Guidelines for the Utilisation and Disposal of Water Treatment Residues

JE Herselman

WATER RESEARCH COMMISSION
TT 559/13

Guideline for the Utilisation and Disposal of Water Treatment Residues

JE Herselman

Report to the

Water Research Commission

by

Golder Associates Africa

WRC Report No. TT 559/13

April 2013

btainable from:

Water Research Commission
Private Bag X03
Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za

The publication of this report emanates from a project entitled: *Guideline for the utilization and disposal of Water Treatment Residues* (WRC Project No. 1723)

ISBN 978-1-4312-0409-0
Printed in the Republic of South Africa

ACKNOWLEDGEMENTS

The Guideline in this Volume emanated from a project funded jointly by the Water Research Commission entitled:

"GUIDELINE FOR THE UTILIZATION AND DISPOSAL OF WATER TREATMENT RESIDUES"

The Reference Group responsible for this project consisted of the following persons:

Mr M du Plessis	Water Research Commission (Chairman)
Ms M Swart	Department of Water and Environmental Affairs , DWEA
Mr KP Taylor	Department of Agriculture, Forestry and Fisheries
Mr N Basson	Sedibeng Water
Ms M Kruger	Midvaal Water Co.
Mr O Baloyi	Department of Water and Environmental Affairs, DWEA

Project team:

Dr JE Herselman	Golder Associates Africa (Project leader)
Mrs P Moodley	Zitholele Consulting
Mrs LA Boyd	Golder Associates Africa
Ms W Mosupye	Zitholele Consulting

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

The project team want to acknowledge Beulah Sanders (graphics design) for her assistance.

STRUCTURE OF THIS GUIDELINE VOLUME

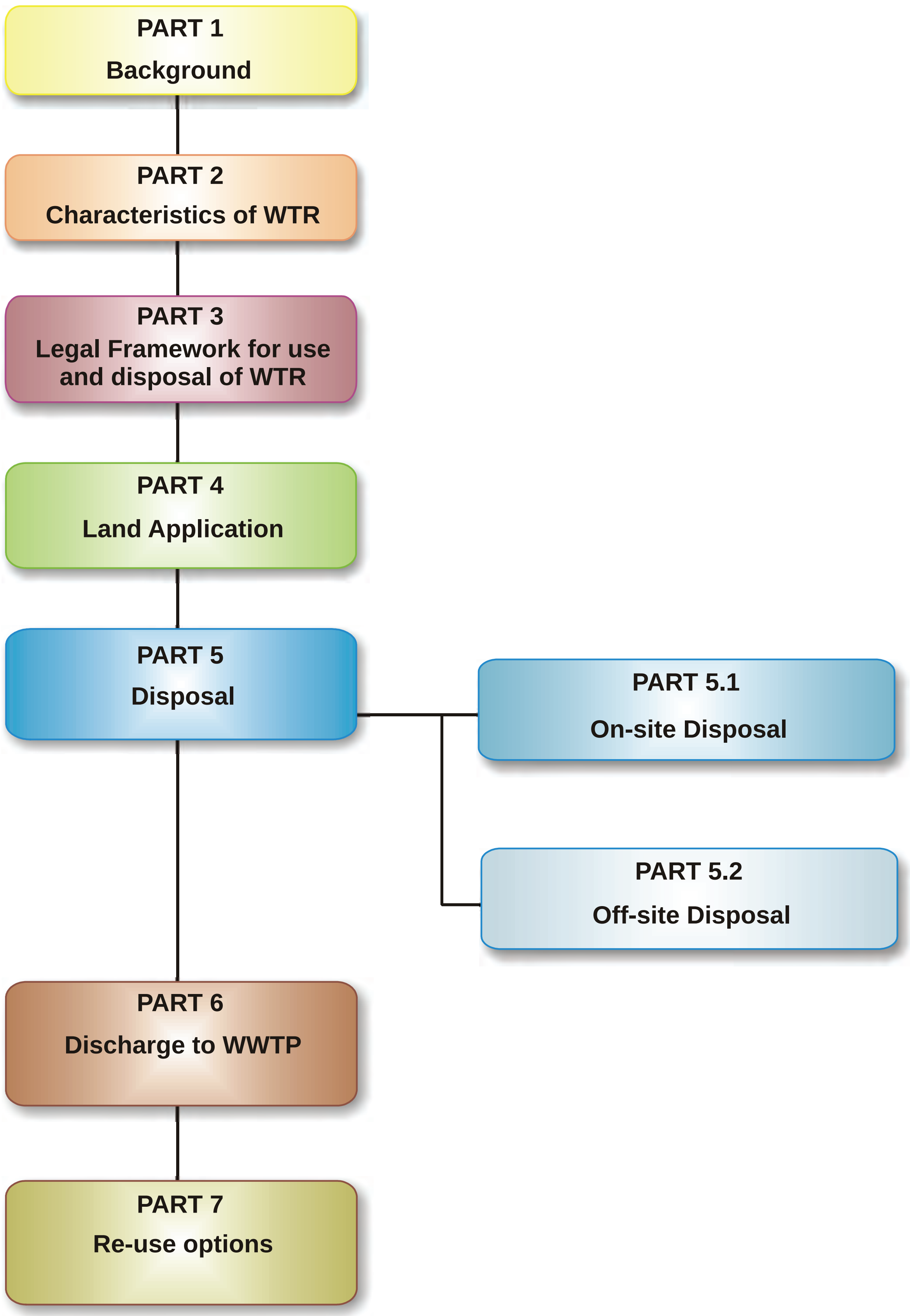


TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AE	Acceptable Exposure
ARL	Acceptable risk level
BOD	Biological oxygen demand
CARA	Conservation of Agricultural Resources Act (Act No. 43 of 1983)
COD	Chemical oxygen demand
DEAT	Department of Environmental Affairs and Tourism (now DWEA, see below)
DWAE	Department of Water and Environmental Affairs (DWEA)
DWAF	Department of Water Affairs and Forestry (now DWEA)
ECA	Environment Conservation Act 73 of 1989
EEC	Estimated Environmental Concentration
EIA	Environmental Impact Assessment
GAC	Granular activated carbon
HR	Hazard rating
MAT	Maximum available threshold
MPL	Maximum permissible level
NEMA	National Environmental Act, No. 107 of 1998
NWA	National Water Act 36 of 1998
OSH	Occupational Health and Safety Act
PAC	Powdered activated carbon
PPE	Personal protective equipment
RoD	Record of Decision
TCLP	Toxicity Characteristic Leaching Procedure
TIL	Total investigative level
TMT	Total maximum threshold
TTV	Total trigger values
WSA	Water services authorities
WSP	Water services providers
WTP	Water treatment plant
WTR	Water treatment residues
WWTP	Wastewater treatment plant

INTRODUCTION

Potable water treatment plants (WTP) produce a hygienically safe drinking water for consumption through a variety of treatment processes. However, they also produce waste products (water treatment residues or WTR) including organic and inorganic compounds in liquid, solid and gaseous phases. The term WTR replaces the previous term "water treatment sludge" to avoid confusion with wastewater sludge.

Definition of water treatment residues:

Water treatment residue (WTR) is defined as '*the accumulated solids or precipitate removed from a sedimentation basin, settling tank, or clarifier in a water treatment plant*'

The solid particles accumulated in the WTR are the result of chemical coagulation, flocculation and sedimentation of raw water. Aluminium sulphate, ferric salts, lime and poly-electrolytes are among the chemicals added to promote flocculation. The type and concentration of chemical(s) present in the WTR depend on the quality of the raw water, added chemicals and the purification process.

AIM OF THE WTR GUIDELINE

This Guideline deals with the requirements of different management options for the utilisation and/or disposal of WTR. The Guideline aim to assist the WTR producer to:

- Utilise/dispose the WTR in an environmentally responsible way;
- Ensure that WTR is handled within the legislative framework;
- Mitigate any potential adverse environmental effects caused by the selected management option by implementing the necessary requirements; and
- Implement the monitoring requirements for the selected management option.

WHO SHOULD USE THIS VOLUME?

This Guideline was developed to ensure safe use and disposal of WTR. Any person who effectively applies the Guideline will comply with environmental, social and regulatory requirements. This Guideline was developed for:

- **Water treatment plant operators and service providers** – to understand the requirements for managing WTR generated at the WTP;
- **Water services providers (WSP) and Water service authorities (WSA)** – to understand what is required to effectively operate and monitor a WTR management strategy and to implement and manage this management strategy;
- **Water treatment plant planners** – to design a scheme that complies with the requirements stipulated in the Guideline, while understanding the long term operational and maintenance requirements;
- **Water 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;
- **Legislators/Regulatory Authorities** – to assess compliance in applicable cases where the WTR Guideline have been referred to in a water use authorisation or waste disposal site permit;
- **Technical advisors** – to provide appropriate advice on the utilisation and/or disposal of WTR;
- **WTR users** – to effectively and responsibly utilise and/or dispose WTR;
- **Landfill site owners/operators** – to manage the WTR accepted on the site;
- **Educators** – to build capacity and create awareness.

DOCUMENT ROADMAP

PART 1
Background

PART 2
Characteristics of WTR

PART 3
Legal Framework for use and disposal of WTR

PART 4
Land Application

PART 5
Disposal

- **PART 5.1** — **On-site Disposal**
- **PART 5.2** — **Off-site Disposal**

PART 6
Discharge to WWTP

PART 7
Re-use options

PART 1:

BACKGROUND

Traditionally, WTR has been sent to landfill for disposal but an option gaining acceptance internationally is land application where WTR is applied directly onto land. The reasoning behind this approach is that physical, chemical and biological properties of the soil can be used to digest the applied waste without inducing negative effects on soil quality, groundwater or plant growth. It is acknowledged that there are still information gaps regarding the characteristics of South African WTR and its beneficial use. However, WTRs are produced on a daily bases and have to be utilized or disposed. Therefore this guideline for the use and disposal of these residues are an important step in the responsible management of WTR.

APPROACH FOLLOWED TO DEVELOP THE GUIDELINE

The WTR Guideline is based on the following information:

- Local and international research findings;
- Local legislative and guiding documents;
- International Guideline and legislative trends;
- The results of risk assessments; and
- Practical considerations.

The scientific foundation for this Guideline was based on a risk assessment and risk management process. All the potential risks associated with the utilisation and disposal of WTR were identified. The process revealed which potential receptors could be affected and methods/limits were developed to protect these receptors.

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

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

- Nutrients – the nutrient content will determine whether WTR could be used as fertiliser while high concentrations of certain nutrients could pose a negative environmental impact due to soil, surface- and groundwater contamination;
- Trace elements and metals – when present in high concentrations, the metal content of WTR may have negative impacts on several receptors; and
- Physical characteristics – the physical properties of WTR may impact on the soil properties, air quality and surface water.

The potential negative effects resulting from land application and disposal were managed by specifying management requirements and restrictions to isolate potential receptors from the potential risk (such as implementing access restrictions and buffer zones to protect the general public).

Some disposal options such as landfill disposal need to comply with the Minimum Requirements [1]and other documents that already exist. In these cases additional guidance is provided that could assist the user to simplify the process required. Therefore, the WTR Guideline expands on the existing requirements without contradicting them. The conceptual thinking, development process and assumptions are presented in a separate document which is available from the WRC[2].

MOTIVATION FOR DEVELOPING THE GUIDELINE

Research has shown that the physical, chemical and biological properties of the soil can be improved with WTR application without inducing negative effects on soil quality, groundwater or plant growth[3]. Land application is thus a more environmentally and economically sound management option than disposal on landfill. However, landfill disposal might still be the only alternative for WTR with excessively high metal concentrations.

The major benefits of land application of WTR are:

- Improvement of soil physical properties to improve water retention, hydraulic conductivity and increased soil structure and aeration;
- Increase in soil pH (especially important for acid soils);
- Supply of some major plant nutrients (calcium (Ca), magnesium (Mg), phosphorus (P), nitrate (NO_3)); and
- Increase the sorption capacity of polluted soils for metals.

However, certain substances present in WTR due to the chemicals added during water treatment might compromise its beneficial use. Therefore the benefits of land application of WTR should always be weighed against the restrictions. Different management options for WTR have been identified each with its own technical and legislative aspects.

Ultimately, the WTR Guideline will allow regulatory bodies to distinguish between sewage sludge and WTR in their characteristics, land application and disposal requirements. This Guideline is a living publication and need to be updated after 5 or 10 years to include data and information collected during this period.

PROCESS FOLLOWED IN DEVELOPING THE GUIDELINE

The aim was to develop user friendly Guideline that could be easily understood by regulatory authorities, managers, practitioners and operators responsible for WTR management.

Literature review

A literature review was conducted to gain information on international experience about approaches that have been adopted to develop Guideline for WTR use and disposal. The rationale behind limitations and restrictions that were implemented were determined and

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

[2] Herselman, J.E. 2013. Technical support document to the development of: Guideline for the utilization and disposal of Water Treatment Residues. WRC Report 1723/1/13.

[3] Hughes, J.C., Snyman, H.G., Herselman, J.E. and Ndoro, E.T. 2007. A scoping report towards the development of guidelines for the disposal of water treatment residue to land. WRC Report 1601/1/07

the unique local considerations and practices that could affect the South African Guideline evaluated.

Legal review

An assessment and review of the legislation governing the specific WTR disposal/use practice under consideration was conducted in order to determine the legal requirements that need to be met. This includes a critical assessment of the appropriateness of existing legal requirements for South African conditions.

Risk assessment

The WTR Guideline was developed by following a similar risk assessment protocol as was followed during the development of the USEPA Part 503 Rule for the land application of wastewater sludge. The risk assessment is based on the consequence that the source (in this case WTR) may have for a certain receptor and the probability of that consequence occurring along a specific pathway. The risk assessment included 11 receptors and 67 possible pathways through which land application and disposal of WTR could impact the environment. This is perceived to be the best way in which to develop Guideline to protect human health as well as the environment.

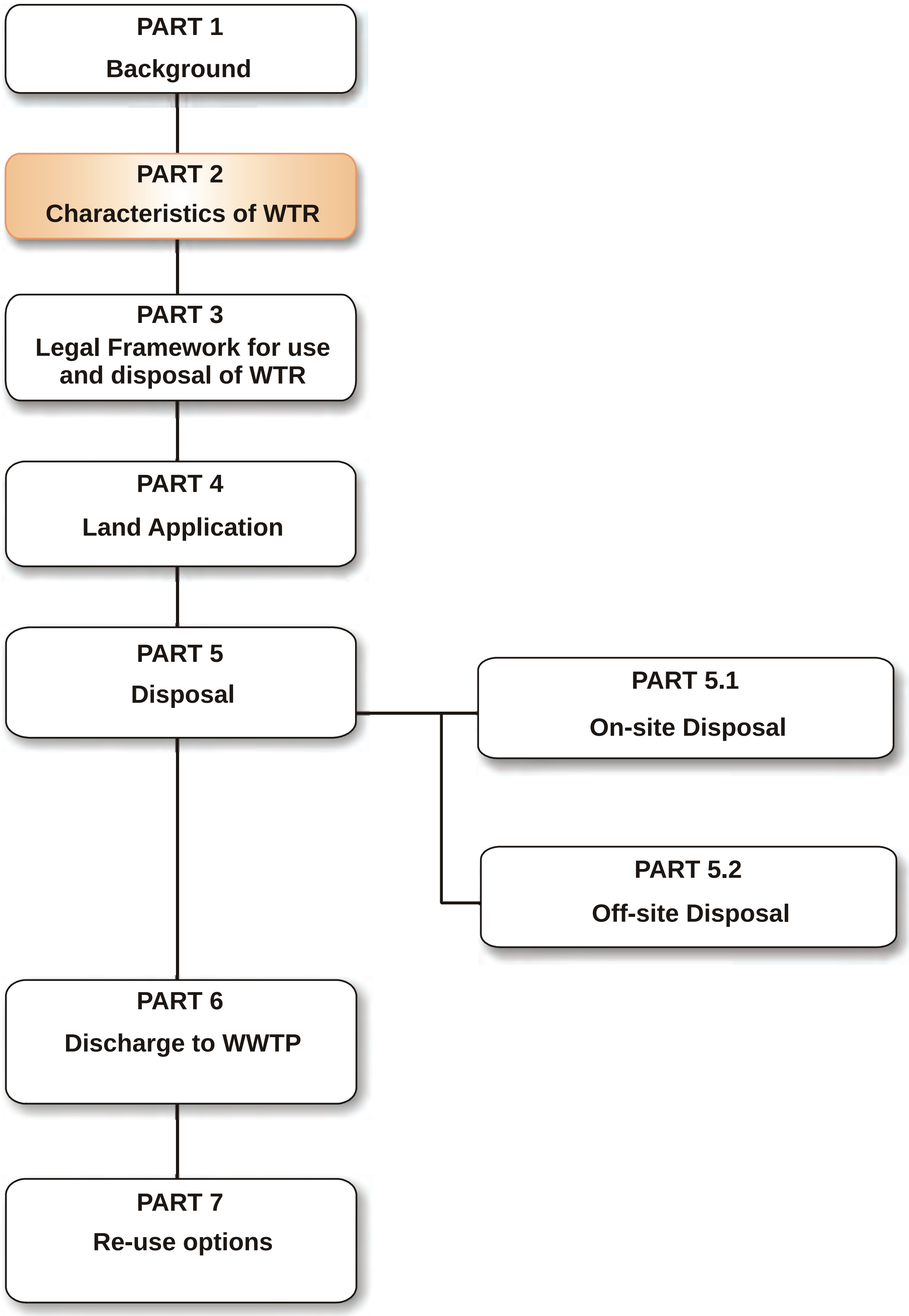
Development of Technical Support document

The Technical Support Document records the rationale that was followed to develop the South African WTR Guideline, the associated limits for South African conditions and the outcomes of the risk assessments. It also records the origin of all limitations placed on the use and disposal of WTR, management systems to be implemented to reduce the risks and limits for constituents of concern relevant to South African conditions.

