludge age of 21 days. The sludge is mechanically de-watered to 20% solids using a belt filter press and stored in a waste pile on-site. Lime is added to the waste pile during the wet season to reduce odours (20 days per year). Analyses results of three (3) samples from the belt filter press are detailed in Table 12.

The faecal coliform count of the sludge places it in Microbiological class B. Lime is added only in the rainy season, therefore <75% compliance to Option 6 of the vector attraction reduction options is achieved and the Stability class is 3. To increase the Stability class classification the WWTP should either implement Option 7 (reduce the moisture content to at least 75% solids) or to reduce the moisture content to at least 90% if the sludge still contains unstabilised solids. The metal concentration is low, therefore the Pollutant class is a.

The applicability of the management options is as follows (sludge Type=B3a):

- Agricultural use at agronomic rates – Not permissible due to the Stability class
- On-site or off-site disposal – Not permissible due to the Stability class
- Beneficial use (not agriculture) – Not permissible due to the Stability class

- Thermal treatment – Allowed with odour control restrictions
- Saleable products – Not allowed due to Microbiological class and Stability class.

This example clearly shows that options are severely limited due to the Stability class. Operators are encouraged to implement a vector attraction reduction option which will enable beneficial and other management options.

Wastewater Treatment Plant 5

Plant 5 produces compost from primary sludge after de-watering with a belt filter press. Analyses results of samples from the dry compost heaps are shown in Table 12. Due to the faecal coliform count the sludge is Microbiological class B. The stability class is 1 (Options 5 and 7) and the low metal content places the sludge in Pollutant class a.

This is a Type B1a sludge. The applicability of the management options is as follows:

- Agricultural use at agronomic rates – Allowed with restrictions due to Microbiological class
- On-site or off-site disposal – Allowed, but should rather be used beneficially
- Beneficial use – Allowed with restrictions
- Thermal treatment – Allowed, but should rather be used beneficially
- Saleable products – Allowed with restrictions due to the Microbiological class for some options

Note that, in this case, it would be in the interest of the producer to sample the compost just after production in order to assess if Microbiological class A cannot be achieved. If the compost sample still fails, small adjustments could be made to the composting operation and the microbiological quality re-assessed. If the producer can enhance the microbiological quality to the class A requirements, the product could be alienated and sold.

CONCLUSIONS

Volume 1 of the Sludge Guidelines was developed to assist the user to decide on an appropriate sludge management option(s) for a wastewater treatment plant. The Volume also assists the user on how to collect and analyse sludge samples and use the results to obtain a preliminary classification using the South African Sludge Classification System. This preliminary classification can then be used to select appropriate management options for each sludge type.

Once the management option is decided upon, the reader is ready to move on to the appropriate Sludge Guidelines Volume:

Volume 2: Requirements for the agricultural use of sludge

Volume 3: Requirements for the on-site and off- site disposal of sludge

Volume 4: Requirements for the beneficial use of sludge

Volume 5: Requirements for thermal sludge management practices and for commercial products containing sludge

The different volumes for different management options simplify the understanding of the requirements and restrictions that pertain to a particular management option.

APPENDIX 1: SELECTING THE APPROPRIATE SAMPLING POINTS AND COLLECTING SAMPLES

Collect at least three daily (24 hour) composite sludge samples from each sludge stream considered for use/disposal. If disinfection processes are employed, an additional three samples should be collected immediately after the disinfection process. The samples need to be cooled and sent to the laboratory as soon as possible to prevent contamination and re-growth. Figure A1 shows appropriate sampling positions for this purpose. It is important not to confuse plant operational sample points such as the clarifier underflow or the activated sludge return flow with the samples required for classification purposes, although in some cases these could be the same.

A laboratory will typically require at least 500 g $_{\text{dry mass}}$ to perform all the required analyses. In other words, if the sludge destined for disposal has a solids content (SS – suspended solids) of 1%, the laboratory can require up to 50 ℓ of sample. Discuss the requirements with the selected laboratory.

1000 ml "Consol" preservative container

Plants that employ dewatering, stabilisation, conditioning and/or disinfection should collect the sludge samples in a glass container and keep it cool (≤ 4 ºC) as this will minimise microbiological activity. The 1ℓ "Consol" preserve bottles are ideal but not required. Helminth ova adhere to glass. It is advisable to collect a separate Helminth ova sample in a plastic container.