Stakeholder consultation

The draft WTR Guideline was presented to the Reference Group for review and comment. Consultation with the regulating authorities and key stakeholders were conducted to test the feasibility of the implementation of the Guideline as well as the acceptability of the rationale and the limitations proposed for the guideline.

DOCUMENT ROADMAP



TYPES OF WATER TREATMENT PLANTS

Metal salts or polymers are added to raw water during the treatment process to coagulate the suspended solids and dissolved contaminants. Most of these coagulants and the impurities they remove settle to the bottom of the settling tank/clarifier where they become part of the WTR. The quantity of WTR generated depends upon the raw water quality, dosage of chemicals, performance of the WTP and the method of residue removal. Figure 1 show an overview of a typical WTP.

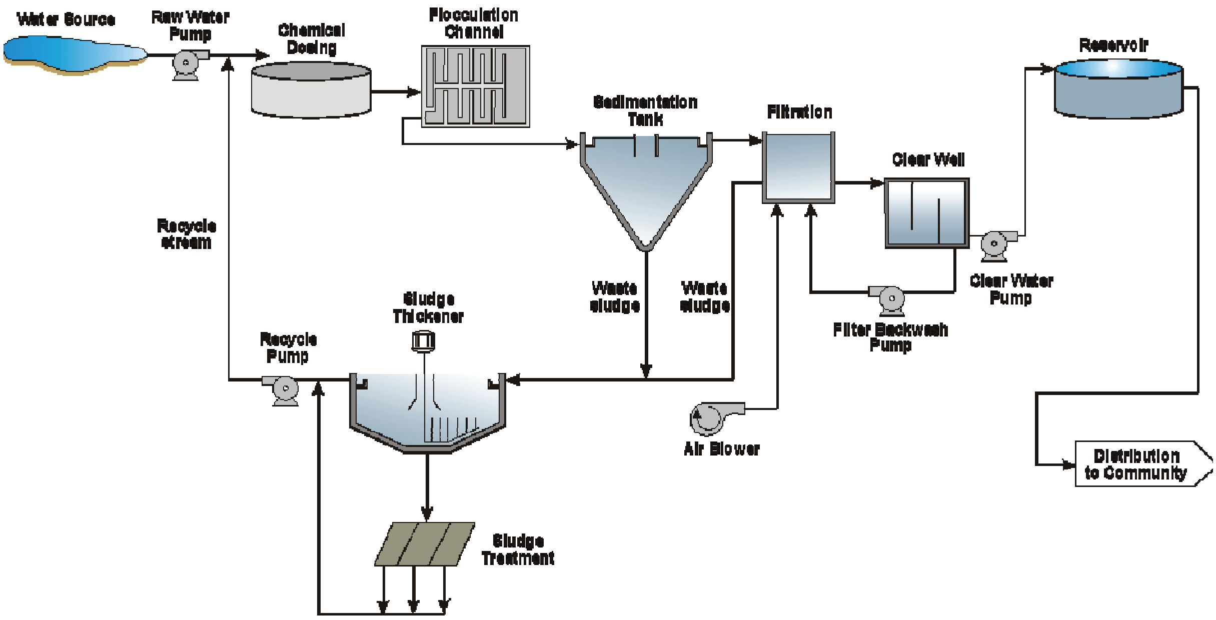


Figure 1: Overview of a typical water treatment plant

Water treatment plants can be divided into the following general categories with different associated waste streams:

Coagulation treatment plants

Treatment plants that coagulate filter and oxidize surface water for removal of turbidity, color, bacteria, algae and elements like iron and manganese. This is the most commonly used water treatment technology and accounts for approximately 70% of the WTR produced. These plants use alum or iron salts for coagulation but other chemicals might be added such as powdered activated carbon, polymer, and lime or activated silica. These elements are usually removed along with the solids in the raw water in a sedimentation tank or clarifier. The waste streams include clarifier WTR and filter backwash wastes and the quantity of solids produced depends on the raw water quality and chemical addition.

Softening plants

Treatment plants treating hard and alkaline water have to soften the water by removing calcium and magnesium from the raw water. These represent the second major waste product produced by water treatment plants. Softening is accomplished either by chemical precipitation of the Ca and Mg by adding lime, sodium hydroxide and/or soda ash or by the use of ion exchange resins. These plants produce settled sludge from the clarifier and filter backwash. Some plants may also add polymer or metal salt to remove fine precipitates, color or turbidity present in the raw water. This type of WTR account for another 25% of WTR produced.

Inorganic removal plants

The removal of trace elements and metals from raw water is becoming more of a problem due to industrialization and pollution of surface water resources. Treatment plants specifically designed to remove trace inorganic substances (nitrate, fluoride etc.) have an additional stage added during treatment to remove these inorganic substances, using processes like ion exchange, reverse osmosis or adsorption. These plants produce spent adsorption material as a waste. Depending on the concentrations of these elements in the raw water and the residue, the WTR may be classified as hazardous waste and may include metals, nitrates and TDS.

CATEGORIES OF WTR

The majority of residuals from WTPs fall into one of four categories:

- Naturally occurring, colloidal/particulate matter (e.g., clay, silt, algae) removed from raw water by sedimentation, filtration, membranes or other processes and inert material in treatment chemicals (e.g., grit in lime);
- Naturally occurring, soluble substances (e.g., iron, manganese, calcium, and magnesium) converted to their insoluble precipitate forms by oxidation or pH adjustment;
- Precipitates formed (e.g. $Al(OH)_3$, $Fe(OH)_3$) when chemicals are added to water; and
- Spent materials (e.g., granular activated carbon (GAC), powdered activated carbon (PAC), filter media, resins) that must periodically be removed from unit treatment processes after exceeding their useful lives.

RESIDUALS HANDLING PROCESS TYPES

WTR can be subjected to a variety of processes for collection and concentration of solids before conveyance to disposal or to another unit process. These processes include:

- Thickening – A process of concentrating the solids content of WTR to reduce the volume before disposal or further treatment;
- Coagulant recovery – A treatment technique for improving solids dewatering characteristics and lowering the concentration of metallic ions in the residuals;
- Conditioning – Application of a chemical to WTR to optimize the dewatering process;
- Dewatering – A process to increase the solids concentration of WTR to >8%;
- Drying – A process to increase the solids concentration of WTR to >35%;
- Disposal and reuse – Removal of WTR from the WTP site or permanent storage of WTR at the WTP site. This category includes hauling to landfill, discharging to WWTP or surface water, land application and various reuse options (e.g., soil supplement, brick manufacture); and
- Recovered water handling – Thickening, dewatering, and drying processes produce both liquid and solids components. The solids component may be further treated and disposed of. The liquid component is returned to the main WTP processes if it is recoverable, which means it has little impact on the main treatment process and no harmful effect on the finished water quality.

CHARACTERISTICS OF DIFFERENT TYPES OF WTR

Lime Softening Residuals

Addition of lime to agricultural soil is a common practice in areas where the soil pH is too low for optimal plant growth. Lime modifies the balance between acidity and alkalinity in the soil. Soil pH should be maintained at 6.5 or above to minimize crop uptake of metals. In addition to providing a desirable pH for plant growth, lime residuals can be substituted for agricultural limestone and offer calcium carbonate equivalence (CCE) or neutralization effectiveness.

Studies show the neutralizing power of lime residuals is equal or superior to that of agricultural limestone. Lime residuals increase the porosity of soils, rendering the soils more workable for agricultural purposes.

Alum Residuals

Alum residuals have the consistency of very fine soils when dry. Although alum WTR contains few if any plant nutrients (usually particularly low in nitrogen), it may contribute other beneficial properties such as improving soil structure, increasing water retention and minimising fertilizer run-off. The incorporation of WTR into soil can improve the soil's cation exchange capacity and enhance the soil's ability to retain fertilizer. Alum residuals may inhibit plant growth by adsorbing phosphorus. This reduction in phosphorus available to plants is different from the toxicity problem that may be associated with elevated Al concentrations. To obtain optimal plant yields, phosphorus fertilizer may be needed. Application of alum residuals at rates that are not considered excessive does not cause environmental degradation.

Ferric residuals

The characteristics of ferric residuals are very similar to that of alum WTR, except for lower Al concentrations and higher Fe concentrations. Available and mobile concentrations of other trace metals in ferric residuals are low. The application of ferric WTR to soils can be beneficial by increasing water retention and general improvement of the soil structure. Elevated Fe concentration might inhibit plant growth and application to agricultural crops and soils have to be monitored. These WTR are generally difficult to dewater and additional application of polymer might be needed before dewatering.

Polyelectrolyte residuals

A polymer is a man-made organic compound made up of a long chain of smaller molecules called monomers. In water and wastewater treatment processes, polymers are also referred to as Polyelectrolyte. Polyelectrolyte are often used together with other coagulants, but may also be used by itself. The chemical characteristics of poly residues are similar to that of alum and ferric residues but generally with lower concentrations of trace metals. Poly WTR may also increase water retention and hydraulic conductivity of soils.

PHYSICAL AND CHEMICAL PROPERTIES OF WTR

Particle size distribution

It might be expected that, in general, residues would exhibit high clay and silt fractions. However, the residues are formed by coagulation of fine particles into larger, stable aggregates. The particle size distributions of the WTR are variable depending on the degree of dispersion attained. The particle sizes featuring most prominent in all the WTR samples are coarse sand (0.5-2 mm), silt (0.002-0.05 mm) and clay (<0.002 mm) fractions.

Pozzolanic properties

Some types of WTR may display pozzolanic (self-cementing) properties i.e., the ability of a material to harden and gain strength in the presence of water. Such characteristics have resulted in WTRs being considered for a wide range of uses, such as making bricks and cement. Many WTRs harden upon drying and these dry aggregates are resistant to water and appear to break down in soil only under conditions of alternate wetting and drying. A large thickness of wet WTR applied to the soil surface could theoretically result in a sealed soil surface that could impact on infiltration or penetration by plant shoots. In practice this may not occur since the WTR cracks on drying thus opening up channels through which water can enter the soil and plants could emerge. However, such risks can be completely eliminated by not applying such a thickness of wet material.

Thickening and Dewatering

The major constituent of WTR is water. The water content of WTR can be divided into:

- Free water which is not held to the WTR solids and can be removed by gravitational settling;
- Floc water / hydrogen bound water which is trapped/attracted in the flocs and can be removed by mechanical dewatering;

- Capillary water which is held to the solids by surface tension and can only be removed by compaction and deformation of the flocs; and
- Chemically bound water which is chemically bound to the individual floc particles and cannot be removed (Cornwell *et al*., 1987).

WTR from a coagulation process typically have a solids content of 0.5-2% and can be thickened with gravity to 3-4% solids. WTR resulting from lime softening process can be removed from the clarifier at 10% solids and may gravity thicken to 30% solids.

pH

The pH of the WTR will influence the mobility of elements in the soil profile after application and the availability of elements to plants. The pH(H_2O) values of South African WTRs range from 6.2 to 9.2.

Organic carbon content

The organic carbon content ranges from 0.5 to 16.7% and will have a positive impact on soils.

Nutrients

The nutrient content of the WTR will determine whether it could substitute for, or be used as, a fertilizer. High concentrations of certain nutrients could also present a negative environmental impact due to surface and groundwater contamination.

- The nitrogen (N) content of WTR may have positive (supplying N to plants) and negative (groundwater contamination due to leaching and surface water contamination due to runoff) impacts on the environment during and after land application. The N in South African WTR are in the following ranges:

  - NO_3-N ranged from 9.7 to 94.2 mg/kg and
  - NH_4-N from 26.3 to 358.4 mg/kg.

  The N content of WTR is too low to be used as a fertilizer on its own and have to be supplemented by additional fertilizer applications.

- The extractable P in WTR is generally low as are many South African soils for crop growth. Additional P application will be necessary for crop growth.

Cation exchange capacity (CEC)

The CEC gives an indication of the material's potential to hold plant nutrients and other cations. The CEC is determined by the type and amount of clay and/or organic material that is present. These two colloidal substances are essentially the cation warehouse or reservoir and are very important because they improve the nutrient and water holding capacity of the material. Sandy material with little organic matter (OM) has a low CEC, but smectitic clay with high amounts of OM would have a much greater capacity to hold cations. The disadvantages of a low CEC obviously include the limited availability of inorganic nutrients to the plant and the WTR's inability to hold applied nutrients. The CEC of the WTRs ranged from 1.4 to 68.4 $cmol_c/kg$ which may have a positive effect on the nutrient and water holding capacity of soils after application.

Trace elements and metals

WTR may have elevated concentrations of trace elements and metals, depending on the quality of raw water source and the chemicals added during treatment. These elements may be present in different fractions including total, plant available and leachable (mobile) fractions. Although only the plant available and mobile fractions have an influence on land application and disposal of WTR, the total trace element and metal content have also been evaluated.

Total trace metal content

The aqua regia extraction method was used to assess the total metal content of WTR. The total trace metal concentrations of WTR are generally lower than that of Pollutant class a wastewater sludge, which can be used without restriction.

Plant available fraction

The ammonium nitrate (NH_4NO_3) extraction method can be used to determine the plant available fraction of elements in soils. Since WTR majorly consist of soil particles, this method can also be used for WTR. The NH_4NO_3 extractable concentrations of the majority of elements in WTR were <1.5 mg/kg. These low extractable concentrations indicate that land application of WTR should not have a negative impact on the receiving environment.

Leachable fraction

The TCLP was used to establish the concentration of trace elements and metals in WTR that will probably leach from the waste. However, importantly, it takes no account of any re-adsorption of the ‘leached’ elements that may occur as a result of interaction with the soil. This is also the method used to classify waste and assign a hazard rating. The TCLP extractable of all trace elements and metals from WTR were low except for Mn. Elevated Mn concentrations can either be due to contamination of the chemicals used during treatment or due to the quality of raw water.

POTENTIAL MANAGEMENT OPTIONS

Land application of WTR

The three most common land application techniques for WTR are:

- Land application on agricultural land;
- Land application on forest land; and
- Land reclamation.

Disposal

WTR disposal can be on-site or off-site. These options include:

- On-site disposal on dedicated land (DLD) or in lagoons;
- Off-site disposal on landfill including:

    - Co-disposal with municipal solid waste;
    - Use as daily landfill cover;
    - Mono-disposal of WTR; and
    - Co-disposal with wastewater sludge.

Discharge to the WWTP

Discharge of WTR to a wastewater treatment plant (WWTP) is another disposal option for water services institutions. This option is often economically attractive and transfer disposal liability to the WWTP. However, it is only feasible when the WWTP and WTP work together cooperatively.

Direct discharge to source stream

Historically, direct discharge of WTR to surface waters has been a commonly practiced disposal method. A key concern regarding the direct discharge of WTR to surface water is aluminium and iron toxicity in the aquatic environment. During the Stakeholder Consultation process consensus was reached that this management option should not be included in the Guideline since it is not an environmentally responsible management option.

WTR reuse

Although WTR do not have the inherent fertilizer value of wastewater sludge, the following reuse alternatives can be considered:

- Recovery of coagulants;
- Use in making bricks (high solids); and
- Use in Portland cement (high solids).

INITIAL CHARACTERISATION OF WTR

Initial characterization of WTR is essential to enable selection of applicable management options and to determine the feasibility of these options. However, the initial characterization is based on the total metal content (*aqua regia* digestion) of the WTR and further investigation and analyses will be required once a management option is selected.

It is recommended that the **Pollutant class a** classification for wastewater sludge, detailed in the Sludge Guidelines[4], be used for this characterization (Table 1). Only 8 metals of concern are included in this classification. However, other elements might also be of concern to the receiving environment (Al, Fe and Mn) and will be addressed in detail in the relevant sections applicable to the selected management options.

---

[4] Snyman, H.G. and Herselman, J.E. 2006. Guidelines for the utilisation and disposal of wastewater sludge. Volume 1 of 5: Selection of management options. WRC Report TT261/06.

PART 2: CHARACTERISTICS OF WTR

Table 1: Recommended limits for total metal concentration in WTR

Constituent	Total concentration (mg/kg)
Arsenic (As)	<40
Cadmium (Cd)	<40
Chromium (Cr)	<1 200
Copper (Cu)	<1 500
Lead (Pb)	<300
Mercury (Hg)	<15
Nickel (Ni)	<420
Zinc (Zn)	<2 800

Note: The total concentration of uranium (U) in WTR from water sources with elevated U concentrations need to be determined before a management option is selected. The recommended limit for U in WTR is <200 mg/kg.

The decision making process for selection of appropriate management options for WTR is shown in Figure 2, while Table 2 show different management options which can be considered based on the total metal content of the WTR, as well as potential restrictions and additional analyses and investigations that might be needed.

Once a management option has been selected, the reader is referred to the applicable chapters in this guideline document where more detailed information on the management option can be found.

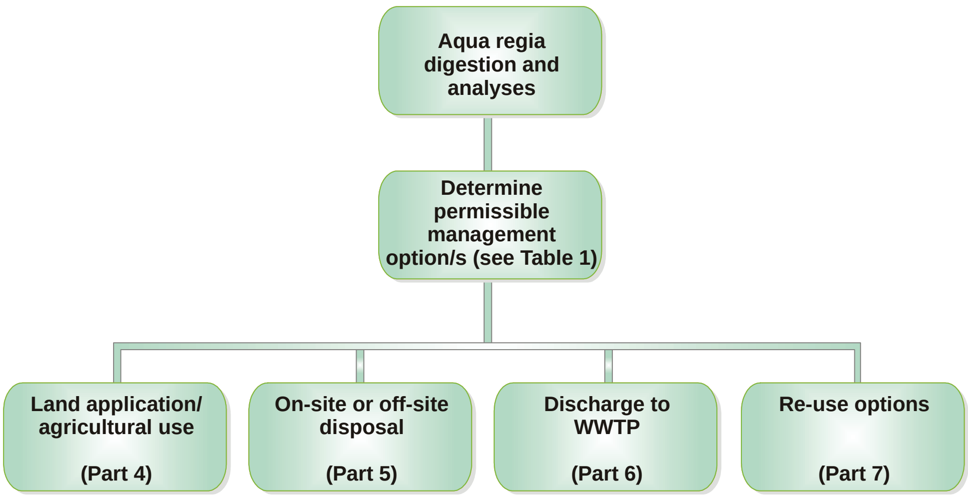
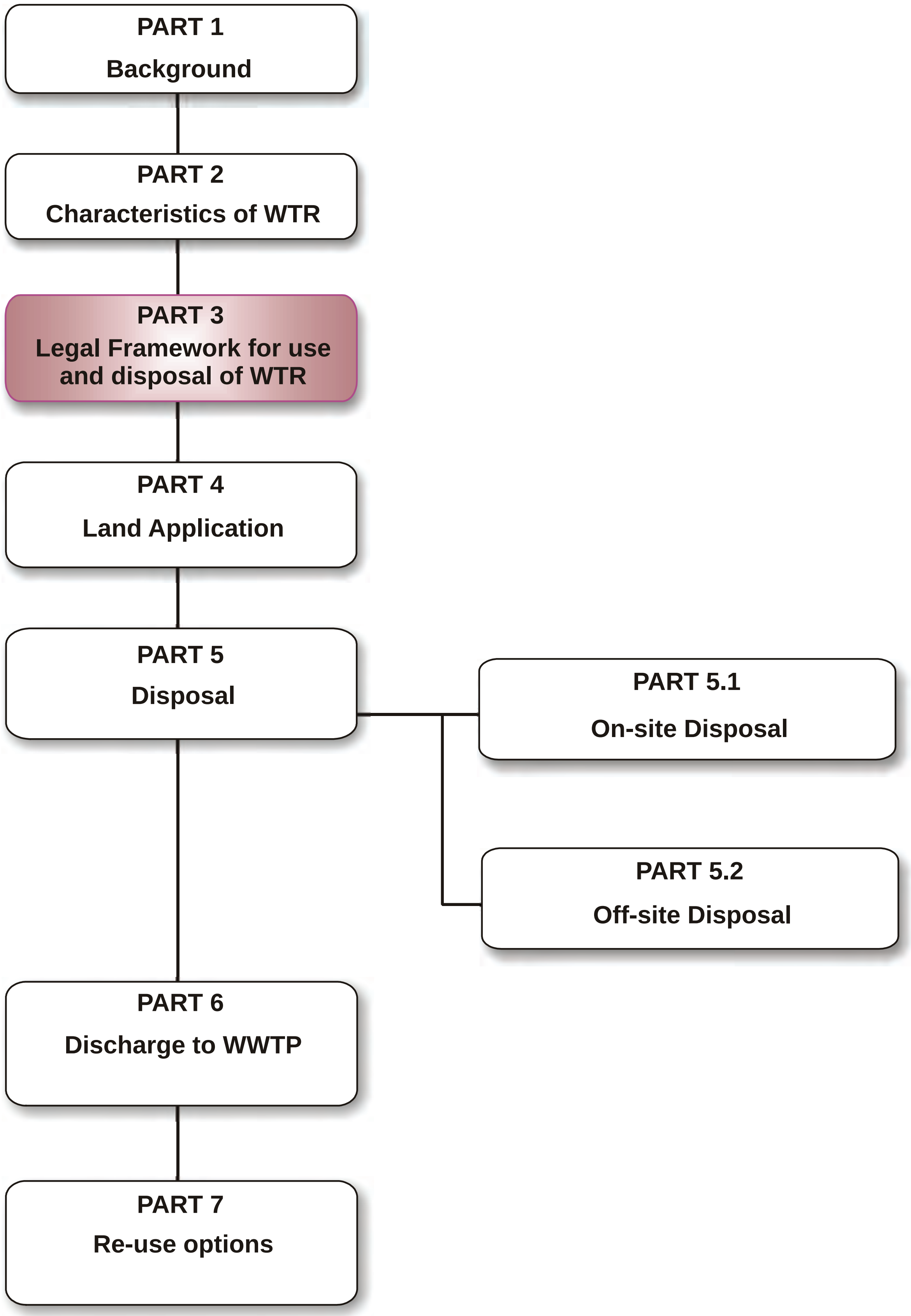


Figure 2: Decision making process for selection of WTR management options

Table 2: Appropriate management options for WTR based on metal content

Management option	Total metals < Metal limit		Total metals > Metal limit	
Land application	✓	Additional NH_4NO_3 analyses	X	Not permissible
On-site disposal	✓	Additional TCLP analyses	!	Maximum load restrictions
Off-site disposal	✓	Additional TCLP analyses	!	Maximum load restrictions
Discharge to WWTP	✓	Additional COD and/or BOD analyses	!	Additional COD and/or BOD analyses, rate and volume restrictions
Discharge to source	!	Additional analyses and restrictions on discharge rate and volume	X	Not permissible
Re-use options	✓	Additional investigations needed	!	Options might be restricted due to metal content
Legend:				
✓ = Permissible	! = Permissible with restriction	X = Not permissible		

DOCUMENT ROADMAP



PART 3:

LEGAL FRAMEWORK FOR USE AND DISPOSAL OF WTR

The South African environmental legislation is complex and authorisation by more than one Government Department needs to be considered. The Department of Water Affairs and Forestry (DWAF), Department of Environmental Affairs and Tourism (DEAT), Department of Health (DoH) and the Department of Agriculture (DoA) have a regulatory role to play in the utilisation and disposal of WTR. The different departments have committed to co-operative governance and to improve inter-departmental communication, which should simplify the regulatory process.

NATIONAL WATER ACT (NWA, ACT 36 OF 1998)

In terms of the National Water Act (NWA, Act 36 of 1998) the following apply to water service providers (WSP) and water service authorities (WSA) regarding water abstraction and treatment:

- If a WSP abstracts, treats and then supplies to reservoirs under control of the WSA:
    - The WSP must have the relevant authorisations, i.e. for abstraction and storage i.e. Section 21(a) and (b) respectively;
    - The WSA would also then need an authorisation for storage, i.e. Section 21(b).
- If a WSA abstracts, treats and then store in reservoirs the WSA must have the relevant authorisations, i.e. for abstraction and storage, i.e. 21(a) and (b) respectively.

Water uses as defined in Section 21 of the NWA:

21 (a) – taking water from a water resource

21 (b) – storing water

21 (c) – impeding or diverting the flow of water in a watercourse

21 (d) – engaging in a stream flow reduction activity (currently only commercial afforestation)

21 (e) – engaging in a controlled activity – activities which impact detrimentally on a water resource (identified in section 37 (1) or declared as such under section 38 (1) viz.:

- Irrigation of any land with waste or water containing waste which is generated through an industrial activity or a waterworks';
- An activity aimed at the modification of atmospheric pollution;
- A power generation activity which alters the flow regime of a water resource; and
- Intentional recharging of an aquifer with any waste or water containing waste.

21 (f) – discharging waste or water containing waste into a water resource through a pipe canal, sewer, sea outfall or other conduit

21 (g) – disposing of waste in a manner which may detrimentally impact on a water resource

21 (h) – disposing in any manner water which contains waste from, or which has been heated in, any industrial or power generation process

21 (i) – altering the bed, banks, course or characteristics of a watercourse

21 (j) – removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people

21 (k) – using water for recreational purposes.

NATIONAL ENVIRONMENTAL MANAGEMENT ACT (NEMA, ACT NO. 107 OF 1998)

The National Environmental Management Act (NEMA, Act No. 107 of 1998) serves as the guiding framework legislation for environmental management in South Africa. The NEMA includes a set of fundamental guiding principles which governs the actions of organs of state that may significantly affect the environment. These principles include amongst others, the "polluter pays", "cradle to grave", "precaution" and "waste avoidance and minimisation". It is a legal requirement that these principles must be taken into consideration in all decisions that may affect the environment.

While the WTR Guideline should be guided by all the principles of NEMA, of specific relevance to the development of the management options are the following:

- Sustainable development requires that a risk averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions.

- Environmental management must be integrated, acknowledging that all elements of the environment are interlinked and interrelated, and it must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option (BPEO). (NEMA defines best practicable environmental option as 'the option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as short term).

- NEMA also imposes a duty on everyone who causes, has caused or may cause significant pollution or degradation of the environment to take reasonable measures to prevent it occurring, continuing or recurring. Where harm to the environment is authorised by law or cannot reasonably be avoided or stopped, a duty exists to minimise and rectify the harm. Although everyone has this duty, the Act singles out the owner of the land or premises, a person in control or a person who has the right to use land or premises on which the activity or process is or was performed or undertaken, or any other situation exists, which causes, has caused, or is likely to cause significant pollution or degradation of the environment, to take reasonable measures.

National Environmental Management: Waste Bill

The National Environmental Management: Waste Bill was developed as subsidiary legislation to NEMA. The Waste Bill is framework legislation that provides the basis for the regulation of waste management, detailing regulation of different types of wastes requiring specific regulatory approaches to ensure that they are optimally managed from an environmental perspective.

Section 17(1) Reduction, re-use, recycling and recovery of waste

"Unless otherwise provided for in this Act, any person who undertakes an activity involving the reduction, re-use, recycling or recovery of waste must, before undertaking that activity, ensure that the reduction, re-use, recycling or recovery of the waste—

a) uses less natural resources than disposal of such waste; and
b) to the extent that it is possible, is less harmful to the environment than the disposal of such waste."

Since the Waste Bill has only been accepted in October 2008, the roll-out is still underway and it is still uncertain how it will impact on the utilization and disposal of WTR.

ENVIRONMENT CONSERVATION ACT (ECA, ACT NO. 73 OF 1989)

Although NEMA has repealed many of the provisions of the Environment Conservation Act (ECA, Act No. 73 of 1989), the Environmental Impact Assessment (EIA) regulations in terms of ECA still remain in force until they are replaced with new regulations under the NEMA. The regulations are made in terms of section 26 of ECA, and relate to EIAs provided for in sections 21 and 22 of the ECA, and the provisions dealing with waste management under section 20. Policies published in terms of the ECA also promote the principle of sustainable development and the polluter pays.

Section 20 Requirements

In terms of section 20 (6) of the ECA, "No person shall discard waste or dispose of waste in any other manner, except

(a) at a disposal site for which a permit has been issued in terms of section 20 (1); or

(b) in a manner or by a means of a facility or method and subject to such conditions as the Minister may prescribe".

Activities identified in terms of Section 21 of ECA relevant to the management of WTR:

1. The construction or upgrading of:

   (c) transportation routes and structures, and manufacturing , storage and handling or processing facilities for any substance which is dangerous or hazardous and is controlled by national legislation.

2. The change of land use from:

   (c) agricultural or undetermined use to any other land use.

8. The disposal of waste in terms of section 20 of the ECA, 1989.

Minimum Requirements for handling and disposal of hazardous waste

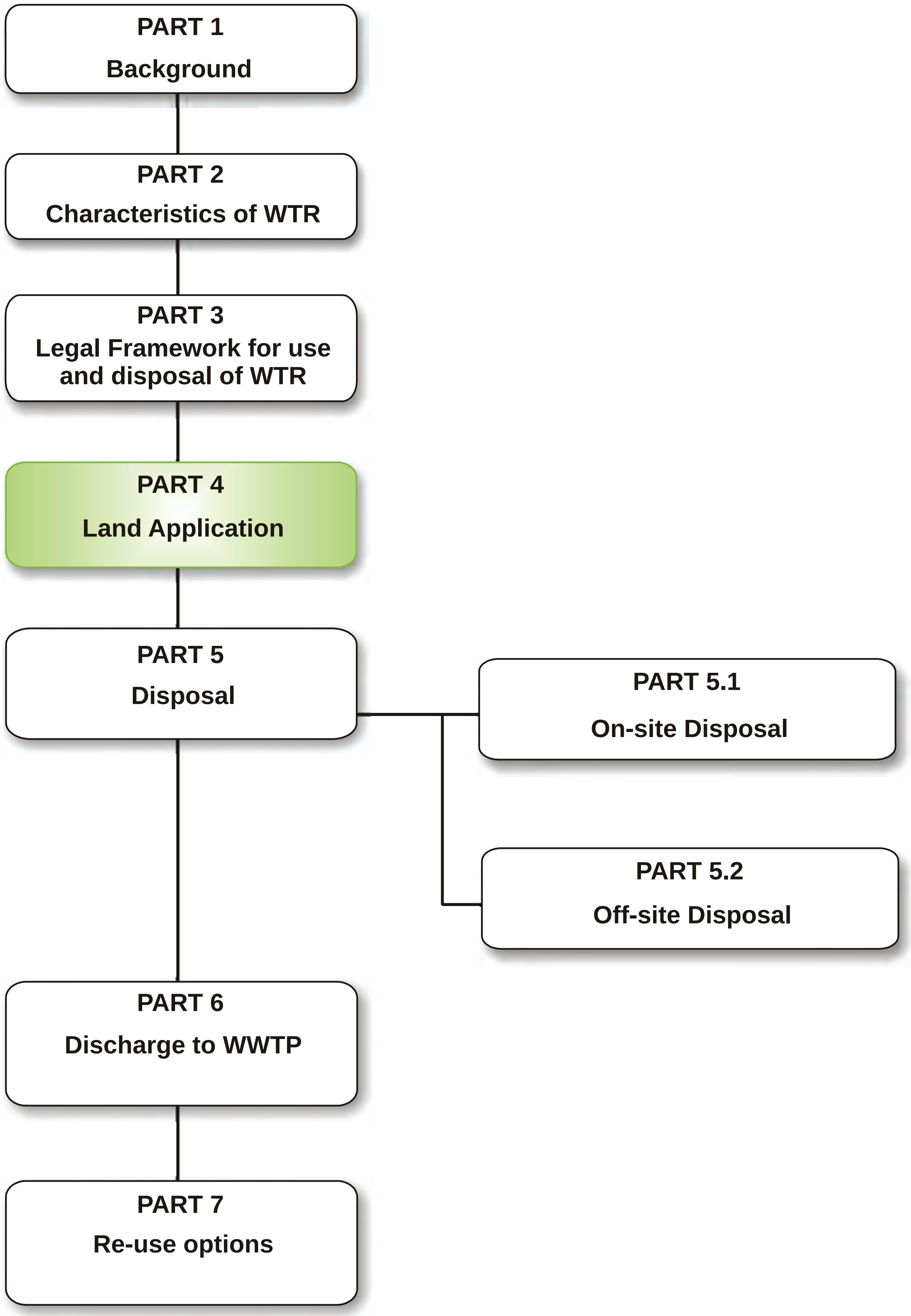
The Minimum Requirements provide the applicable waste management standards or specifications that must be met in the absence of any valid motivation to the contrary. These documents also provide a point of departure against which environmentally acceptable waste disposal practices can be distinguished from those that are environmentally unacceptable. The Minimum Requirements is enforceable through the Section 20(6) of ECA, 1989 and Section 22 of NWA, 1998. Conformance to the Minimum Requirements means conformance to its objectives which include prevention of water pollution, and the protection of human health and the environment.

AUTHORISATIONS AND/OR LICENSES APPLICABLE TO WTR MANAGEMENT

Different utilization and disposal for WTR will require different authorisations and/or licenses and can be summarized as follows:

- Discharge of residue from WTP into a water course falls under Section 21 of the NWA and should be authorised accordingly (Section 21(g));
- On-site disposal of WTR on land requires:
    - A disposal site permit i.e. Section 20 of ECA; and
    - A Water Use Authorisation i.e. Section 40 of NWA;
- Off-site disposal of WTR on land and landfill requires a Section 20 ECA permit;
- Off-site beneficial use – user must comply with Directions in terms of Section 20 (5)(b) of ECA (Act No. 73 of 1989);
- Agricultural use – producer/user must comply with Sections 3 and 6 of the Conservation of Agricultural Resources Act (CARA) (Act No. 43 of 1983).

DOCUMENT ROADMAP



PART 4:

LAND APPLICATION

Land application of WTR is an increasingly popular management option in the water supply industry due to the escalating regulatory and environmental constraints associated with disposal. This application process may beneficially modify soil properties while recycling residual components. Potential disadvantages of land application of WTR include an increase in the concentration of metals in the soil and possibly in ground water; adsorption of soil phosphorus by WTR, decreasing the productivity of the soil; and possible effects caused by the application of poorly crystallized solids of aluminum and iron.

The most common land application techniques for WTR are:

- Land application on agricultural land (Figure 3);
- Land application on forest land (Figure 4);
- Land reclamation (Figure 5).