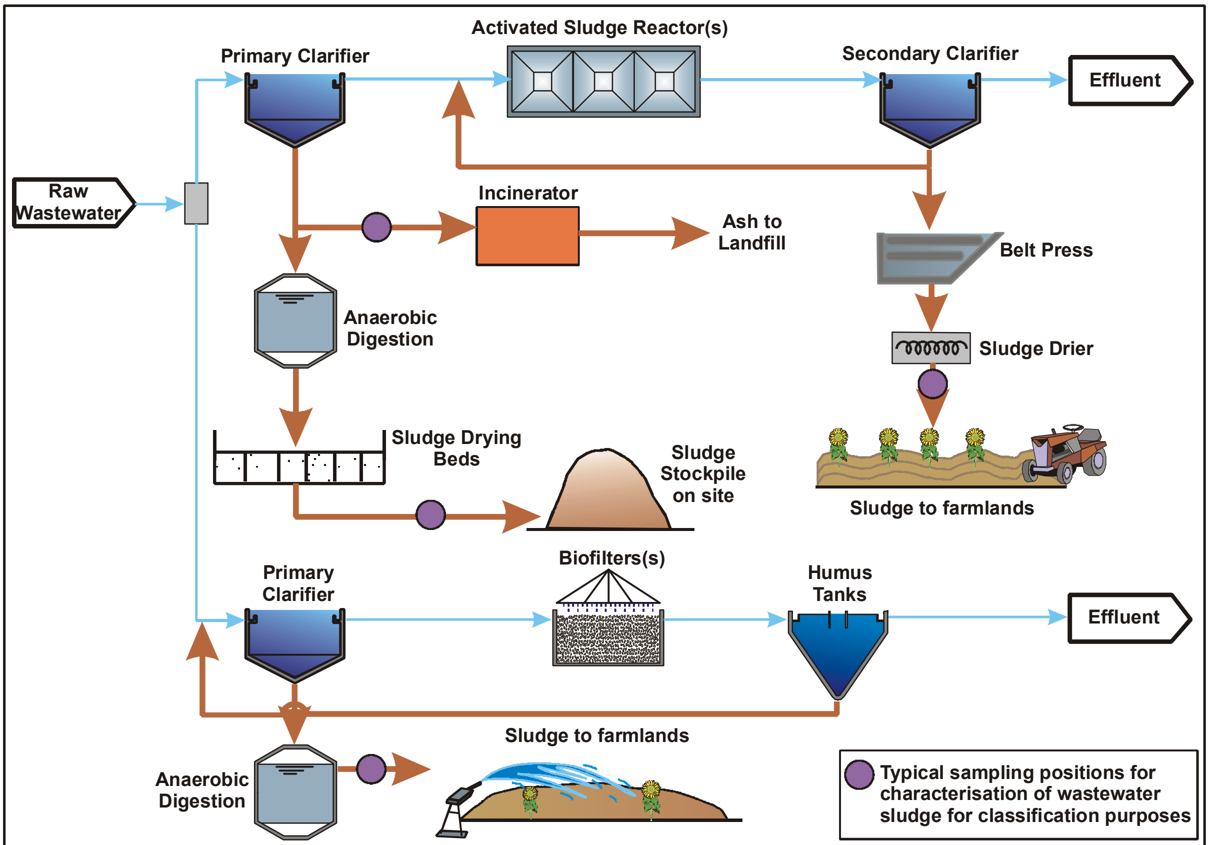

Figure A1 : Appropriate sampling positions for the collection of samples for the comprehensive characterisation of wastewater sludge

APPENDIX 2: ANALYTICAL METHODS

Appendix 2.1 Volatile acids and alkalinity

1. Scope

This method is applicable to the determination of volatile acids and alkalinity in sludge.

2. Principle

Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid to a pH 4.0. Evaporation of volatile material and titration to pH 6.2.

3. Interferences

Do not dilute, concentrate or alter sample. Soaps, oily matter, suspended solids, or precipitates may coat the glass electrode and cause a sluggish response.

4. Equipment

4.1 Where applicable use only class A volumetric glassware.
4.2 Centrifuge with centrifuge tubes.
4.3 Digital burette.
4.4 Pipette.
4.5 100 mℓ Erlenmeyer flask.
4.6 pH meter.
4.7 Magnetic stirrer with stirring bars.

5. Reagents and Standard Solutions

5.1 *Distilled water*: Conductivity should be less than ≤ 0.5 mS m^{-1}.

5.2 *Standard 0.1 mole per litre sulphuric acid H_2SO_4.*

5.2.1 Prepare a 0.1 mℓ H_2SO_4 solution by diluting 5.6 mℓ concentrated H_2SO_4 (sg = 1.84) to 1000 mℓ with distilled water.

5.3 *Standardisation of 0.1 mole per litre H_2SO_4.*

5.3.1 Standardise against 0.1 mol ℓ^{-1} Na_2CO_3. Dissolve 10.599 g Na_2CO_3 in 1000 mℓ of distilled/de-ionised water. Retention time: 3 months. Store in fridge.

5.3.2 Pipette 25 mL of the 0.1 mol ℓ^{-1} Na_2CO_3 in an Erlenmeyer flask.

5.3.3 Dilute with ± 25 mℓ distilled/de-ionised water.

5.3.4 Add 3 drops BDH "4.5" indicator.

5.3.5 Titrate with 0.1 mol ℓ^{-1} H_2SO_4, colour change from blue to orange.

5.3.6 Determine the H_2SO_4 concentration. See section 8.1.

5.4 *0.05 M/ℓ Sodium hydroxide (NaOH) solution.*

5.4.1 Prepare a 0.05 mol ℓ^{-1} sodium hydroxide (NaOH) solution by dissolving 2.0 g NaOH in about 800 mℓ distilled water. Cool down and make up to 1 ℓ.

5.5 *Standardisation of 0.05 mol ℓ^{-1} sodium hydroxide (NaOH).*

5.5.1 Standardise against 0.1 mol ℓ^{-1} H_2SO_4.

5.5.2 Pipette 25 mℓ of the 0.05 mol ℓ^{-1} NaOH in an Erlenmeyer flask.

5.5.3 Dilute with $\pm$ 25 mℓ distilled/de-ionised water.

5.5.4 Add 3 drops BDH "4.5" indicator.

5.5.5 Titrate with 0.1 mol ℓ^{-1} H_2SO_4.

5.5.6 Determine the NaOH concentration. See section 8.1.

5.6 *Quality Control solutions for alkalinity: (QC 1: 1500 mg/ℓ.)*

5.6.1 Dissolve 1.65 g Na_2CO_3 (dried for 4 hours at 105°C $\pm$ 2°C) in an A grade 1L Volumetric Flask and bring to the mark with distilled/de-ionised water. Store in the fridge in a polyethylene bottle. Retention time: 1 month.