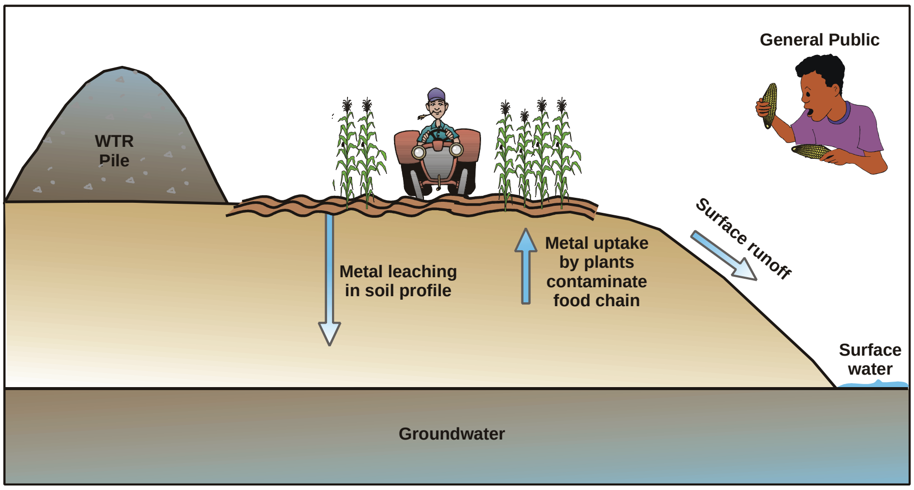


Figure 3: Agricultural use of WTR

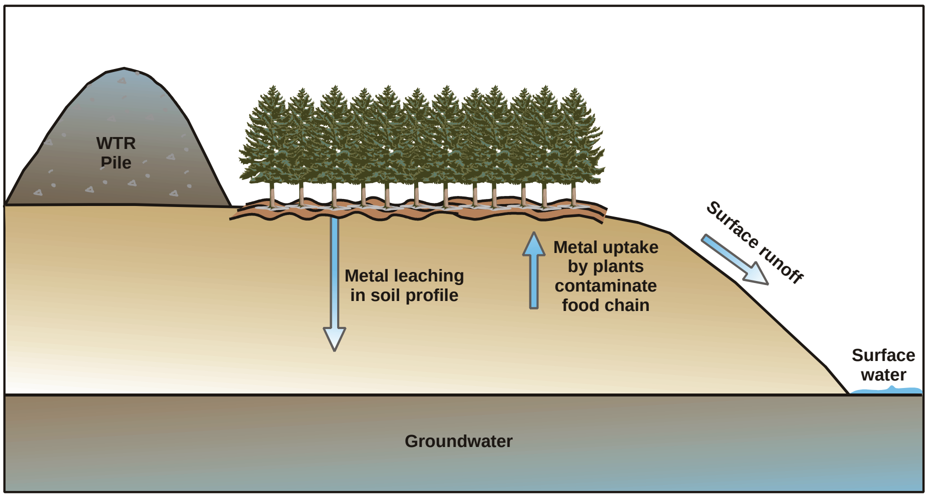


Figure 4: Use of WTR on forested land

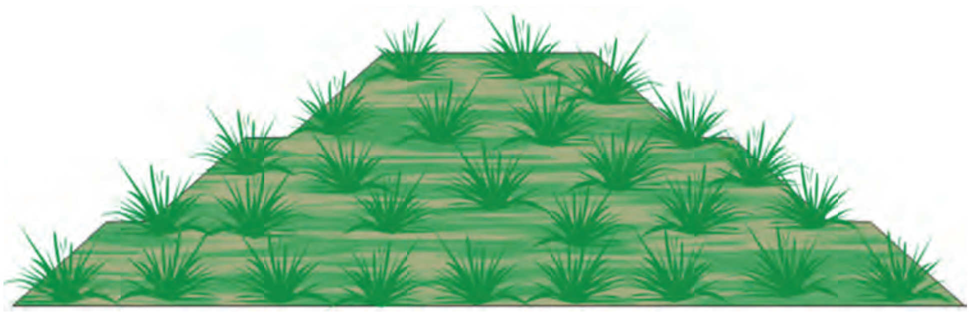


Figure 5: Use of WTR for land reclamation

Whether adding WTR to soil has adverse environmental effects or is beneficial depends on a multitude of factors, some interrelated. Some of the factors that will affect the suitability of this disposal system include:

- pH and chemical content of the WTR and receiving soil;
- plant available and leaching characteristics of the WTR;
- WTR application rate and frequency;
- the soil type;
- cation exchange capacity of the soil;
- rainfall/irrigation rates;
- the intended use of the land; and
- the nutrient requirements of plants.

CHARACTERISATION OF WTR INTENDED FOR LAND APPLICATION

WTR intended for land application, especially for agricultural use, have to be of exceptional quality in order to protect the general public as well as the receiving environment. In order to protect the food chain as well as the soil, surface- and groundwater resources, the available fraction of metals and other elements in the WTR need to be determined. It is recommended that the NH_4NO_3 extraction be used for this assessment and that all potential constituents of concern be determined, including Al, Fe and Mn.

- NH_4NO_3 extractable trace element and metal concentrations (Appendix A);
- Kjeldal digestion to determine N (Appendix A);
- Bray 1 extraction to determine available P (Appendix A); and
- Dominant cations and anions (NO_3, SO_4, Cl etc.).

Since certain crops are more tolerant than others for some of these constituents, these analytical results can be used to assess whether agricultural use will be feasible and which crops could be cultivated. The application rate will also depend on these results as well as the results of the soil investigation.

The concentrations of organic constituents (pesticides) and infectious substances (pathogens and parasites) are perceived to be low in SA WTR. However, in cases where the WTP are aware that these substances are present in the raw water, the WTR need to be tested for these substances before land application, especially agricultural use.

IMPACT OF WTR ON RECEIVING SOILS

The agronomic application of WTR to land presents an attractive and potentially sustainable management option for many water treatment plants. Successful implementation of this management option requires an understanding of the effects of WTR on soil fertility and physical properties. The physical characteristics of soil that determine whether it can support vegetative growth include cohesion, aggregation, strength and texture. These parameters directly affect the hydraulic properties of a soil, such as moisture-holding capacity, infiltration, permeability, and drainage. Any adverse impact on these hydraulic soil characteristics from land-applied WTR can effect crop growth and ultimately degrade ground water quality. Management strategies need to be implemented and parameters such as pH control, crop selection and availability, application rates, and fertilizer requirements must be included in the management planning.

Soil physical properties

Application of WTR to soils has an influence on the physical properties of soils:

- Soil bulk density decrease following the addition of WTR;
- An increase in porosity and water retention;
- An increase in saturated hydraulic conductivity; and
- An increase in permeability of the soil.

These effects of WTR on soil properties are all positive with regard to agricultural land as well as reclamation of degraded soils.

A potentially negative effect of WTR is its ability to form an impermeable crust when dry, especially when WTR with low solids content is irrigated onto soil and left to dry. Incorporation of WTR into the soil upon drying will reduce the crust forming potential and its associated negative effect.

Soil chemical properties

Application of WTR to soils has an impact on soil fertility and chemical properties. WTR applications generally increase the soil pH and in some instances even the organic carbon content of the soil.

Crop nutrients

- Phosphorus – The plant available P fractions in soil decrease as WTR application rates to agricultural soils are increased. This indicates that P is adsorbed and complexed by Fe, Al and Ca complexes, making it unavailable for plant uptake and leading to P deficiencies. Plant available P may also be bound by cationic polymers added during WTR thickening.
- Nitrate – Although the NO_3 concentration in WTR is low, elevated NO_3 concentrations in soils were documented after WTR applications. Depending on the application rate of WTR this might potentially lead to groundwater contamination.

Trace elements and metals

The low concentrations of plant available trace elements and metals in WTR indicate that this will not pose a threat to crops. However, available concentrations of Al, Fe and Mn in the WTR might be elevated due to chemicals added during treatment. Therefore the tolerance of the selected crops for these elements needs to be considered. It is also recommended that the soil pH be maintained between 6.5 and 8 to reduce the mobility and availability of these elements.

INITIAL SOIL INVESTIGATION

Initial soil investigation is necessary to collect background/baseline data which could be used to assess the impact of land application of WTR over time as well as to determine the feasibility of WTR use in agricultural practices. The soil investigation for existing and new land application sites should include (as a minimum):

- Physical properties – The soil structure, permeability and water retention can be increased with WTR application. Baseline data can be used to assess the improvement;
- The soil pH needs to be optimal for crop cultivation and baseline data can be used to assess the impact of WTR application. The soil pH will also indicate whether acidic conditions could cause metals to be available for plant uptake or leach through the soil profile and whether lime softening residues can be used to alleviate acidity; and
- Chemical properties –
    - The concentration of nutrients (N and P) need to be determined to establish the nutrient requirement for the selected crop; and
    - Total (*aqua regia*) and/or NH_4NO_3 extractable trace element and metal concentrations will determine whether WTR application is permissible (see Table 5).

LEGAL REQUIREMENTS APPLICABLE TO LAND APPLICATION OF WTR

The following regulatory requirements are applicable to land application:

- Agricultural use – producer/user must comply with Sections 3 and 6 of the Conservation of Agricultural Resources Act (CARA) (Act No. 43 of 1983);
- Land reclamation (off-site beneficial use) – user must comply with Directions in terms of Section 20 (5)(b) of ECA (Act No. 73 of 1989).

In addition to the above, the minimum legal requirements for land application of WTR are:

- The producer must have a legal contract with the user; and
- The user must comply with this guideline document.

RESTRICTIONS AND REQUIREMENTS FOR LAND APPLICATION

Once land application is selected as the preferred disposal option, the next step is to evaluate the land application site, the costs associated with that site and the potential social and environmental impacts on the site. Initial site investigation will enable the producer/user to collect background/baseline data which could help to assess the impact of land application over time.

Prevention of erosion

The slope of the site and land preparation influence the amount of soil erosion and potential surface run-off and ponding from applied WTR.

Soil quality

It is recommended that the total (aqua regia) and/or NH_4NO_3 extractable trace element and metal concentrations be determined to assess soil quality. Ideally, the total metal concentrations need to be below the total investigative level (TIL) (Table 3). At locations where the total metal content exceeds the total maximum threshold (TMT) indicated in Table 3 or the available metal concentrations exceed the MAT (Table 3), land application of WTR is not permissible.

Table 3: Recommended limits for metals in WTR amended soils (mg/kg)

Metal Elements	Total investigative level (TIL) (aqua regia)	Total maximum threshold (TMT) (aqua regia)	Maximum available threshold (MAT) (NH_4NO_3)
Arsenic (As)	2	2	0.014
Cadmium (Cd)	2	3	0.1
Chromium (Cr)	80	350	0.1
Copper (Cu)	100	120	1.2
Lead (Pb)	56	100	3.5
Mercury (Hg)	0.5	1	0.007
Nickel (Ni)	50	150	1.2
Zinc (Zn)	185	200	5.0

The concentration of Al, Fe and Mn should also be considered because the concentrations of these elements in the WTR might be elevated and additional application might induce toxicity symptoms in crops. These elements are major constituents in soils and therefore no maximum limits can be set. The normal ranges (total concentrations) of these elements are detailed below and can be used as a baseline:

- Al: 10 000 mg/kg – 40 000 mg/kg;
- Fe: 1000 mg/kg – 100 000 mg/kg; and
- Mn: 10 mg/kg – 9000 mg/kg.

However, for agricultural use the available or soluble concentrations of Al, Fe and Mn are more important than the total concentrations, which are strongly influenced by the pH and redox (especially for Mn) conditions in the soil. The normal ranges of soluble Al, Fe and Mn in soils are as follows:

- Al: 0.4 mg/L at neutral pH and 5 mg/L in acidic soils (pH <4.5);
- Fe: 0.03 – 0.55 mg/L at neutral pH and up to 2 mg/L in acidic soils; and
- Mn: 10 mg/L in normal soils.

Application rate

The WTR need to be applied at **agronomic rates**, which are determined using agricultural methods, the same as with fertilizer. The application rate therefore depends on the nutrient requirements for the crops and is based on the expected yield and the available nutrients in the soil. Extremely high loading rates should be avoided to ensure sustainable use of WTR on land without increasing the trace element and metal content of the receiving soil.

The first nutrient to consider is nitrogen. WTR tend to be very low in this nutrient. Basing the application rate on nitrogen alone, however, may cause problems with the crop yield because aluminum and/or iron hydroxide solids present in WTR are strong adsorbents of inorganic phosphorus. The low concentrations of phosphorus in WTR may further diminish total phosphorus in soils, restricting plant growth. It is therefore recommended that both the N and P concentrations be considered when the application rate is calculated. Additional P fertilizer might be necessary.

The concentrations of Al, Fe and Mn have to be considered to prevent toxicity of these elements. By applying WTR at agronomic rates, the nutrients and essential trace elements will be utilized by the crop and reduce leaching and the potential for surface and groundwater contamination.

MONITORING REQUIREMENTS FOR LAND APPLICATION SITES

WTR monitoring

The quality of WTR needs to be confirmed before application. At least 3 composite samples of WTR must be collected and the following analyses are recommended:

- NH_4NO_3 extractable trace element and metal concentration (Appendix A);
- Kjeldal digestion to determine N (Appendix A);
- Bray 1 extraction to determine available P (Appendix A);
- Dominant cations and anions (NO_3, SO_4, Cl etc.); and
- Organic constituents and infectious substances where necessary.

Soil monitoring

A soil monitoring programme is recommended to determine nutrient requirements before application as well as the plant available trace element and metal concentrations in the soils. The following programme is proposed:

- Collect soil samples from all areas where WTR application is considered;
- Determine the nutrient requirement for the particular crop to be cultivated using the following methods:

    - Kjeldal digestion to determine N (Appendix A);
    - Bray 1 extraction to determine available P (Appendix A);
    - Soil pH (Appendix A).

Note: Soil pH(H_2O) >6.5 and <8 should be maintained at all times to limit the solubility and availability of metals, Al and Fe for plant uptake, in order to reduce plant toxicity.

- Determine the total (*aqua regia*) and/or NH_4NO_3 extractable concentration of trace elements and metals as well as Al, Fe and Mn to establish whether the soil can continue to receive WTR (Appendix A).

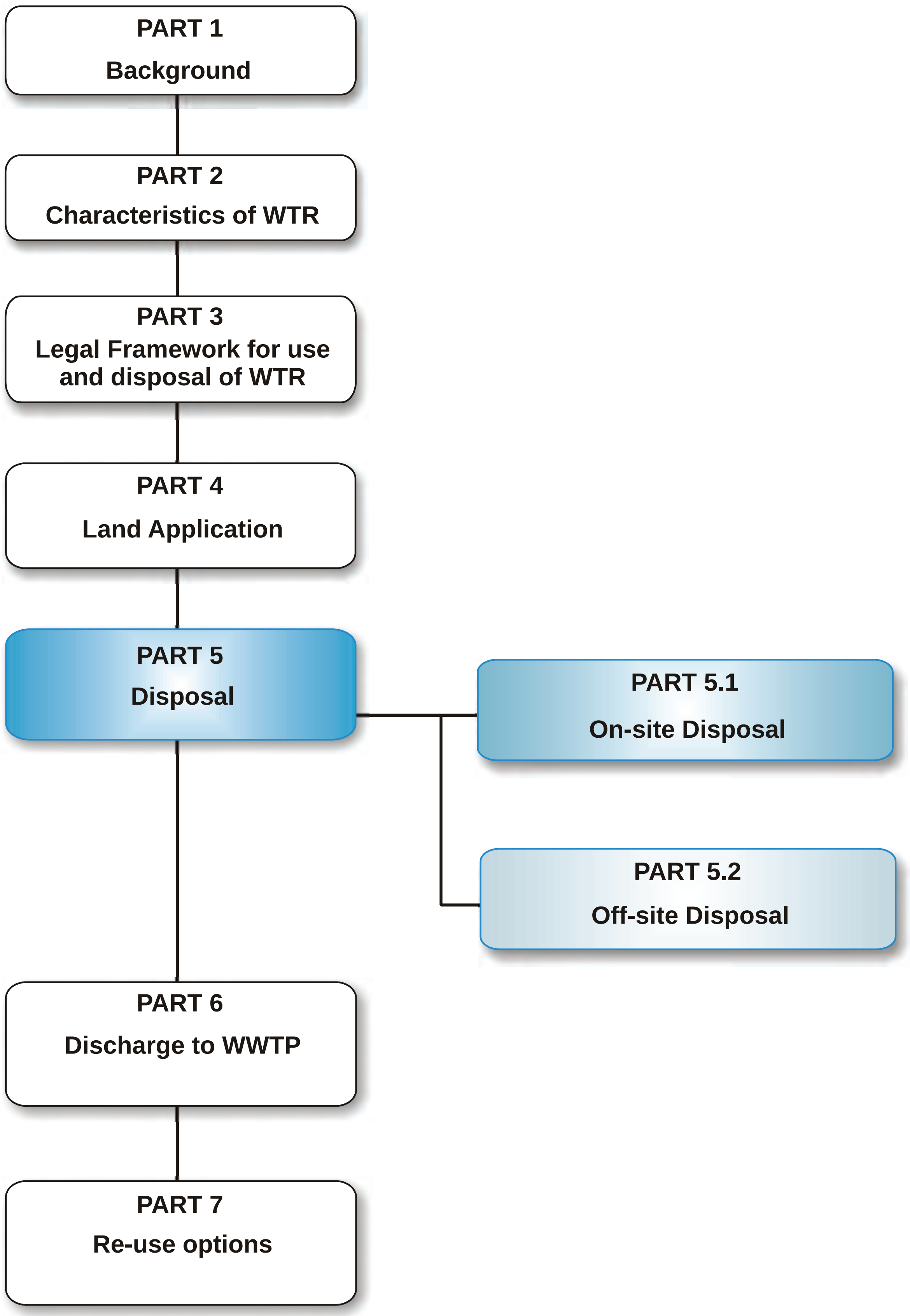
The soil monitoring data have to be compared to the metal limits detailed in Table 5 to determine whether further WTR application will be permissible and to ensure that the soil quality do not deteriorate to such an extent that the land-use are compromised.

RECORD KEEPING REQUIREMENTS

Once the applicable permits and licences have been granted, WTR utilisation and disposal essentially become self-regulatory. This implies that certain records must be kept by the producer and user. The following record need to be kept:

- Copy of the applicable licences and permits;
- The original or certified copy of the contract between the producer and user (if applicable);
- Data on the mass of WTR applied to land; and
- Monitoring results of WTR and soils.

DOCUMENT ROADMAP



PART 5:

DISPOSAL

WTR is an industry specific waste with specific characteristics and properties pertaining to it. The nature and characteristics of WTR compared to other wastes warrants the need for sector-specific Guideline to ensure its responsible management. The reality is that many WTPs use on-site lagoons as management and final disposal options. These facilities are not designed as waste disposal facilities and do not comply with the Minimum Requirements. The water industry is generally not accustomed to the complex waste management requirements in South Africa, but rather to the legislation and requirements of DWAF. This Part of the WTR Guideline attempts to form a “bridge” between the waste management industry and the water industry and aims to consolidate all the requirements of managing WTR as a waste in one document.

DESCRIPTION OF WTR DISPOSAL OPTIONS

On-site disposal options

The most common on-site disposal option for WTR is disposal into lagoons (Figure 6), while disposal on land is a practice less commonly practiced (Figure 7).

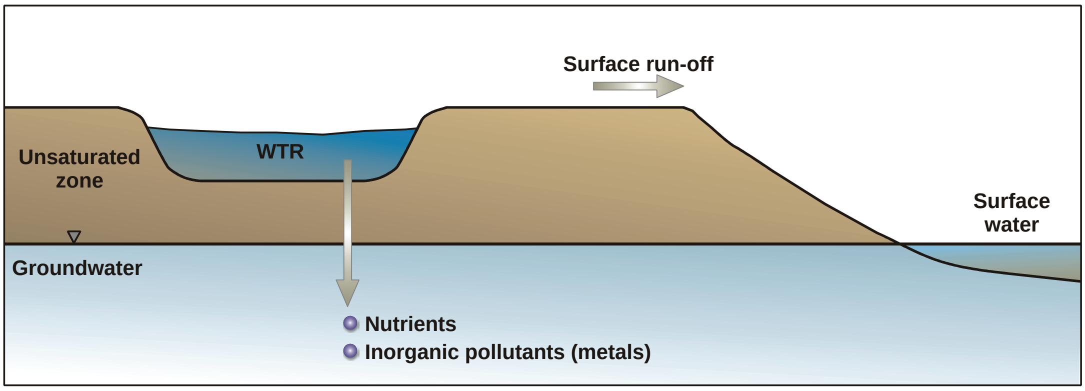


Figure 6: On-site disposal of WTR in a lagoon

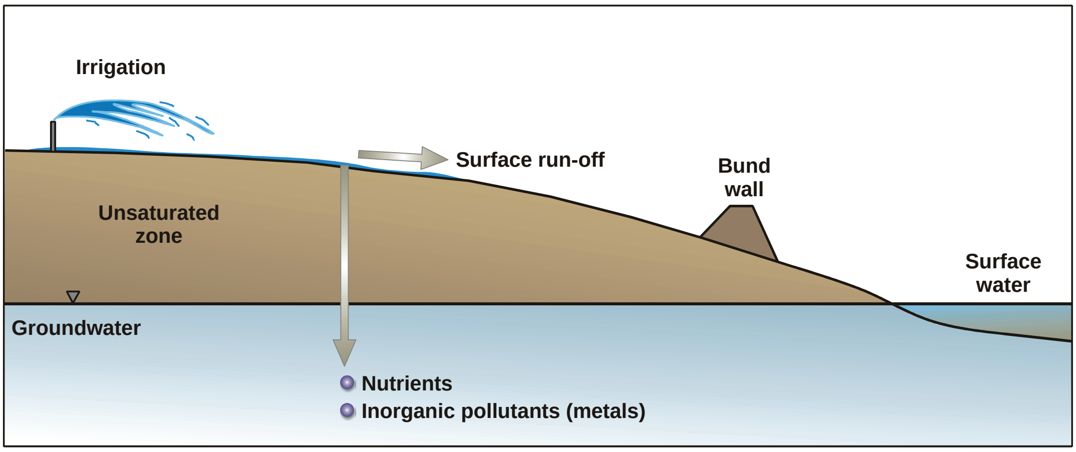


Figure 7: On-site disposal on land

Off-site disposal options

Off-site disposal of WTR on landfill include the following options:

- Co-disposal with municipal solid waste on landfill (Figure 8);
- Monofill of WTR only on landfill;
- Co-disposal with WWTP biosolids; and
- Use as daily landfill cover (Figure 9).

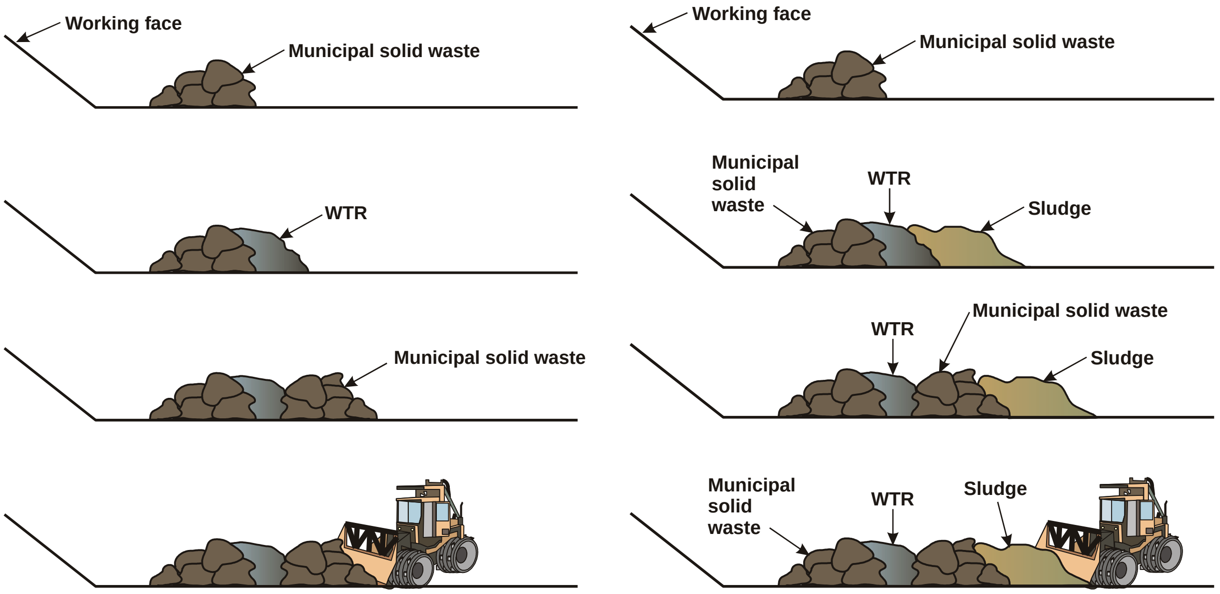


Figure 8: Co-disposal of WTR with municipal solid waste and wastewater sludge on landfill

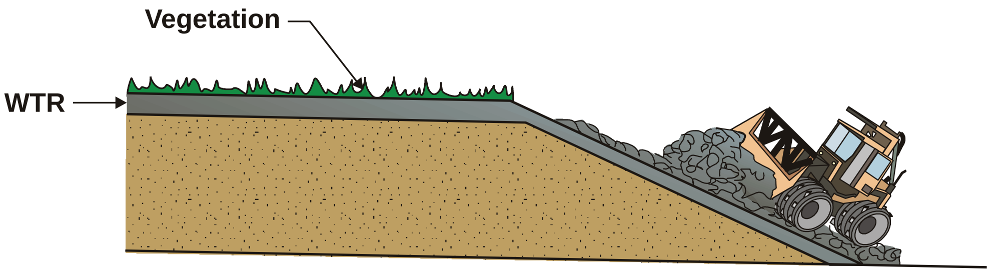


Figure 9: Use of WTR as landfill cover material

CHARACTERISATION OF WTR INTENDED FOR DISPOSAL

The mobile/leachable fraction of metals and trace elements present in WTR will determine the restrictions and requirements applicable for on-site and off-site disposal. The toxicity of WTR intended for disposal should be determined as follows:

1. Obtain a hazard rating using test results (based on the Toxicity Characteristic Leaching Procedure (TCLP) test (Appendix A));
2. Find the LD_{50}'s and LC_{50}'s for the compounds required (Acceptable Risk level; ARL);
3. Calculate the Estimated Environmental Concentration (EEC) and total load; and
4. Determine the hazard rating (HR) and the potential to delist the WTR to a lower HR.

These steps will be discussed in the sections that follow.

Hazard rating and delisting of waste

Hazard Rating (HR) takes into account the toxicity (LD_{50}), ecotoxicity (LC_{50}), carcinogenicity, mutagenicity, teratogenicity, persistence, environmental fate and Estimated Environmental Concentration (EEC) of the waste. The HR indicates the risk posed to humans and the environment by the disposal of the waste and differentiates between a Hazardous Waste that is fairly or moderately hazardous and one that is very or extremely hazardous.

Delisting is based on the estimated environmental concentration (EEC) and the acceptable risk level (ARL) of a particular pollutant (Figure 10). The determination of EEC establishes potential exposure to target populations or organisms. A TCLP analysis of the WTR should be done before delisting.

The EEC is the concentration of a hazardous substance that may migrate from the disposal site, based on the assumption that the total mass of the hazardous substance disposed of on one hectare of a disposal site will leach into one hectare of groundwater with a depth of 15 centimetres underlying the disposal site within one month. The EEC of the substance in the waste is calculated in grams disposed of per hectare per month multiplied by a factor of 0.66.

Therefore, **EEC** (ppb) = g/ha/month x 0.66

A waste may delist if the EEC of a substance is equal to or less than one tenth of the LC_{50} for that specific substance. The LC_{50} or acute eco-toxicity is the concentration at which a substance would kill 50% of organisms if it were disposed of directly into a body of water. If the concentration of the hazardous substance does not exceed 10% of the LC_{50}, it represents an Acceptable Risk Level (ARL) that would cause a mortality incidence of one in three hundred thousand (1:300 000) in the aquatic environment.

Delisting is regulated by the most hazardous contaminant in a waste stream. The EEC of such a contaminant must be compared to the ARL to determine whether such a waste stream will delist or not. The EEC may also be used to determine the maximum acceptable load of a hazardous substance that may be disposed per hectare.

Since a single substance can determine the HR, treatment can be used to reduce the hazardousness of the substance. Thereafter, the next most hazardous substance will determine the HR. Treatment (liming) can thus be used to delist a waste to a lower HR or to allow a waste to be disposed of as a general waste. Note, however, that the treated waste will have to be tested and analysed once more to confirm the efficacy of the treatment.

Examples of waste delisting are presented in the *Minimum Requirements for waste disposal by landfill (Latest edition)*[5].

---

[5] Department of Water Affairs & Forestry. Waste Management Series (Latest Edition). Document 2: Minimum Requirements for waste disposal by landfill.

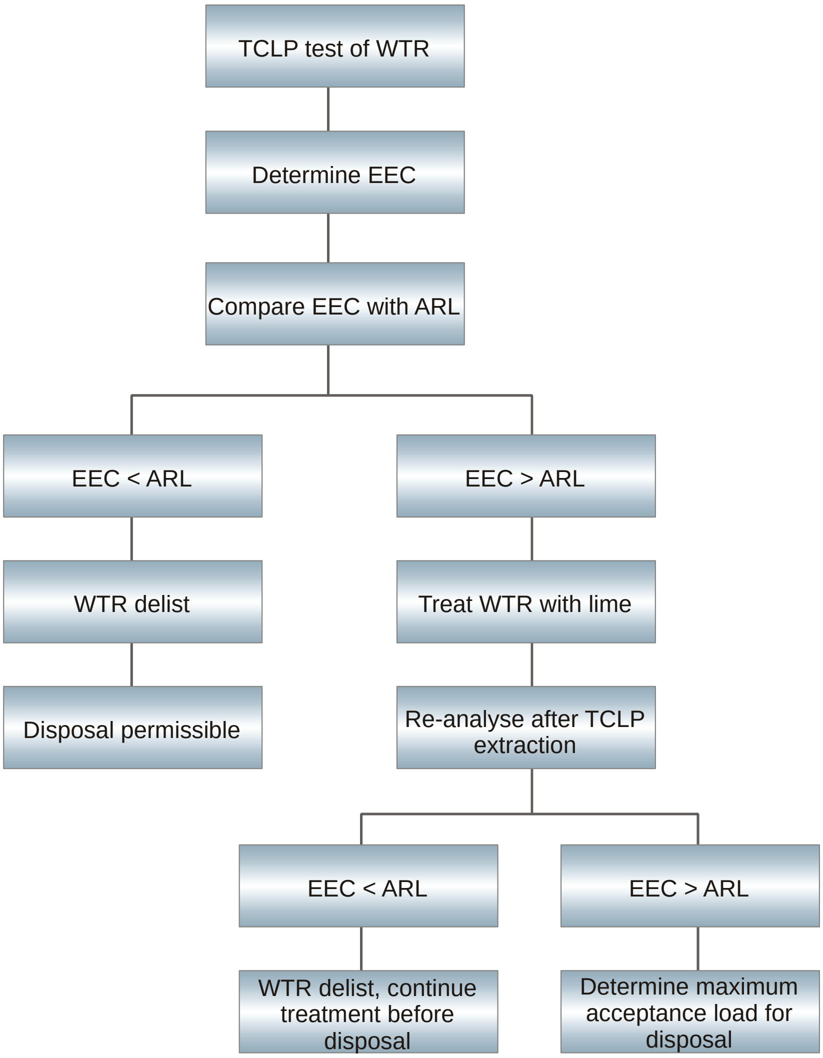


Figure 10: Schematic presentation of delisting process

LEGAL REQUIREMENTS FOR DISPOSAL

Authorisation required

The authorisation/s required for WTR disposal is/are as follows:

- **On-site disposal** – Water Use Authorisation in terms of Section 40 of the National Water Act (Act No. 36 of 1998). On site disposal of WTR is usually included in the water use authorisation for the WTP, and does not necessarily require a separate authorisation. The authorisation may be in the form of a water use licence, general authorisation or an existing lawful use.
- **Off-site land disposal** – Waste Permit in terms of Section 20 of the Environment Conservation Act (Act No. 73 of 1989)

On-site disposal is the disposal of WTR <u>within the boundaries</u> of the water treatment plant (WTP); and

Off-site disposal is the disposal of WTR <u>outside the boundaries</u> of the WTP.

Regulatory requirements

The relevant regulatory requirements applicable to the on-site and off-site disposal of WTR are listed in Table 4. The responsible authority (DWAF or DEAT) may require an Environmental Impact Assessment (EIA) to be carried out before a waste permit or water use authorisation is issued.

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

Table 4: Regulatory requirements applicable for on-site and off-site disposal of WTR

Disposal Option	On-site disposal	Off-site land disposal
Applicable Act Governing Practice	National Water Act (Act No. 36 of 1998)	Environmental Conservation Act (Act No. 73 of 1989) Natural Environment Management - Waste Management Act
Authorisation Required	Water Use Authorisation	Disposal Site Permit
Lead Authority	DWAF	DEAT
Regulatory Instrument	Water use licence (Or general authorisation or existing lawful water use)	Disposal Site Permit
Regulatory Guidelines	WTR Guidelines and Minimum Requirements	

PART 5.1: ON-SITE DISPOSAL

On-site disposal of WTR on dedicated land (DLD) or lagoons is generally the alternative chosen by those WTP that generate high quantities of residuals or have quality concerns. Due to high application rates of WTR, the disposal site needs to be carefully designed to contain any of the residual constituents that might threaten public health or the environment. Surface runoff controls including physical structures such as dikes, ditches and lagoons have to be implemented and control must be taken of leachate that is generated which may require collection and treatment prior to discharge or disposal.

RESTRICTIONS AND REQUIREMENTS FOR ON-SITE DISPOSAL OF WTR

Initial site investigation

Initial site investigation is necessary to collect background/baseline data which could be used to assess the impact of the disposal practices over time. In cases where a new site is selected as part of a new WTP or major extension, the initial site investigation will form part of the EIA that will be required to obtain a RoD from DEAT. The EIA process might require a more detailed investigation. The site investigation for existing and new sites should include (as a minimum):

- **Topography** – The slope of the disposal site should be considered to minimise run-off, erosion and ponding.

- **Soil properties** –

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

  > **Note**: Soils with clay content <20% should not be considered for land disposal unless the site is to be lined

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

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

  - The concentration of nutrients, macro elements (Al, Fe and Mn), trace elements and metals will give baseline concentrations to determine the incremental effects of disposal on the soil.

- **Surface water** – Where surface water resource contamination is a possibility, background water quality sampling is required to determine the baseline values which can be used for comparative purposes in future.

- **Groundwater** – Groundwater quality (up gradient and down gradient) will give baseline information to assess future impact of disposal on groundwater quality.

Consideration of sensitive areas:

- Unstable areas (fault zones, seismic zones and dolomitic or karst areas where sinkholes and subsidence are likely).
- Areas characterised by steep gradients where slope stability could be a problem and soil erosion would be prevalent.
- Areas of groundwater recharges on account of topography and/or highly permeable soils to minimise groundwater pollution.

Buffer zones:

- Depth to aquifer >5 m.
- Distance from surface water/borehole must be >200 m.

Note: These buffer zones may be relaxed on condition that proof is provided that the groundwater and surface water is adequately protected. An increase in buffer zones may also be required depending on site conditions.

MANAGEMENT REQUIREMENTS FOR ON-SITE DISPOSAL

Run-off collection

Run-off includes rainwater and other liquid that drains over the land and runs off the land surface. Run-off may be contaminated by WTR and must be collected and disposed of according to the licence requirements. In some disposal practices like existing, unlined lagoons, this is not possible. In these cases, a stringent monitoring program should be adopted.

Surface water protection

Surface water resources near the disposal sites need to be protected against contamination by constituents from the waste disposed of at the site. This could be achieved by:

- Constructing cut-off trenches or bund walls down-gradient of the disposal site to intercept run-off;
- Increasing the distance between the waste disposal site and the water body to ensure no run-off will reach the water body;
- Planting non-edible crops/plants/trees with a high water demand that will intercept run-off.