5.7 *Quality Control solutions for alkalinity: (QC 2: 500 mg/ℓ.)*

5.7.1 Dissolve 0.55 g Na_2CO_3 (dried for 4 hours at 105°C $\pm$ 2°C) in an A grade 1ℓ Volumetric Flask and bring to the mark with distilled/de-ionised water. Store in the fridge in a polyethylene bottle. Retention time: 1 month.

6. Sampling and Storage:

Collect samples in polyethylene or borosilicate glass bottles and store at a low temperature. Fill bottles completely and cap tightly.

7. Analytical Procedure

7.1 Centrifuge the sludge sample for about 5 minutes at 4000 r.p.m.

7.2 Measure out 50 mℓ of the water into a 100 mL Erlenmeyer flask.

7.3 Titrate with 0.1 mol ℓ^{-1} H_2SO_4 solution to pH 4.0 and determine alkalinity by noting amount of acid titrated.

7.4 Add acid to bring pH to 3.2 to 3.5.

7.5 Evaporate on water bath for 30 minutes. Cool to room temperature and titrate with 0.05 mol ℓ^{-1} sodium hydroxide to a pH of 4.0. Zero the burette.

7.6 Titrate to a pH of 6.2 with 0.05 mol ℓ^{-1} sodium hydroxide and note titration volume needed.

8. Calculation of Results

8.1 Standardisation of acid or base

C_aV_a = C_bV_b
C_a = Concentration of acid
V_a = Volume of acid titrated
C_b = Concentration of base: $^{\text{mass primary standard}}/_{\text{molar mass}}$ = mol
V_b = Volume of base used
MF = Multiplication factor

8.1.1 Concentration of acid $= \frac{C_b V_b}{V_a}$

$= \frac{\text{Concentration x 25 m}\ell}{V_a\ (\text{m}\ell)}$

$= \pm 0.1\ \text{mol}\ \ell^{-1}$

8.1.2 Concentration of base $= \frac{2(C_a V_a)}{V_b}$

$= \frac{2(\text{concentration x } V_a)}{25\ \text{m}\ell}$

$= \pm 0.05\ \text{mol}\ \ell^{-1}$

8.1.3 Multiplication factor for alkalinity $= \frac{\text{Concentration of acid calculated in 8.1.1}}{\text{Actual concentration of acid}}$

$= \frac{\pm 0.1000\ \text{mol}\ \ell^{-1} \text{ x } 200}{0.1000\ \text{mol}\ \ell^{-1}}$

± 200

8.1.4 Multiplication factor for acid $= \frac{\text{Concentration of acid calculated in 8.1.2}}{\text{Actual concentration of base}}$

$= \frac{\pm 0.05\ \text{mol}\ \ell^{-1} \text{ x } 200}{0.05\ \text{mol}\ \ell^{-1}}$

± 1

8.1.5 Alkalinity determination $= \frac{\text{Concentration of acid calculated in 8.1.1 x normalityx50 000}}{\text{Volume of sample}}$

$= \frac{\text{Titrated (m}\ell\text{) x (}\pm\text{0.2N) x 50 000}}{50\ \text{m}\ell}$

$= \text{Titrated (m}\ell\text{) x (}\pm 2000\text{)}$

8.2 Total alkalinity = (acid titration to pH 4) x (±200)

To convert from molarity to normality:

M = D x V

= 1.84 x (5.6 mL)

= 10.304g

$$\text{BUT equivalent mass} = \frac{\text{molar mass}}{Z}$$

Z is the factor that depends on the chemical context (chemical reaction involved). For acids the value of Z is equal to the number of moles of H^+, displaceable from one mole of acid, e.g. for HCl, =Z = 1, while for H_2SO_4, Z = 2.

$$\text{Molar mass of } H_2SO_4 = 89.08 \text{ g mol}^{-1}$$

$$\text{The equivalent mass of } H_2SO_4 = \frac{89.08 \text{ g mol}^{-1}}{2} = 49.04 \text{ g mol}^{-1}$$

The normality when 5.6 mL of H_2SO_4 is used will then be:

$$\text{Normality} = \frac{\text{mass used}}{{}^{g}\!/_{\text{equivalent}}}$$

$$= \frac{10.304 \text{ g}}{49.04\ {}^{g}\!/_{\text{equivalent}}}$$

$$= 0.21 \text{ N}$$

$$\therefore\ 0.1 \text{ M } H_2SO_4 = 0.21 \text{ N } H_2SO_4$$

If NaOH titration from 4.0 to 6.2 < 3.7, then x 50.

If NaOH titration from 4.0 to 6.2 $\geq$ 3.7, then x 75.

9. Reporting of Results

9.1 Express results as Total Alkalinity in mg $CaCO_3\ \ell^{-1}$.

9.2 Express results as Volatile Acid in mg $CH_3COOH\ \ell^{-1}$.

Reference: Adapted from Standard Methods. 1998. American Public Health Association, American Water Works Association, Water Environment Federation. *Standard methods for the examination of water and wastewater.* Edited by M.A.F. Franson, A.D. Eaton, L.S. Clesceri, and A.E. Greenberg. 20th Edition. Washington DC. USA. American Public Health Association

Appendix 2.2 Procedure to determine Helminth ova in wastewater sludge

The method below was developed for the determination of *Ascaris* ova in wastewater and sludge samples. The method can also be used for the determination of all helminth' ova. The method is currently being optimised and adapted to ensure better recovery (Jimenez-Cisneros, 2005). The updated method will be communicated as soon as it becomes available. In the interim, laboratories are urged to adopt the method detailed below (adapted from EPA/625/R-92/013).

Test Method for Detecting, Enumerating, and Determining the Viability of Ascaris Ova in Sludge

1. Scope

This test method describes the detection, enumeration, and determination of viability of *Ascaris* ova in water, wastewater, sludge, and compost. These pathogenic intestinal helminths occur in domestic animals and humans. The environment may become contaminated through direct deposit of human or animal faeces or through sewage and wastewater discharges to receiving waters. Ingestion of water containing infective *Ascaris* ova may cause disease.

This test method is for wastewater, sludge, and compost. It is the user's responsibility to ensure the validity of this test method for untested matrices.

This standard does not purport to address all the safety problems associated with it use. It is the responsibility of the user of this standard to establish appropriate safety and health practices.

2. Terminology

The normal nematode life cycle consists of the egg, 4 larval stages and an adult. The larvae are similar in appearance to the adults; that is, they are typically worm-like in appearance.

Molting *(ecdysis)* of the outer layer *(cuticle)* takes place after each larval stage. Molting consists of 2 distinct processes, the deposition of the new cuticle and the shedding of the old one or escheatment. The cuticle appears to be produced continuously, even throughout adult life.

A molted cuticle that still encapsulates a larva is called a *sheath.*

Ascarid egg shells are commonly comprised of layers. The outer tanned, bumpy layer is referred to as the *mammillae* layer and is useful in identifying Ascaris eggs. The mammillae layer is sometimes absent. Eggs that do not possess the mammillae layer are referred to as *decorticated eggs.*

A potentially infective Ascaris egg contains a third stage larva encased in a sheath of the first larval stage.

3. Summary of Test Method

This method is used to concentrate pathogenic *Ascaris* ova from wastewater, sludge, and compost. Samples are processed by blending with buffered water containing a surfactant. The blend is screened to remove large particulates. The solids in the screened portion are allowed to settle out and the supernatant is decanted. The sediment is subjected to density gradient centrifugation using magnesium sulfate (specific gravity 1.20). This flotation procedure yields a layer likely to contain Ascaris and some other parasitic ova if present in the sample. Small particulates are removed by a second screening on a small mesh size screen. Proteinaceous material is removed using an acid alcohol/ethyl acetate extraction step. The resulting concentrate is incubated at 26°C. until control *Ascaris eggs* are fully embrocated. The concentrate is then microscopically examined for the categories of *Ascaris* ova on a Sedgwick-Rafter counting chamber.

4. Significance and Use

This test method is useful for providing a quantitative indication of the level of *Ascaris* ova contamination of wastewater, sludge, and compost.

This test method will not identify the species of *Ascaris* detected nor the host of origin.

This method may be useful in evaluating the effectiveness of treatment.

5. Interferences

Freezing of samples will interfere with the buoyant density of *Ascaris* ova and decrease the recovery of ova.

6. Apparatus

6.1 A good light microscope equipped with bright field, and preferably with phase contrast and/or differential contrast optics including objectives ranging in power from.

6.2 Sedgwick-Rafter cell.

6.3 Pyrex beakers, 2 ℓ. Coat with organosilane.

6.4 Erlenmeyer flask, 500 mℓ. Coat with organosilane.

6.5 A centrifuge that can sustain forces of at least 660 X G with the rotors listed below.

6.4.1 A swinging bucket rotor to hold 100 or 250 mℓ centrifuge glass or plastic conical bottles.

6.4.2 A swinging bucket rotor to hold 15 mℓ conical glass or plastic centrifuge tubes.

6.6 Tyler sieves.

6.5.1 20 or 50 mesh.

6.5.2 400 mesh, stainless steel, 5 inch (12.7 cm) in diameter.

6.5.3 A large plastic funnel to support the sieve. Coat with organosilane.

6.7 Teflon spatula.

6.8 Incubator set at 26°C.

6.9 Large test tube rack to accommodate 100 or 250 mℓ centrifuge tubes.

6.10 Small test tube rack to accommodate 15 mℓ conical centrifuge tubes.

6.11 Centrifuge tubes, 100 or 250 mℓ. Coat with organosilane.

6.12 Conical centrifuge tubes, 15 mℓ. Coat with organosilane.

6.13 Stoppers.

6.14 Wooden applicator sticks.

6.15 Pasteur pipettes. Coat with organosilane.

6.16 Vacuum aspiration apparatus.

6.16.1 Vacuum source.
6.16.2 Vacuum flask, 2 ℓ or larger.
6.16.3 Stopper to fit vacuum flask, fitted with a glass or metal tubing as a connector for l/4 inch tygon tubing.

6.17 Wash bottles (500 mℓ), label "Water".

6.18 Spray bottles (16 fl oz.) (2).

6.18.1 Label one "Water".

6.18.2 Label one "1% 7X".

7. Reagents and Materials

7.1 Purity of Reagents - Reagent grade chemicals shall be used in all tests. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 Purity of Water - Unless otherwise indicated, references to water shall be understood to mean reagent water.