Groundwater protection

Groundwater is a valuable resource in the South African context and WTR placed on land should not contaminate the aquifer. The owner/operator should provide proof that groundwater is not contaminated by means of:

- Implementing a groundwater monitoring programme;
- Monitoring of the transmission zone at regular intervals (every 3 years);
- Proof that groundwater monitoring is not required based on a detailed study by a qualified person, either because of the depth of the water table, the amount of waste disposed or other site specific factors

Liner requirements

A liner is a low permeability layer placed beneath a land disposal site, designed to direct leachate to a collection drain or sump, or to contain leachate. It may comprise natural materials, synthetic materials, or a combination thereof. Appropriate liners might be required when:

- WTR with HR that cannot be delisted (high metal content) are disposed; and
- The disposal site is situated on sandy soil (<20% clay).

For more information on liner design requirements, consult the latest edition of the *Minimum Requirements for Waste Disposal by Landfill (Latest edition).*

Soil quality

Total trigger values (TTV) and maximum permissible levels (MPL) for 8 metals in the receiving soil (Table 5) have been set to ensure that the soil quality in unlined facilities does not degrade to such an extent that major intervention is required to restore soil functionality.

When the total metal content (*aqua regia* digestion, Appendix A) of the soil exceeds the TTV the capacity of the soil to receive WTR at high loading rates is approaching its limit and that additional management requirements should be implemented (additional liming to ensure immobility of metals in the soil profile). The monitoring requirements are explained in the "Soil monitoring" section. Waste disposal on the site should cease (no remediation needed) when the soil metal concentration reach the MPL.

Table 5: Recommended metal limits for soil at unlined WTR disposal sites

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

Other elements that might be of concern at disposal sites will be indicated during the hazard rating of the WTR. These elements might include Al, Fe and Mn, depending on the treatment process of the raw water. Although these elements are not included in Table 5, they should also be monitored (see "Soil monitoring" section).

These elements are major constituents in soils and therefore no maximum limits can be set. The normal ranges (total concentrations) of these elements are detailed below and can be used as a baseline:

- Al: 10 000 mg/kg – 40 000 mg/kg;
- Fe: 1000 mg/kg – 100 000 mg/kg; and
- Mn: 10 mg/kg – 9000 mg/kg.

However, for groundwater protection the available or soluble concentrations of Al, Fe and Mn are more important than the total concentrations, which are strongly influenced by the pH and redox (especially for Mn) conditions in the soil. The normal ranges of soluble Al, Fe and Mn in soils are as follows:

- Al: 0.4 mg/L at neutral pH and 5 mg/L in acidic soils (pH <4.5);
- Fe: 0.03 – 0.55 mg/L at neutral pH and up to 2 mg/L in acidic soils; and
- Mn: 10 mg/L in normal soils.

It is therefore recommended that the water soluble fraction of Al, Fe and Mn be determined to assess the potential for groundwater contamination (see "Soil monitoring" section).

Restrictions on crop production

No **edible crops** (grain, fruit and vegetables) may be grown on disposal sites (during operation and after closure) unless the owner/operator at the disposal site can demonstrate to the permitting authority that public health and the environment are protected from reasonably anticipated adverse effects of certain pollutants present in the waste.

Public access restrictions

Public access must be restricted at all disposal sites while the site is in operation and 3 years after closure.

Restrictions on grazing animals

No grazing animals are allowed on disposal sites unless the owner/operator at the disposal site can demonstrate to the permitting authority that public health, health of the animals and the environment are protected from reasonably anticipated adverse effects of certain pollutants present in the waste.

MONITORING REQUIREMENTS FOR ON-SITE DISPOSAL

The analytical data collected during monitoring must be interpreted by the WTR producer. If any problems are identified it must be communicated to the relevant Authority.

WTR monitoring

WTR monitoring is recommended to determine whether WTR quality increased or decreased with time. Management options may be re-evaluated if the quality of the WTR increases. It is recommended that quarterly TCLP analyses be conducted on WTR samples.

Note: The frequency for WTR monitoring could be relaxed if the producer can proof that the quality of WTR remains constant. Monitoring need to be at least biannually to account for seasonal variation.

Groundwater monitoring

Monitoring boreholes should be located to intersect groundwater moving away from a disposal site. The number and location of boreholes have to be determined by a responsible person.

- Boreholes should be located on either side of the disposal site in the direction of the groundwater flow (up-stream and down-stream).
- Site monitoring boreholes must be such that the section of the aquifer most likely to be polluted first is monitored.
- Groundwater levels must be recorded on a regular basis to detect any changes or trends.
- Quarterly sampling and analyses (pH, EC, PO_4, NH_4, NO_3 and elements with elevated concentrations in TCLP extract) of groundwater is recommended.

Note: The frequency for groundwater monitoring could be relaxed when:

- Water table >5 m;
- Soil clay content >35%; or
- Monitoring results over a period of at least 5 years indicate an insignificant impact. It is recommended that the regulating authority be consulted and that supporting information be provided.

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

- Water sampling, preservation and analyses should be done according to prescribed procedures (Appendix B).
- If the restrictions and requirements in this guideline are adhered to, groundwater should be adequately protected. However, it is recognised that in some unforeseen circumstances groundwater contamination may be observed for which a closure and remediation plan is required.

Surface water monitoring

Surface water should be monitored to ensure that surface water bodies are not contaminated by WTR disposal practices.

- Surface water quality should be monitored monthly during the rainy season, 20-50 m upstream and downstream of the application site;
- Water sampling, preservation and analyses should be done according to prescribed procedures (Appendix B);
- Analyses should, as a minimum, include pH, EC, PO_4, NH_4, NO_3 and elements with elevated concentrations in TCLP extract.

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

- The distance to the nearest surface water resource or borehole is > 400 m;
- The user can prove that the surface water resource is adequately protected through run-off interception;

- Monitoring results over a period of at least 5 years indicate an insignificant impact. It is recommended that the regulating authority be consulted and that supporting information be provided.

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

Soil monitoring

Soil monitoring is only required at unlined disposal sites. Soil monitoring will serve as an early warning system on the mobility of constituents of concern in the soil profile and the potential for groundwater contamination.

- Soil sampling and analyses should be conducted biannually;
- Increase the sample frequency when the soil pH<6.5 and/or soil clay content <20%.
- Soil analyses should include, as a minimum:

  - *aqua regia* digestions with an ICP scan to determine the concentration of metals;
  - water soluble extraction to determine the soluble concentrations of Al, Fe and Mn (Appendix A);
  - determination of the pH, EC, PO_4, NH_4, NO_3 and other major cations and anions present in the WTR

- Soil sampling and analyses should be done according to described procedures (Appendix B). Soils should be sampled at 100 mm intervals to a depth of at least 500 mm.

CLOSURE AND REMEDIATION PLANS FOR ON-SITE DISPOSAL SITES

Once the operation has ceased, aftercare is necessary to ensure sustained acceptability of the disposal site. A remediation and closure plan for all disposal sites is required and should be developed by a responsible person (see “Definitions and Descriptions” at the end of this document).

Aspects that should be addressed include:

- Remedial design to address identified problem areas (or future problems);
- Size of the disposal site (localised waste pile or large area irrigated with WTR);
- Extent of pollution – sites where metals have not migrated down the soil profile will require a less complicated rehabilitation plan than sites where groundwater contamination has already occurred;
- Future land-use;
- Final landscaping and re-vegetation;
- Permanent storm water diversion measures, run-off control and anti-erosion measures; and
- Post-closure monitoring plan and implementation.

RECORD KEEPING REQUIREMENTS FOR ON-SITE DISPOSAL SITES

Once the applicable permits and authorisations have been granted, WTR disposal areas essentially become self-regulatory. This implies that certain records must be kept by the WTR producer and disposal site owner/operator.

The following records need to be kept:

- Copy of the applicable licences and permits;
- Initial site investigation/baseline data of soils, surface- and groundwater; and
- Monitoring results of WTR, groundwater, surface water and soils.

PART 5.2:

OFF-SITE DISPOSAL

Part 5.2 deals with specific restrictions and requirements for off-site disposal of WTR on a General or Hazardous landfill. The disposal of waste on landfills in South Africa is dealt with in the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous waste* and *Minimum Requirements for Waste Disposal by Landfill*. All actions required in the design, operation, monitoring and closure of landfill sites in South Africa are described in these publications. This part of the WTR Guideline presents procedural Guideline for disposal of WTR on landfill.

LANDFILL CLASSIFICATION

The Minimum Requirements detail landfill designs based on the specific landfill classification. Waste type, waste volumes and the water balance determine the landfill classification.

Table 6: Landfill classification

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

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

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

BASIC PROCEDURE FOR DISPOSAL ON LANDFILL

The **basic procedure** followed for landfill disposal is as follows:

- Determine the hazard rating (HR) of the waste using analytical results (TCLP test) as follows:

    - Compare the EEC with the ARL;
    - The constituents of concern (COCs) exceeding the ARL determine the HR (HR1 most toxic – HR4 least toxic);
    - Determine the maximum acceptable load that may be disposed per hectare per month;

- Determine the potential to delist the WTR to a lower HR (treatment or total load principle);
- HR2 – HR4 waste may be delisted and disposed on a properly designed and permitted GLB$^+$ or GMB$^+$ site;

- HR1 waste should be disposed on H:H or H:h sites.

Examples of hazard rating and delisting of waste are presented in the *Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (Latest edition)*.

SOLIDS CONTENT

General landfill sites will not accept WTR with a liquid or viscous consistency. Table 7 show the physical consistency of coagulant and lime softening residues at different solids content. Since the different WTR show different characteristics at different solids content, no blanket minimum solids content can be recommended, but will depend on the WTR and the landfill operator. This requirement should be based on site specific investigation and specific landfill site requirements.

Table 7: Physical consistency of coagulant and chemical softening residues at different solids contents

Coagulant Residue		Lime Softening Residue	
Solids content	**Physical consistency**	**Solids content**	**Physical consistency**
0-5%	Liquid	0-1%	Liquid
8-12%	Spongy, semi-liquid	25-35%	Viscous liquid
18-25%	Soft clay	40-50%	Semi-solid
40-50%	Stiff clay	60-70%	Crumbly cake

WTR MONITORING

WTR should be monitored on a regular basis to ensure that the quality stays within the limits required for disposal to landfill. Although quarterly TCLP analyses on WTR samples is recommended, the landfill operator may require additional monitoring, especially in the case of WTR that needs to be treated before it can be delisted for disposal.

ADDITIONAL SITE INVESTIGATION REQUIREMENTS FOR LANDFILL

The initial site selection and investigation for the landfill site should be conducted according to the *Minimum Requirements for Waste Disposal by Landfill.* The following components should receive particular attention:

Specific water balance studies

A site specific water balance should be undertaken for landfill sites where WTR disposal is proposed. Operators of landfill sites with a negative water balance must prove that no leachate will be generated due to WTR co-disposal.

PART 5.2: OFF-SITE DISPOSAL

Site stability assessment

- Site stability assessments are essential to the landfill design. Stability assessments must be done by a professional engineer at sites where WTR co-disposal is practised.
- The spacing and orientation of trenches must be considered in 6-monthly stability assessments. As a precautionary principle the shear strength of WTR should be assumed to be zero.
- As a general rule, trench orientation should be perpendicular to the crest of a landfill and no trenching should occur within 30 m of the crest.
- The effective degree of mixing that is achieved with trenching should be taken into account when calculating an acceptable co-disposal ratio in terms of leachate generation.

MANAGEMENT REQUIREMENTS FOR LANDFILL SITE

All the management requirements as specified in the *Minimum Requirements for Waste Disposal by Landfill: Landfill Operation* (Latest edition) should be adhered to. Only the requirements specific to WTR disposal will be discussed in this section.

WTR analyses/monitoring information

Since the waste quality is fundamental in the management of the landfill site, the landfill operator should be certain of the WTR quality/toxicity. This is especially important in cases where the WTR needs to be treated (limed) before it delists. The landfill operator should regularly receive the WTR analyses results and/or monitoring information.

Co-disposal ratio

- The co-disposal ratio may not exceed 1:10 (mass of wet WTR to mass of waste)
- Metal concentrations must be considered in the determination of an appropriate co-disposal ratio and based on these; the co-disposal ratio may need to be lower than 1:10.

The procedure for calculating co-disposal ratios for co-disposal of liquid waste is explained in the section on "*Landfill operation" (Minimum Requirements for Waste Disposal by Landfill (Latest edition))*.

Run-off collection and management

- Run-off and storm water must always be diverted around one or both sides of the waste body, by a system of berms and/or cut-off drains.
- Water contaminated by contact with waste, as well as leachate, must be contained within the site. If it is to be permitted to enter the environment, it must conform or be treated so as to conform to the water quality limits specified in terms of the Permit.
- The basis of trenches and cells must be so designed that water drains away from the deposited waste.
- The contaminated run-off from the landfill must be stored in a sump or retention dam. It may be pumped from the dam and disposed of if it conforms to the water quality limits specified and stipulated in the Permit.
- A 0,5 m freeboard, designed for the 1 in 100 year flood event, must always be maintained in the case of contaminated water impoundments and drainage trenches.

- All temporarily and finally covered areas must be graded and maintained to promote run-off without excessive erosion and to eliminate ponding or standing water.
- Clean, uncontaminated water, which has not been in contact with the waste, must be allowed to flow off the site into the natural drainage system, under controlled conditions.
- All drains must be maintained. This involves ensuring that they are not blocked by silt or vegetation.

SPECIFIC MONITORING REQUIREMENTS FOR LANDFILL

Monitoring serves to quantify any effect of the operation on the environment, especially the water regime, and act as an early warning system, so that any problems that arise can be identified and rectified. Such problems would include:

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

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

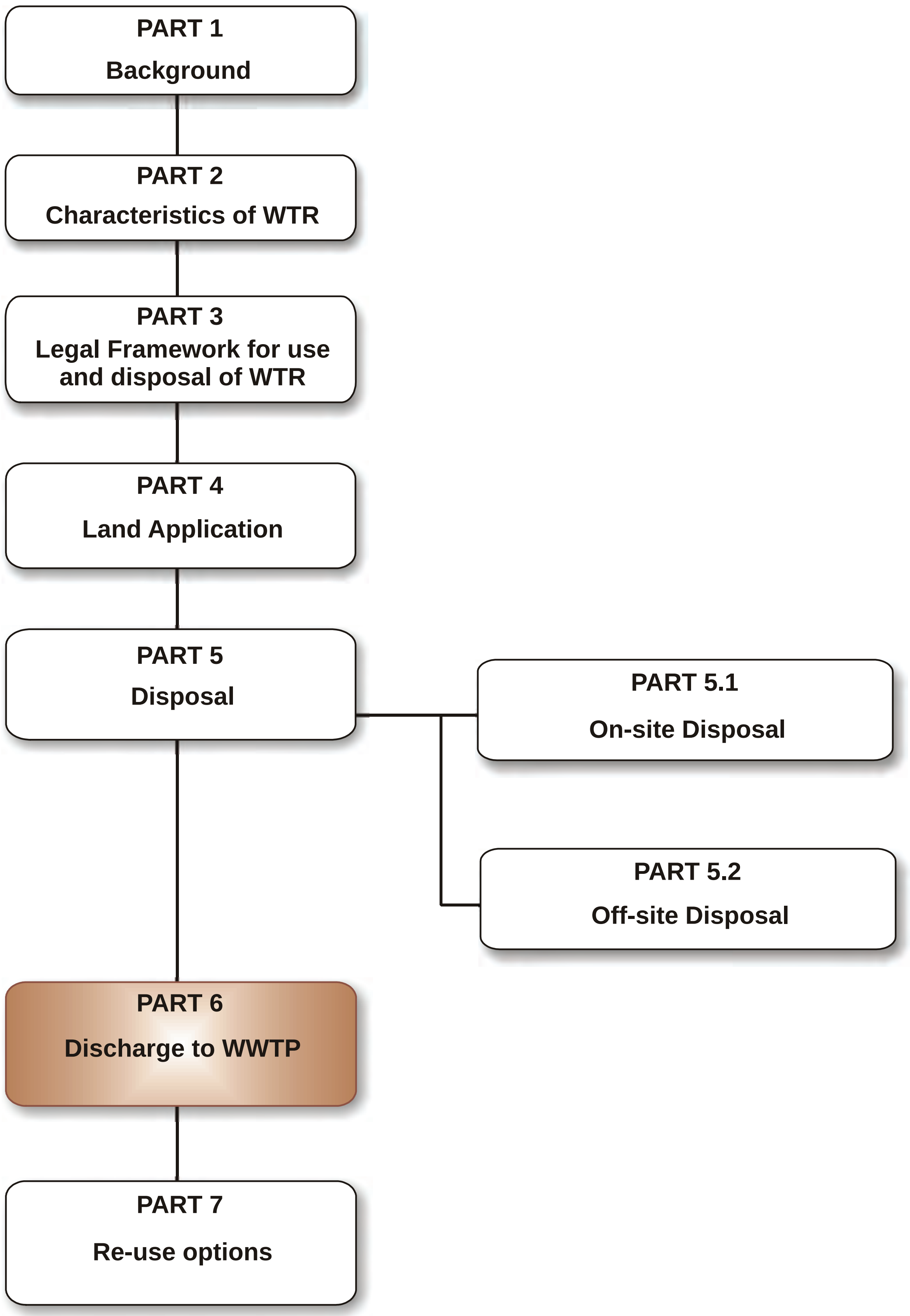
CLOSURE OF LANDFILL SITES

The objectives of disposal site closure are:

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

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

DOCUMENT ROADMAP



PART 6:

DISCHARGE TO WWTP

Discharge of WTR to a wastewater treatment plant (WWTP) is another disposal option for water services institutions. These options are often economically attractive and transfer disposal liability to the WWTP. Conventional WTPs (coagulation, sedimentation and filtration) commonly discharge filter backwash solids and/or clarification basin residuals to a sanitary sewer system for eventual treatment at a WWTP.