7.3 Preparation of Reagents

7.3.1 Phosphate buffered water (1 ℓ = 34.0 g KH_2PO_4, pH adjusted to 7.2 ± 0.5 with 1 N NaOH).

7.3.2 1% (v/v) 7X ("Limbro" laboratory detergent) (1 ℓ = 999 ml phosphate-buffered water, 1 ml 7X "Limbro", Adjust pH to 7.2 + 0.1 with 1 N NaOH).

7.3.3 Magnesium sulphate, sp. gr. 1.20. (1 ℓ= 215.2 g $MgSO_4$ check specific gravity with a hydrometer; adjust as necessary to reach 1.20).

7.3.4 Acid alcohol. 0.1 N H_2SO_4, made in 35% ethyl alcohol. (100 mℓ = 35 ml EtOH, 0.9807 g H_2SO_4)

7.3.5 Ethyl Acetate, reagent grade.

7.4 Organosilane. For coating glassware (This is to prevent the Helminth Ova from adhering to the glass). Coat all glassware according to manufacturer's instructions. (Alternatively, only use only plastic equipment)

7.5 Fresh *Ascaris* ova for positive control, either dissected from *Ascaris* suum gravid adult female worms or purified from *Ascaris* infected pig faecal material. (Other Helminth ova can also be used)

8. Precautions

8.1 When harvesting *Ascaris* ova (or any other Helminth ova) from gravid female worms, the analyst must wear latex gloves, a surgical mask and protective goggles or full face mask, and laboratory coat before dissecting the worms. Moreover, it is recommended that the *Ascaris* ova (or any other Helminth ova) (or any other Helminth ova) harvest be carried out either in a biological safety cabinet or minimally a chemical hood. These precautions are designed to prevent the development of an allergy to *Ascaris* pseudocoelomic fluid. If infective Ascaris ova are ingested they may cause disease.

9. Sampling

9.1 Collect 1 litre of compost, wastewater, or sludge in accordance with standard sampling methodology.

9.2 Place the sample container(s) on wet ice or around chemical ice and transport back to the laboratory for analysis within 24 hours of collection.

9.3 Store the samples in the laboratory refrigerated at 2 to 5°C. Do not freeze the samples during transport or storage.

10. Preparation of Apparatus

Follow the manufacturer's instructions

11. Calibration and Standardization

Follow the manufacturer's instructions

12. Procedure

12.1 The percentage moisture of the sample is determined by analysing a separate portion of the sample, so the final calculation of ova per gram dry weight can be determined. The concentration of ova in liquid sludge samples may be expressed as ova per unit volume.

12.2 Initial preparation:

12.1.1 Dry or thick samples: Weigh about 300 g (estimated dry weight) and place in about 500 mℓ water in a beaker and let soak overnight at 4 - 10°C. Transfer to blender and blend at high for one minute. Divide sample into four beakers.

12.1.2 Liquid samples: Measure 1000 mℓ or more (estimated to contain at least 50 g dry solids) of liquid sample. Place one half of sample in blender. Add about 200 mℓ water. Blend at high speed for one minute transfer to a beaker. Repeat for other half of sample.

12.3 Pour the homogenized sample into a 1000 mℓ tall form beaker and using a wash bottle, thoroughly rinse blender container into beaker. Add 1% 7X to reach 900 mℓ final volume.

12.4 Allow sample to settle four hours or overnight at 4 - 10°C. Stir occasionally with a wooden applicator, as needed to ensure that material floating on the surface settles. Additional 1% 7X may be added, and the mixture stirred if necessary.

12.5 After settling, vacuum aspirate supernatant to just above the layer of solids. Transfer sediment to blender and add water to 500 mℓ, blend again for one minute at high speed. (Aspiration can also be done manually using plastic pipettes)

12.6 Transfer to beaker, rinsing blender and add 1% 7X to reach 900 mℓ. Allow to settle for two hours at 4 - 1O°C, vacuum aspirate supernatant to just above the layer of solids.

12.7 Add 300 mℓ 1% 7X and stir for five minutes on a magnetic stirrer.

12.8 Strain homogenized sample through a 20 or 50 mesh sieve placed in a funnel over a tall beaker. Wash sample through sieve with a spray of 1% 7X from a spray bottle.

12.9 Add 1% 7X to 900 mℓ final volume and allow to settle for two hours at 4 - 1O°C.

12.10 Vacuum aspirate supernatant to just above layer of solids. (Aspiration can also be done manually using plastic pipettes). Mix sediment and distribute equally to 50 mℓ graduated conical centrifuge tubes. Thoroughly wash any sediment from beaker into tubes using water from a wash bottle. Bring volume in tubes up to 50 mℓ with water.

12.11 Centrifuge for 10 minutes at 1000 X G. Vacuum aspirate supernatant from each tube down to just above the level of sediment. (Aspiration can also be done manually using plastic pipettes). The packed sediment in each tube should not exceed 5 mℓ. If it exceeds this volume, add water and distribute the sediment evenly among additional tubes, repeat centrifugation, and vacuum aspirate supernatant.

12.12 Add 10 to 15 mℓ of $MgSO_4$ solution (specific gravity 1.20) to each tube and mix for 15 to 20 seconds on a vortex mixer. (Use capped tubes to avoid splashing of mixture from the tube.)

12.13 Add additional $MgSO_4$ solution (specific gravity 1.20) to each tube to bring volume to 50 mℓ. Centrifuge for five to ten minutes at 800 to 1000 X g.

12.14 Allow the centrifuge to stop without the brake. Pour the top 25 to 35 mℓ of supernatant from each tube through a 400 mesh sieve supported in a funnel over a tall beaker.

12.15 Using a water spray bottle, wash excessive flotation fluid and fine particles through sieve.

12.16 Rinse sediment collected on the sieve into a 100 mℓ beaker by directing the stream of water from the wash bottle onto the upper surface of the sieve.

12.17 After thoroughly washing the sediment from the sieve, transfer the suspension to the required number of 15 mℓ centrifuge tubes, taking care to rinse the beaker into the tubes. Usually one beaker makes one tube.

12.18 Centrifuge the tubes for three minutes at 800 X G, then discard the supernatant.

12.19 If more than one tube has been used for the sample, transfer the sediment to a single tube, fill with water, and repeat centrifugation.

12.20 Re-suspend the pellet in 7 mℓ acid alcohol solution and add 3 ml ethyl acetate.

12.21 Cap the tube with a rubber stopper and invert several times, venting after each inversion.

12.22 Centrifuge the tube at 660 x G for 3 minutes.

12.23 Aspirate the supernatant above the solids.

12.24 Re-suspend the solids in 4 ml 0.1 N H_2SO_4 and pour into a 220-mℓ polyethylene scintillation vial or equivalent with loose caps.

12.25 Before incubating the vials, mark the liquid level in each vial with a felt tip pen. Incubate the vials, along with control vials containing *Ascaris* or other Helminth ova mixed with 4 mℓ 0.1 N H_2SO_4 at 26°C for three to four weeks. Every day or so, check the liquid level in each vial. Add reagent grade water up to the initial liquid level line as needed to compensate for evaporation. After 18 days, suspend, by inversion and sample small aliquots of the control cultures once every 2 - 3 days. When the majority of the control *Ascaris* ova are fully embryonated, samples are ready to be examined.

12.26 Examine the concentrates microscopically using a Sedgwick-Rafter cell to enumerate the detected ova. Classify the ova as either unembryonated, embryonated to the first, second or third larval stage. In some embryonated *Ascaris* ova the larva may be observed to move.

See Figures below for examples of various Ascaris egg categories.

13. Calculation

13.1 Calculate % total solids using the % moisture result:

% Total solids = 100% - % Moisture

13.2 Calculate categories of ova/g dry weight in the following manner:

$$\text{Ova/g dry wt} = \frac{(NO) \times (CV) \times (FV)}{(SP) \times (TS)}$$

Where:

NO = no. ova

CV = chamber volume(= 1 mℓ)

FV = final volume in mℓ

SP = sample processed in mℓ or g

TS = % total solids

14. Report

14.1 Report the results as the total number of *Ascaris* ova, number of unembryonated *Ascaris* ova, number of 1st, 2nd or 3rd stage larva; reported as number of *Ascaris* ova and number of various larval *Ascaris* ova per g dry weight. Representative reporting forms are shown in Figures below.

Reference: EPA Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge. EPAl625/R-921013, Revised October 1999

Note: This method is currently being revised and adapted and the most recent version will be communicated to interested parties as soon as it becomes available.

Figure 2. *Ascaris* ovum: fertile, note the bumpy outer mammilated layer.