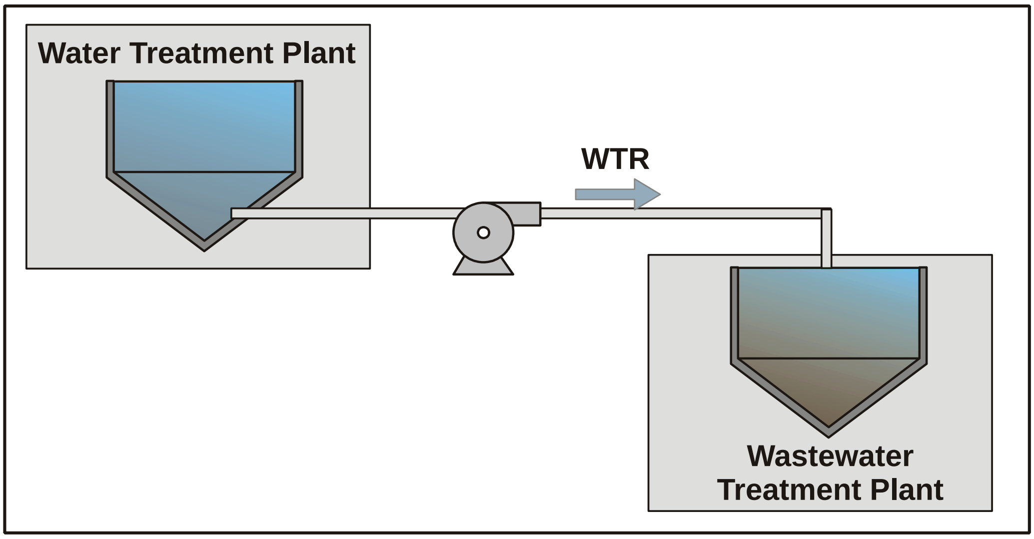


Figure 11: Discharge of WTR to the WWTP

Several factors must be considered when evaluating the feasibility of discharging residuals to a WWTP. The interests and concerns of WWTP managers and operators are different from those of similar personnel in water utilities. Factors for a WWTP to consider are available capacity (conveyance system and treatment plant), treatment process compatibility and final disposal requirements. Introducing WTR to a WWTP may offer some benefits in terms of process performance. On the water treatment facility side, pre-treatment requirements, storage facilities and conveyance systems must be considered. Costs and service agreement terms must also be evaluated.

ADVANTAGES

The advantages for the receiving WWTP include:

- Increased removal of suspended solids and/or biochemical/chemical oxygen demand (BOD/COD);
- Increased removal of phosphorus; and
- The discharge of WTP ferric residuals can counteract the problems of H_2S formation in sewers and at the WWTP.

DISADVANTAGES

Potential limiting concerns for a WWTP when it accepts WTR include:

- Increased final suspended solids,
- Decreased effective digester capacity,
- Overloading of primary clarifier and sludge removal systems, and
- Overloading of dewatering operations.

AGREEMENT BETWEEN WTP AND WWTP

Discharge to a WWTP is possible only when WWTP and WTP work together cooperatively. Information sharing is imperative to establish such a relationship. The WTP should provide information concerning WTR quality and quantity, dry solids content, pH, nutrients, heavy metals and other relevant parameters.

In addition, the WWTP and WTP must cooperate to determine whether positive or negative effects can be expected at the WWTP with respect to hydraulic conditions in the sewer lines, hydraulic and process capacity at the WWTP, sludge treatment and ultimate disposal of WWTP sludge.

It is therefore recommended that there be a legal contract between the WTP and the WWTP.

CONSIDERATIONS / REQUIREMENTS FOR DISCHARGE TO WWTP

The local discharge requirements imposed by a WWTP may be governed by:

- Impact of WTR on the waste conveyance system (sewer, pump station, force mains, abrasion and corrosion);
- Impact of WTR on the treatment system at the WWTP (rate of discharge, solids concentrations, need for flow equalization); and
- Concerns about biotoxicity (within the WWTP or in the plant's effluent).

Equalization of discharge flow

WWTP often impose requirements on a WTP that govern the release of WTR to a sanitary sewer. The most common of these requirements is equalization of discharge flow. Equalization restrictions may include limitations on the time of day of discharge, the maximum flow over a certain period, or the maximum solids discharge that is allowed. Sometimes, discharges of peak flows during otherwise low flow periods in the sanitary sewer may be desirable.

pH of WTR

The WTR discharged must be in a pH range of 6 to 9. This could cause problems for lime WTR. Neutralization facilities for pH adjustment before discharge at the WWTP may be required.

Trace elements and metals

Passing the TCLP test allows a WTR to be classified as nonhazardous; however, it does not preclude the possibility of toxic effects on a WWTP if the WTR is discharged to the facility. Although organics and inorganics can be the cause of toxic effects from WTR, heavy metals are most often responsible for toxicity problems at WWTPs.

Organic Loading

The organic content of WTR varies widely, depending heavily on the quality of the raw water processed at the WTP. The concentration of organic matter in WTR, as measured by BOD or COD, is not typically in the range of that found in wastewater.

Although organics loading is typically the controlling parameter for the biological unit treatment processes in both the liquid and solids handling process trains at a WWTP, the additional organics loading encountered by introducing WTR generally does not have a significant impact.

Solids Loading

The introduction of additional solids from WTR generally does not significantly affect the WWTP. The introduction of alum and iron residuals can actually improve the efficiency of primary clarification in WWTPs. A common factor related to the discharge of WTR to a WWTP is an increase in sludge from the WWTP.

The effects of the additional residuals on clarification, digestion, dewatering and final disposal must be considered. Generally, final sludge volume increases as the amount of influent WTR increases.

Liquid/Solids Separation

When WTR are discharged into a sanitary sewer system, one of the first unit processes that they encounter is primary sedimentation at a WWTP. When WTR were accepted on a regular basis at the WWTP, the primary sludge solids content can drop from 5.8 to 4.7%.

Although the efficiency of primary settling may decrease by approximately 10%, scum removal and settling in secondary clarification can improve.

Lime softening residuals settle very well and should not affect the wastewater treatment primary settled sludge volume as much as coagulation residuals do.

Dewatering

Although available information has generally shown that sludge dewaterability is not negatively impacted by alum residuals, gravity settling of the sludge may be affected.

ASPECTS FOR WWTP TO CONSIDER

Capacity

When evaluating the option of discharging WTR to a WWTP via a sanitary sewer system, sedimentation tank capacities must be checked to ensure that they will not be overloaded by the additional solids. This precaution is especially critical for primary sedimentation, since the majority of the residuals solids will be removed here.

The capacity of sludge pumps, pipes, and subsequent conveyance systems must also be examined; the removal of a larger volume of sludge at a lower solids concentration would require a larger pumping capacity and/or a higher pumping frequency.

Aerobic digestion and activated sludge processes

To accommodate WTR, an aerobic digestion system must have the physical capacity to accept the additional solids loading that WTR bring. Although the volatile solids contribution from the residuals is expected to be low and should not significantly affect the overall volatile solids loading to the digester, the impact of the WTR on hydraulic and solids retention time must be considered.

Toxic compounds present in WTR can adversely affect the biological processes of wastewater treatment facilities. If the dosing of WTR is equalized so that surges do not occur and the dose is kept below 150 to 200 mg/L, no direct effect on the activated sludge process is likely to take place, although downstream process effects or solids handling process effects are possible.

Anaerobic digestion

Because softening residuals can cause lime deposition, discharging softening residuals to a WWTP may adversely affect the performance of the anaerobic digester. If softening residuals are added directly into the anaerobic digester, the temperature can fall because of the additional volume of inert material. Additional heating may be required in this event.

Unless WTR are introduced at a very high rate, anaerobic digesters are unlikely to be significantly affected, provided the digester has adequate capacity to accommodate the increased solids loading. In assessing digester capacity, the reduced volatile solids concentration of the residuals stream must be taken into account.

WTR MONITORING REQUIREMENTS

Due to the characteristics of WTR which may have an influence on the downstream WWTP, the quality and properties of the WTR need to be monitored on a regular base. The monitoring should include, as a minimum, the following:

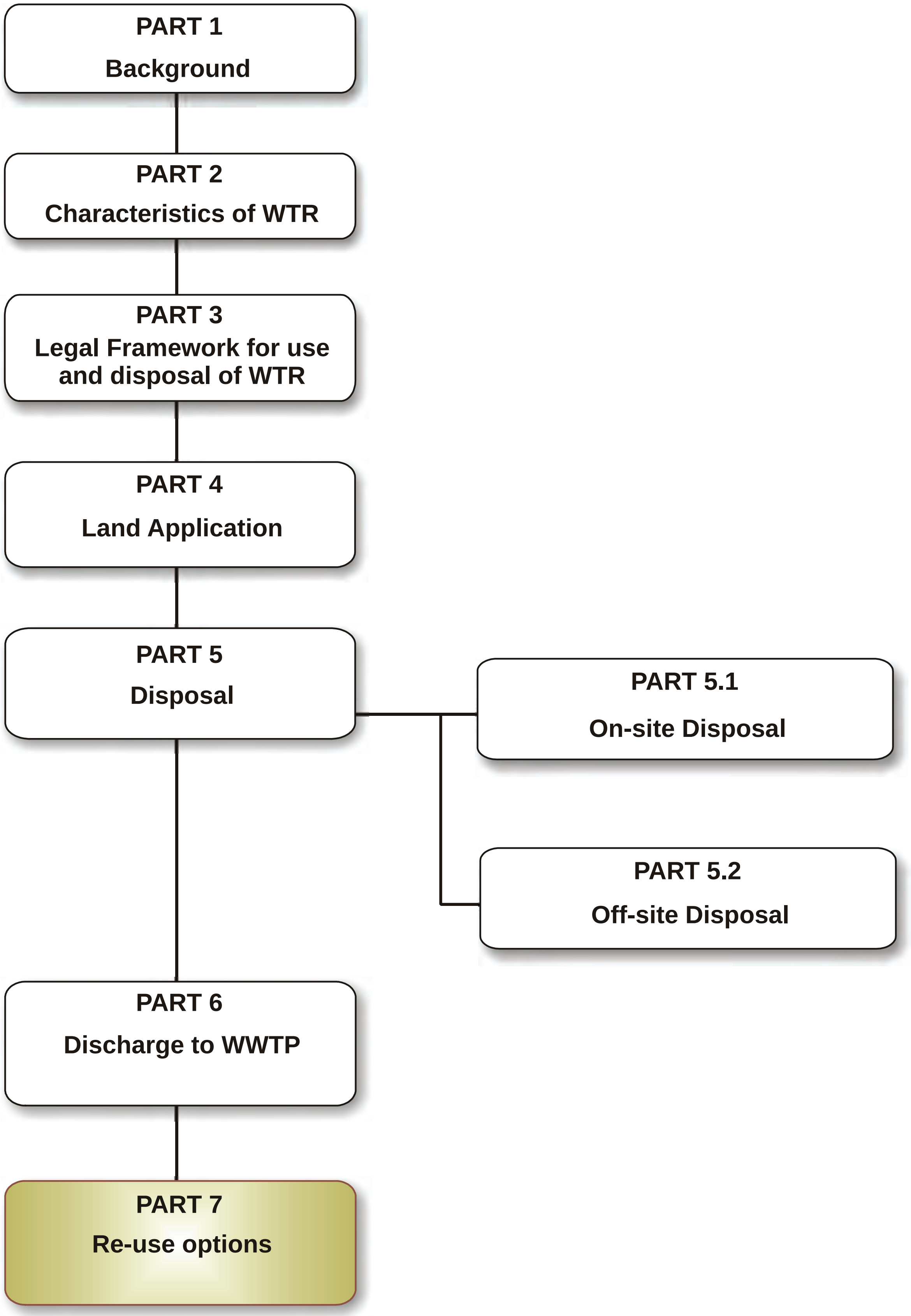
- pH;
- Organic load (COD and/or BOD);
- Mobile metals (water or TCLP extract); and
- Solids content.

RECORD KEEPING REQUIREMENTS

The following records need to be kept by the WTP:

- Copy of the applicable licences and permits;
- Legal contract between WTP and WWTP;
- Discharge volumes and frequency; and
- Monitoring results of WTR.

DOCUMENT ROADMAP



PART 7:

REUSE OF WTR

Although not practiced in SA, potential reuse alternatives (other than land application) practiced internationally include the following:

- Recovery of coagulants;
- Use in making bricks; and
- Use in Portland cement.

RECOVERY AND RE-USE OF COAGULANTS

The coagulants added during the water treatment process form a large part of the WTR. An attempt at recovering these coagulants for use in water and wastewater treatment is an attractive option if the WWTP will not accept the WTR itself. The recovery process normally includes acidification to mobilize the alum and ferric, but alkaline treatment and liquid ion exchange is also possible treatment options.

The effectiveness and purity of the recovered coagulants are varied and the economy of the recovery process is also subject to debate. The following positive effects on WTR after coagulant recovery can be possible:

- Significantly reduce the cost of coagulants used at the WTP and WWTP;
- Can help meet discharge standards at a reduced cost;
- Reduced WTR volume and associated disposal cost;
- Make WTR more suitable for disposal (lower metal content);
- Improve dewatering characteristics of WTR; and
- Increase the life of the disposal facility.

USE IN MAKING BRICKS

The WTR need to be characterized to determine the components that will affect the process, *i.e.* organic and water content. Ferric WTR are more feasible than alum WTR due to their Fe and organic matter content. Ferric WTR also provides some energy savings in brick making because it acts as a fluxing agent. It also provides raw material savings in the use of water and clay. WTR can also be used together with wastewater sludge in the brick-making process.

However, there have been concerns about the compressive strength and shrinkage characteristics of brick made from WTR and further, site specific investigation is recommended.

USE IN MANUFACTURING OF CEMENT

Recycling of WTR to the cement industry is a practical alternative because the chemical composition of the inorganic WTR is similar to the clay used in cement production. WTR can increase the compressive strength of the concrete. However, the chlorine level of the WTR has to be low because the chlorine could erode the cement kiln and block its duct.

OTHER POTENTIAL OPTIONS

A number of studies have specifically examined the potential of WTR to remove excess nutrients from contaminated land, water and other waste products. Water treatment residues were found to be beneficial in removing excess N and P from land that had received excess nutrients from poultry litter, manure or fertilizer. The WTR is thus able to prevent or reduce eutrophication. The principle has also been successfully extended to co-application of WTR with wastewater sludge with the aim of reducing the high active P concentrations in the WTR.

The use of industrial by-products to improve the conditions of mine wastes for plant growth and to simultaneously act as a potential disposal option for the by-product have been reported extensively in the literature. The use of WTR for mine rehabilitation to neutralize acid mine drainage has the following positive effects:

- WTR is suitable as a liming agent, especially at alkaline pH;
- Application of WTR to acid gold tailings may increase the leach water pH from 4.5 to more than 7.5;
- The addition of WTR may further reduce the solubility of iron, manganese, copper and zinc in the ameliorated gold tailings.

Use of WTR, especially lime WTR, to rehabilitate coal mine waste was researched in SA with the following results:

- Grass biomass decreased in mean total yield with increasing WTR application rate, but yield was good up to the 200 g/kg;
- The pH and EC of the leachate generally increased with increasing WTR addition;
- The concentration of nutrients in the grasses did not indicate any deficiencies or toxicities.

From these studies it was concluded that lime WTR could be applied to the coal mine spoil medium at relatively high concentrations without severely negatively impacting on grass growth, but that more caution should be used when applying this material to the soil medium.

CONCLUSION

Although there are limited information available on the characteristics of WTR and its impact on soil, surface- and groundwater, this Guideline will serve as a first step to ensure responsible handling, application and/or disposal of WTR into the environment.

This Guideline document was developed to assist the WTR producer to decide on an appropriate management option for WTR. It informs the reader regarding the legal requirements for each management option as well as restrictions and requirements applicable to the different options. Monitoring programmes are introduced to collect data on the variability of WTR quality as well as to determine the potential impact of the management options on the receiving environment.

It is recognized that new information will be generated through future research and monitoring and it is recommended that these Guideline be updated every 5 to 10 years. This will allow the South African water industry sufficient time to implement the Guideline and highlight shortcomings and constraints. Through the introduced record keeping process, case specific data will be generated that will enrich the local knowledge base.

APPENDIX A: ANALYTICAL METHODS REQUIRED FOR MONITORING OF WTR, WATER AND SOIL SAMPLES

Appendix A1: Method for the determination of total metal content of WTR and soil samples (*aqua regia* digestion)

The method is summarized below.

- Weigh 3 g of the <150 µm sludge or soil sample into a 250 mL reaction vessel.
- Moisten with 0.5-1 mL water and add, while mixing, 21 mL hydrochloric acid followed by 7 mL nitric acid, drop by drop if necessary to reduce foaming.
- Stand for 16 h at room temperature
- Boil under reflux for 2 h
- Decant the sediment-free supernatant into 100 mL flask through filter paper
- Fill the flask to the mark with 0.5 mol/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 A2: Toxicity Characteristic Leaching Procedure (TCLP) extraction for WTR destined for co-disposal (USEPA Method 1311)

Summary of method

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

Apparatus

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

TCLP solution 1

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

TCLP solution 2

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

Samples

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

TCLP extractions

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

A. Preliminary evaluation:

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

1. Weigh out 5.0 g of the dry waste into a 500 mL beaker or Erlenmeyer flask. (In this exercise the particle size of the 5 g should be 1 mm or less).

2. Add 96.5 mL of double distilled water, cover with a watch glass and stir vigorously for 5 minutes with a magnetic stirrer.

3. Measure the pH.

4. If the pH is less than 5.0, then use TCLP solution – No 1.

5. If the pH is greater than 5.0, then proceed as follows:

   5.1 Add 3.5 mL 1N HCL and stir briefly.
   5.2 Cover with a watch glass, heat to 50°C and hold at 50°C for ten minutes.
   5.3 Let cool to room temperature and record the pH.