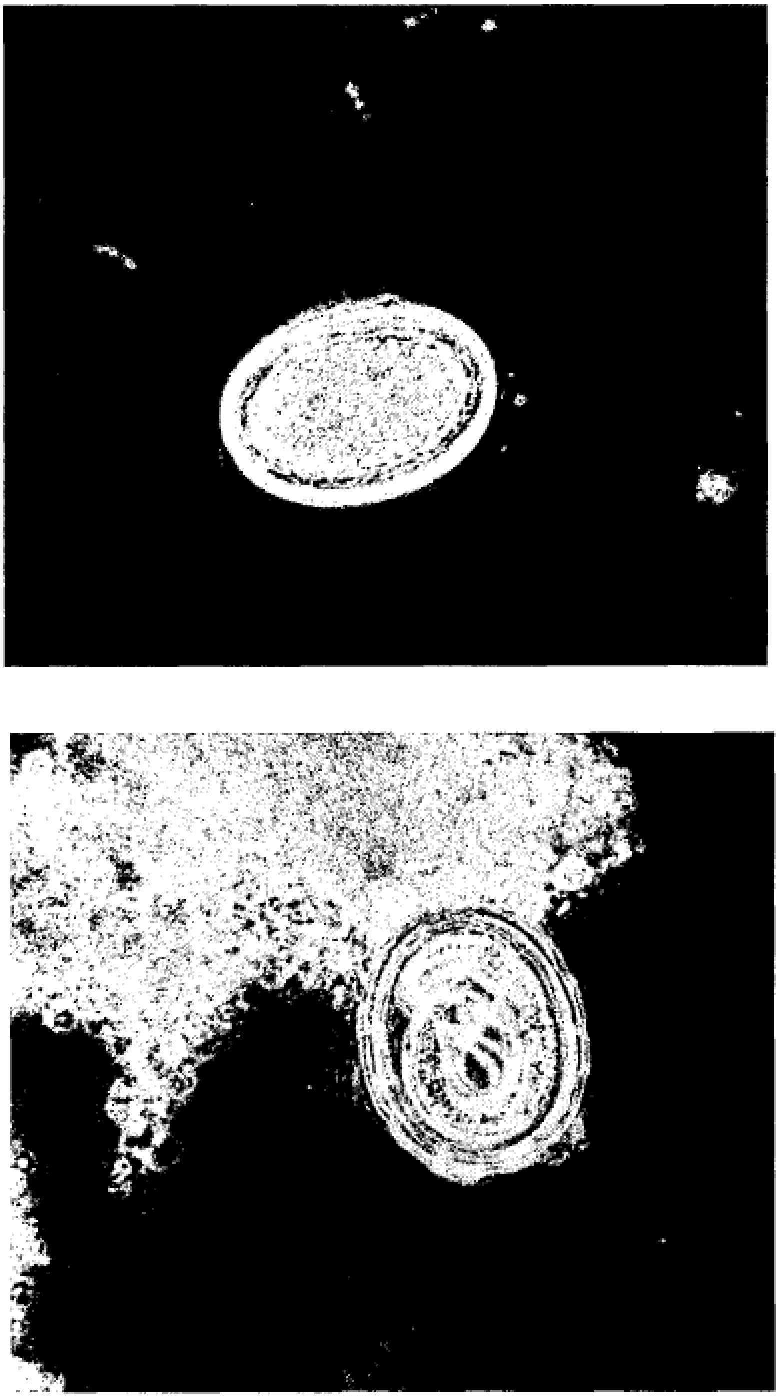

Figure 4. *Ascaris* ovum: decorticated and embryonated.

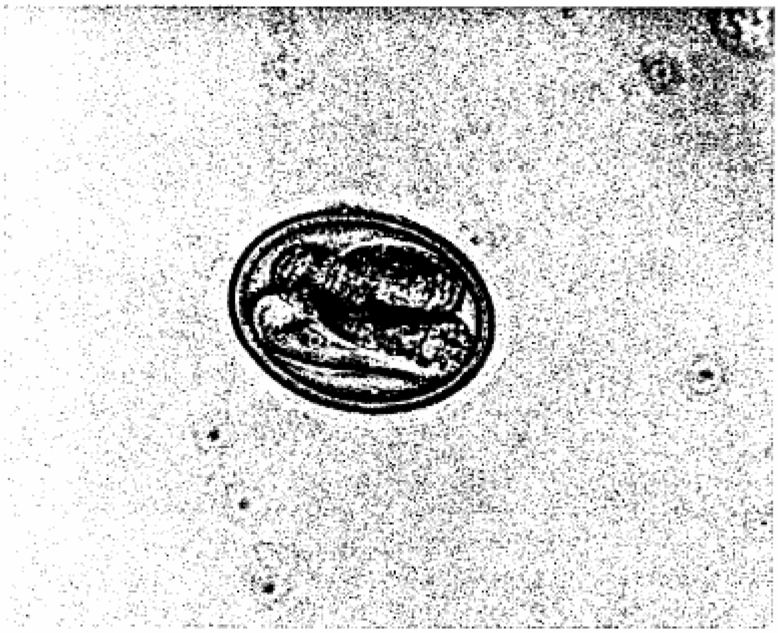

FIgure 5. *Ascaris* ovum: decorticated, embryonated.

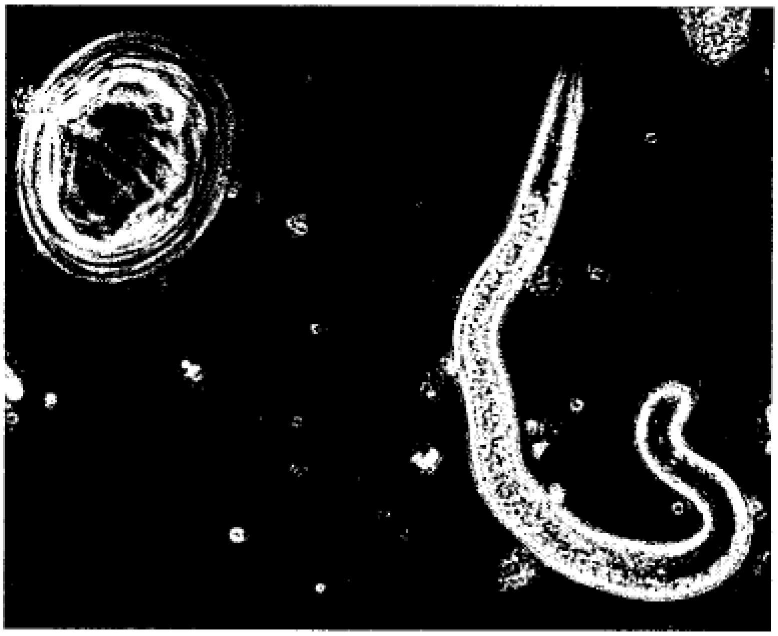

Figure 6. *Ascaris* ovum with second stage or potentially third stage larva; note the first stage larval sheath at the anterior end of the worm.

Appendix 2.3 Methods for the determination of Total Kjeldahl Nitrogen and Total Phosphorus in sludge samples

Kjeldahl digestion to determine N

REAGENTS: Concentrated Sulphuric Acid,(H_2SO_4) Digestion Mixture: Potassium sulphate (AR) very finely ground (1500g) mixed with 4g finely ground (AR) Cu $SO_4 \cdot 5H_{20}$.

Weigh out 1.000g of sludge into a digestion tube, and mix it with 2.0g of the digestion mixture. Place this on a block at 360ºC, covered with glass "pears". Digest for 2 hours or until solution is clear. Do not allow to dry. Remove from the block and cool slightly, then add 5 mℓ deionised water before cooling completely. Once cooled, rinse into a 100ml volumetric flask, bringing it up to volume. Filter using Whatman no 2 filter paper.

Reference: Croll BT, Tomlinson T and Whitfield RW. 1985. Determination of Kjeldahl nitrogen in sewage effluents, trade effluent and sewage sludge. *Analyst* 110:861-866.

Method for Digestion and Determination of P and K

Sample Digestion: 1g of sample is digested with 7mℓ HNO_3 (conc. nitric acid) and 3mℓ $HClO_4$ (perchloric acid) at temperature up to 200°C and brought to volume in a 100mℓ vol. flask. (Adapted from method for plant digestion at ISCW).

P and K Determination

The P and K can then be determined by ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectroscopy). Values can also be confirmed by DCP (Direct Current Plasma Emission Spectroscopy) at a wavelength of 253.565 nm.

Reference: Zasoski, RJ and Burau, RG. 1977. A Rapid Nitric-Perchloric Acid Digestion Method for Multi-Element Tissue Analysis. *Communications in Soil Science and Plant Analysis. vol. 8 (*5):425-436.

Appendix 2.4 Method for the determination of total metal content of sludge and soil samples (aqua regia digestion)

The method is summarized below.

- Weigh 3g of the <150µm sludge or soil sample into a 250mℓreaction vessel.
- Moisten with 0.5-1mℓ water and add, while mixing, 21mℓ hydrochloric acid followed by 7ml nitric acid, drop by drop if necessary to reduce foaming.
- Stand for 16h at room temperature
- Boil under reflux for 2h
- Decant the sediment-free supernatant into 100ml flask through filter paper
- Fill the flask to the mark with 0.5mol/ℓ nitric acid

The full method can be found in the reference below.

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

APPENDIX 3: 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 x 0.68)} x 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 30º and 37ºC, 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 20ºC, 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 20ºC, 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 ºC basis. This test is only applicable to liquid aerobic sludge withdrawn from an aerobic treatment process.

Option 5: Aerobic Processes at Greater than 40 ºC

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 40ºC and the average temperature must be higher than 45ºC.

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 ºC, 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 re-grow 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 times referred 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.

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 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.

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 need to monitor the development of odours and manage the situation diligently.

DEFINITIONS AND DESCRIPTION OF KEY TERMS

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.
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.
BPEO:	Best Practicable Environmental Option. BPEO is the outcome of a systematic consultative and decision-making procedure that emphasises the protection of the environment across land, air and water. It establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole at acceptable cost in the long term as well as the short term.
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.

Cumulative pollutant loading rate: The maximum amount of a pollutant that can be applied to a unit area of land.

Dedicated land disposal Sites that receive repeated applications of sludge for the sole purpose of final disposal.

Delisting: DWAF Minimum Requirements. If the EEC (Estimated Environmental Concentration) is less than the Acceptable Risk Level (0,1 x 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 ($G:B^{+}$landfill).

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.

Domestic septage: Liquid or solid material removed from a septic tank, cesspool, portable toilet, marine sanitation device, or similar treatment works that receives only domestic sewage. Domestic septage does not include liquid or solid material removed from a septic tank, cesspool, or similar treatment works that receives either commercial or industrial wastewater and does not include grease removed from a grease trap at a restaurant.

Domestic sewage: Waste and wastewater from humans or household operations that is discharged to, or otherwise enters a treatment works.

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).

***E. coli*:** A subset of coliforms found in the intestinal tract of humans and other warm-blooded animals. They can produce acid and gas from lactose at 44 to 44.5ºC; hence the test for them is more specific than for total coliforms and selects a narrower range of organisms. They are a more specific indicator of faecal contamination than total coliforms.

Estimated Environmental Concentration (EEC): The Estimated Environmental Concentration represents the concentration of a substance to 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.
General Waste:	Waste that does not pose an immediate threat to man or to the environment, i.e., household waste, builders' rubble, garden waste, dry industrial and commercial waste. It may, however, with decomposition, infiltration and percolation, produce leachate with an unacceptable pollution potential.
Hazardous Waste:	Waste, other than radioactive waste, which is legally defined as Hazardous in the state in which it is generated, transported or disposed of. The definition is based on the chemical reactivity or toxic, explosive, corrosive or other characteristics which cause, or are likely to cause, danger to health or to the environment, whether alone or when in contact with other waste. After UNEP definition.
Helminth ova:	The eggs of parasitic intestinal worms.
Immobilisation:	Immobilisation (or chemical stabilisation) is a process in which the material is converted to a more chemically stable or more insoluble or more immobile form.
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.
Industrial wastewater:	Wastewater generated in a commercial, industrial, or manufacturing process.
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 grade, 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.
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.

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

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.

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.

Precautionary principle: Where a risk is unknown; the assumption of the worst-case situation and the making of provision for such a situation.

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.

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

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

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.

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 soils where further investigation is necessary before sludge application can commence.

Total maximum threshold (TMT): The maximum total metal concentration allowed in soils receiving sludge.

Toxic: Poisonous.

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.

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.

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).