9. If the pH is less than 5.0, then use TCLP solution – No 1.

10. If the pH is less than 5.0, then use TCLP solution – No 2.

B. Extraction for analysis of contaminants:

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

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

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

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

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

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

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

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

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

Appendix A3: Surface and groundwater analyses required for monitoring purposes

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

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

Appendix A4: Soil analyses required for monitoring purposes

Nutrients

Kjeldahl digestion to determine N

REAGENTS: Concentrated Sulphuric Acid (H_2SO_4), Digestion Mixture: Potassium sulphate (AR) very finely ground (1500 g) mixed with 4 g finely ground (AR) Cu $SO_4 \cdot 5H_20$.

Weigh out 1 g of WTR into a digestion tube, and mix it with 2 g 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 100 mL 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.*

Bray 1 P extraction

Reagents

- Ammonium fluoride stock solution: Dissolve 185.5 g NH_4F(AR) in about 4 L de-ionised water. Mix and make up to 5 L.
- Bray-1 extracting solution: Decant 600 mL NH_4F solution in a 20 L aspirator bottle. Add 10 L de-ionised water and 50 mL concentrated HCl (AR) (32%). Dilute to 20 L with de-ionised water and mix well.
- Flocculant: Add 100 mg Superfloc N-100 or N-127 slowly to 100 mL lukewarm de-ionised water. Stir at 400 rpm or shake gently till dissolved.
- 1-amino-2-naphthol-4-sulfonic acid (ANSA) stock solution: Dissolve 137 g $Na_2S_2O_5$ and 5 g Na_2SO_3 in 800 mL warm de-ionised water. Add 2.5 g ANSA and dilute to 1 250 mL with de-ionised water. Filter into an amber glass bottle and store in a cool place.
- ANSA working reagent: Dilute 100 mL stock solution to 1 dm^3 with de-ionised water. For best results make up fresh daily.
- Ammonium molybdate/Sulphuric acid: Dissolve 7.5 g ammonium molybdate in 800 mL de-ionised water containing 53 mL concentrated sulphuric acid. After cooling make up to 1 L in a volumetric flask. The reagent must be clear.

Procedure

- Place 6.67 g soil (< 2 mm) in an extraction bottle.
- Add 50 mL Bray-1 solution (20°C).
- Stopper the bottle and shake contents manually (up and down) for 60 seconds.

- Add 2 drops flocculant.
- Filter immediately through Whatman no 2 filter paper into a suitable bottle.

Reference: *Non-affiliated Soil Analysis Work Committee. 1990. Handbook of Standard Soil Testing Methods for advisory purposes. Soil Science Society of South Africa. ISBN: 0-620-14800-4.*

Trace elements and Metals

Method for the determination of NH_4NO_3 extractable (available) metal content of soil samples (DIN 19730)

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

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

APPENDIX B: SAMPLING PROCEDURES FOR WATER AND SOIL SAMPLES

WATER SAMPLING[6] PROCEDURE

Sampling equipment needed

- Equipment to collect microbiological samples

  - Sterile sample bottles (glass bottle needed)
  - Sealed container or cool box which can be kept cool (preferably with ice)

- Equipment to collect chemical and physical samples

  - Plastic bottles with plastic cap without liner / Glass bottles
  - Cooler box with ice (if necessary)

Special precautions

- Microbiological water samples

  - Keep sample bottle closed and in a clean condition up to the point where it has to be filled with the water to be sampled.
  - Do not rinse bottle with any water prior to sampling.
  - When samples for chemical and microbiological analysis are to be collected from the same location, the microbiological sample should be collected first to avoid the danger of microbiological contamination of the sampling point.
  - The sampler (person taking the sample) should wear gloves (if possible) or wash his/her hands thoroughly before taking each sample. Avoid hand contact with the neck of the sampling bottle.

- Chemical water samples

  - Some plastic caps or cap liners may cause metal contamination of the water sample. Please consult with the laboratory on the correct use of bottle caps.
  - Keep sample bottle closed and in a clean condition up to the point where it has to be filled with the water to be analysed.
  - Never leave the sample bottles (empty or filled with the water sample) unprotected in the sun.
  - After the sample has been collected the sample bottle should be placed directly in a cooled container (e.g. portable cooler box). Try and keep cooled container dust-free.

---

[6] For more detail on the water sampling procedure, consult the following documents:
- Department of Water Affairs and Forestry. 1998. Waste Management Series. Minimum Requirements for Water Monitoring at Waste Management Facilities.
- Venter, A. 2000. Quality of domestic water supplies. Volume 2: Sampling Guide. WRC no TT117/99.
- Weaver, J.M.C, Cavé, L. and Talma, A.S. 2007. Groundwater sampling: A comprehensive guide for sampling methods. 2nd Edition. WRC Report No: TT/303/07.

Surface water sampling technique

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

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

Composite Borehole Water Sampling

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

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

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

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

SOIL SAMPLING[7]

Sampling equipment needed

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

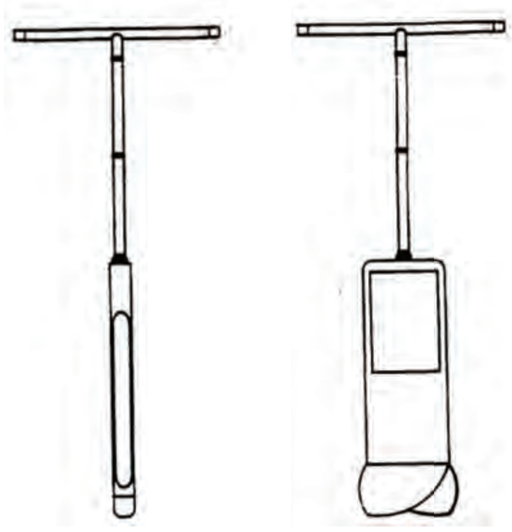


Figure B1: Soil augers

Number of samples

For mono-fills, waste piles and lagoons at least 4 composite samples of each disposal area at each depth will be required. For DLD sites the number of samples will vary according to the size of the disposal site and different soil types present at the disposal site. At least three composite samples for each depth increment for every hectare of the DLD site are required.

Sampling procedure

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

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

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

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

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

Table B1: Recommended soil sample containers, preservation and holding times

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

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

1. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.
2. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling.
3. Place the samples into plastic or other appropriate containers, secure the caps tightly and label the sample.
4. If composite samples are to be collected, place a sample from another sampling site into the same container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.
5. Preserve the samples as recommended in Table B1 and submit to a reputable laboratory

DEFINITIONS AND DESCRIPTION OF KEY TERMS

Acceptable exposure:	The concentration of a substance that will have minimal effect on the environment or human health.
Agricultural land:	Land on which a food crop, a feed crop, or a fibre crop is grown. This includes grazing land and forestry.
Agricultural use:	The use of WTR to produce agricultural products. It excludes the use of WTR for aquaculture and as an animal feed.
Agronomic rate:	The WTR 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 WTR that passes below the root zone of the crop or vegetation grown on the land to the groundwater.
Aquifer:	A geological formation which has structures or textures that hold water or permit appreciable water movement through them.
Assimilative capacity:	This represents the ability of the receiving environment to accept a substance without risk.
Attenuation:	The process of reducing the concentration of a substance by means of natural physical, chemical and biochemical processes such as dilution, oxidation and cell synthesis. Natural systems have an attenuation capacity, which may render small volumes of contaminants insignificant. However, when this capacity is exceeded, pollution results.
Available metal content (Soil):	Metal fraction extracted with ammonium nitrate in soil samples, simulating the plant available fraction.
Beneficial uses:	Use of WTR with a defined benefit, such as a soil amendment.
Bioavailability:	Availability of a substance for uptake by a biological system.
Biological oxygen demand (BOD):	An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste.
Borehole:	A well, excavation or any artificially constructed or improved underground cavity which can be used for the purpose of: • intercepting, collecting or storing water in or removing water from an aquifer; • observing and collecting data and information on water in an aquifer; or • recharging an aquifer.
Bund wall:	A properly engineered and constructed run-off interception device around a waste disposal site or down slope of a waste disposal site.
Chemical oxygen demand (COD):	A measure of the amount of oxygen consumed for chemical oxidation of pollutants.
Coagulant:	A substance that causes fine particles to stick together to be more easily settle or be removed by filters.
Coagulation:	A separation or precipitation from a dispersed state of suspension particles resulting from their growth.
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 WTR with dry waste):	The mixing of dewatered WTR with dry waste in a general landfill site or hazardous landfill site without affecting the water balance of the site.
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 WTR application areas is restricted or controlled, such as via fences or signage, for a period of time stipulated by this guideline.
Cradle-to-grave:	A policy of controlling a Hazardous Waste from its inception to its ultimate disposal.
Cumulative pollutant loading rate:	The maximum amount of a pollutant that can be applied to a unit area of land.
Cut-off trench:	A properly engineered and constructed trench to intercept and collect run-off.
Dedicated land disposal:	Sites that receive repeated applications of WTR for the sole purpose of final disposal.
Delisting:	If the estimated environmental concentration (EEC) is less than the Acceptable Risk Level (ARL) which is 10% of the LC_{50}, the waste can be delisted, *i.e.* be moved to a lower Hazard Rating or even disposed of at a General Waste landfill with a leachate collection system.
Dewatering:	Dewatering processes reduce the water content of WTR to minimise the volumes for transport and improve handling characteristics. Typically, dewatered WTR can be handled as a solid rather than as liquid matter.
Disinfection:	A process that destroys inactivates or reduces pathogenic microorganisms.
Disposal:	The discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into the environment (land, surface water, ground water, and air).
Disposal site:	A site used for the accumulation of waste with the purpose of disposing or treatment of such waste. See also Waste Disposal Site.
Domestic waste:	Waste emanating, typically, from homes and offices. Although classified as a General Waste, this waste contains organic substances and small volumes of hazardous substances.
Dose:	In terms of monitoring exposure levels, the amount of a toxic substance taken into the body over a given period of time. See also LD_{50}
Dose-response:	How an organism's response to a toxic substance changes as its overall exposure to the substance changes. For example, a small dose of carbon monoxide may cause drowsiness; a large dose can be fatal.
Drying:	A process to reduce the water content further than a dewatering process. The solids content after a drying process is typically > 75%.
Dry-weight (DW) basis:	The method of measuring weight where, prior to being weighed, the material is dried at 105°C until reaching a constant mass (i.e., essentially 100 % solids content).

Dump: A land site where wastes are discarded in a disorderly or haphazard fashion without regard to protecting the environment. Uncontrolled dumping is an indiscriminate and illegal form of waste disposal. Problems associated with dumps include multiplication of disease-carrying organisms and pests, fires, air and water pollution, unsightliness, loss of habitat, and personal injury.

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

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

Environment: The surroundings within which humans exist and that are made up of--

- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of the above and the interrelationships among and between them; and
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

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

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

Exposure: The amount of a hazardous substance available to man or living matter.

Feasible: Acceptable, capable of being used or implemented successfully, without unacceptably damaging the environment.

Flocculation: The intentional grouping of very small particles or colloids in a suspension in water or other liquids, the purpose being to increase the settlement rate of the solids.

Hazard: A source of or exposure to danger.

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

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

Infectious Substances: Micro-organisms including those which have been genetically modified pathogens, cells, cell cultures and human endoparasites which have the potential to provoke infection, allergy or toxic effects.

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

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

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

Landfill: To dispose of waste on land, whether by use of waste to fill in excavation or by

	creation of a landform above ground, where the term "fill" is used in the engineering sense.
LC_{50}:	The median lethal dose is a statistical estimate of the amount of chemical, which will kill 50% of a given population of aquatic organisms under standard control conditions. The LC_{50} is expressed in mg/L.
LD_{50}:	The median lethal dose is a statistical estimate of the amount of chemical, which will kill 50% of a given population of animals (e.g. rats) under standard control conditions.
Leachate:	An aqueous solution with a high pollution potential, arising when water is permitted to percolate through decomposing waste.
Liner:	A layer of low permeability placed beneath a landfill and designed to direct leachate to a collection drain or sump, or to contain leachate. It may comprise natural materials, synthetic materials, or a combination thereof.
Maximum available threshold (MAT):	The maximum available (NH_4NO_3 extractable) metal concentration allowed for soils receiving WTR.
Maximum permissible level (MPL):	The maximum total metal concentration allowed in soils at WTR disposal sites. Soil remediation would not be necessary except if this level is exceeded.
Minimum Requirement:	A standard by means of which environmentally acceptable waste disposal practices can be distinguished from environmentally unacceptable waste disposal practices.
Monthly average:	The arithmetic mean of all measurements taken during a given month.
Off-site:	WTR disposal site outside the boundaries of the water treatment plant (WTP).
On-site:	WTR disposal site within the boundaries of the water treatment plant (WTP).
pH:	The logarithm of the reciprocal of the hydrogen ion concentration. The pH measures acidity/alkalinity and ranges from 0 to 14. A pH of 7 indicates the material is neutral. Moving a pH of 7 to 0, the pH indicates progressively more acid conditions. Moving from a pH of 7 to 14, the pH indicates progressively more alkaline conditions.
Pollution:	The direct or indirect alteration of the physical, chemical or biological properties of a (water) resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used; or harmful or potentially harmful to the welfare, health or safety of human beings; to any aquatic or non-aquatic organisms; to the resource quality; or to property.
Qualified person:	A person is suitably qualified for a job as a result of one, or any combination of that person's formal qualifications, prior learning, relevant experience; or capacity to acquire, within a reasonable time, the ability to do the job.
Receptor:	Sensitive component of the ecosystem that reacts to or is influenced by environmental stressors.
Recycle:	The use, re-use, or reclamation of a material so that it re-enters the industrial process rather than becoming a waste.
Rehabilitation:	Restoring a waste site for a new industrial function, recreational use, or to a natural state.
Remediation:	The improvement of a contaminated site to prevent, minimize or mitigate damage to human health or the environment. Remediation involves the development and application of a planned approach that removes, destroys, contains or otherwise reduces the availability of contaminants to receptors of concern.
Residue:	A substance that is left over after raw material or a waste has been treated or destroyed.
Responsible authority:	In relation to a specific power or duty in respect of water uses, means the catchment management agency or the Minister.
Responsible person:	A person(s), who takes professional responsibility for ensuring that all or some of the facets of the handling and disposal of Hazardous Waste are properly directed, guided and executed, in a professionally justifiable manner.
Risk:	The scientific judgement of probability of harm. This basic and important

	concept has two dimensions: the consequences of an event or set of circumstances and the likelihood of particular consequences being realised. Both dimensions apply to environmental risk management with it generally being taken that only adverse consequences are relevant
Risk assessment:	The evaluation of the results of risk analysis against criteria or objectives to determine acceptability or tolerability of residual risk levels, or to determine risk management priorities (or the effectiveness or cost-effectiveness of alternative risk management options and strategies).
Risk management:	The systematic application of policies, procedures and practices to identify hazards, analysing the consequences and the likelihood associated with those hazards, estimating risk levels, assessing those risk levels against relevant criteria and objectives, and making decisions and acting to reduce risk levels to acceptable environmental and legal standards.
Sedimentation:	The separation of a dilute suspension of solid particles into a supernatant liquid and concentrated slurry.
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.
Supplier:	A person or organisation that produces and supplies WTR for use.
Surface water interception mechanism:	A mechanism placed between the disposal site and the surface water body to intercept possible run-off from the disposal site before it can reach the water body.
Sustainability:	Being able to meet the needs of present and future generations by the responsible use of resources.
Sustainable use:	The use of nutrients in WTR at or below the agronomic loading rate and/or use of the soil conditioning properties of WTR. 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 further WTR application can commence.
Total load capacity:	The capacity of a landfill site to accept a certain substance or the amount of a substance, which can be safely disposed of at a certain site. The total load capacity is influenced by the concentration levels and mobility of the waste, and by the landfill practice and design.
Total metal content:	Metal fraction extracted using an *aqua regia* solution (HCl/HNO_3 solution).
Total trigger value (TTV):	The total metal concentration in soils at disposal sites indicating that additional management options should be implemented to reduce the impact on the soil.
Toxic:	Poisonous.
Toxicity:	An intrinsic property of a substance which can cause harm or a particular adverse effect to humans, animals or plants at some dose.
Toxicity Characteristic Leaching Procedure (TCLP):	A test developed by the USA Environmental Protection Agency to measure the ability of a substance to leach from the waste into the environment. It thus measures the risk posed by a substance to groundwater.
Transporters:	A person, organisation, industry or enterprise engaged in or offering to engage in the transportation of waste.
Treatment:	Treatment is used to remove, separate, concentrate or recover a hazardous or toxic component of a waste or to destroy or, at least, to reduce its toxicity in order to minimise its impact on the environment.

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. In terms of the NWA, it 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.
Waste disposal site:	Any place at which more than 100kg of a Waste is stored for more than 90 days or a place at which a dedicated incinerator is located.
Water board	An organ of state established of the NWA to perform as its primary activity a public function.
Watercourse:	• a river or spring; • a natural channel in which water flows regularly or intermittently; • a wetland, lake or dam into which, or from which, water flows, and • any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and • a reference to a watercourse includes, where relevant, its bed and banks.
Water resource:	Includes a watercourse, surface water, estuary, or aquifer.
Water services	Water supply services and sanitation services.
Water service authority (WSA)	Any municipality, including a district or rural council as defined in the Local Government Transition Act, 1993 (Act No. 209 of 1993). Responsible for ensuring access to water services.
Water services institution	A water services authority, water services provider, water board or a water services committee.
Water service provider (WSP)	Any person who provides water services to consumers or to another water services institution.
Wet weight:	Weight measured of material that has not been dried (see Dry-weight basis).