Western Cape Government
Environmental Affairs & Development Planning

SEWAGE SLUDGE

Status Quo Report 2020/21

Executive Summary

The Western Cape Integrated Waste Management Plan (WCIWMP) 2017 identified the need for a better understanding of how sewage sludge is managed in the Province. This supports Goal 2, a key activity of the WCIWMP, which aims to develop a guideline on the beneficiation of treated sewage sludge. The WCIWMP 2017 provides organic waste diversion targets which will be one of the drivers in ensuring the sustainable end-use of sewage sludge.

This Status Quo Report on sewage sludge from municipal wastewater treatment works, details the current management practices as well as highlighting the challenges and opportunities that exist at municipalities with regards to sewage sludge management. A questionnaire was drafted and circulated to municipalities and other sub-directorates within the Department to obtain input to the draft questionnaire as prt of survey. The final questionnaires were then sent to all municipalities with a feedback response rate of 80%, from a 107 wastewater treatment plants, which will form the basis of this report.

Analysis of the feedback gained indicates that most Waste Water Treatment Works (WWTWs) dispose of their sewage sludge by land farming (22%) or to general (20%) or hazardous landfills (10%). 22% of WWTWs currently stockpile sewage sludge while 11% using their sewage sludge for composting/agricultural/irrigation use.

Landfill airspace is declining across the Province and more beneficiation options need to be considered and implemented where possible. In the 2021/22 financial year the Department will continue work on wastewater sewage sludge and is planning to develop a guideline for the beneficiation of treated sewage sludge. There are municipalities which have been successful in implementing localised solutions and these will be highlighted and shared to stimulate some thought and more importantly, action into better usage of this resource.

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Abbreviations

ADS	Anaerobically digested sludge
BBFs	Biosolids Beneficiation Facilities
CoCT	City of Cape Town
COD	Chemical Oxygen Demand
CKDM	Central Karoo District Municipality
CWDM	Cape Winelands District Municipality
GRDM	Garden Route District Municipality
ODM	Overberg District Municipality
POPs	Persistent Organic Pollutants
PS	Primary Sludge
WAS	Waste Activated Sludge
WCDM	West Coast District Municipality
IWMP	Integrated Waste Management Plan
WWTW	Wastewater Treatment Works
WRC	Water Research Commission
WDFs	Waste Disposal Facilities
WCIWMP	Western Cape Integrated Waste Management Pla

1 Introduction

1.1 Background and purpose

"Rapid population growth, climate change, urbanization, and the depletion of natural resources are obliging the global society to prepare for a stressful position for some natural resources" (Shaddel et al, 2019). Alternative forms of resources such as the recycling of waste and in particular the recycling of sewage sludge will aid in alleviating this problem (Water Research Commission (WRC), 2018). In support of this option the Department of Human Settlements (DHS, 2019) have also stated that sewage sludge should be viewed as a valuable resource and not as a waste product. Shaddel et al, (2019) have added that wastewater contains nutrients, essential for food production and that wastewater and sludge have been extensively investigated over the last decade for nutrient recovery. Shaddel et al, (2019) have however cautioned that sludge may contain hazardous organic and inorganic pollutants.

A majority of the waste disposal facilities (WDFs) in the Western Cape are at, or close to capacity and receive sewage sludge for disposal. Waste disposal is still seen by the majority of local authorities as the default option which is contrary to the waste management hierarchy which prioritizes waste diversion measures such as waste avoidance, re-use, recovery, and recycling over disposal. The WC IWMP, 2017 provides organic waste diversion targets of 50% (based on mass) by 2022 and 100% by 2027 which will be one of the drivers in ensuring the sustainable end-use of sewage sludge. The purpose of this report is to firstly understand how sewage sludge is currently managed in the Province and further to unlock and maximise the potential of sewage sludge as an alternative resource for use in various sectors including the popular use as a fertilizer in agriculture (DHS, 2019).

The project is aligned to Goal 2 of the WC IWMP, 2017 i.e., improved integrated waste management planning and implementation for efficient waste services and infrastructure. A key activity under this goal is to develop a guideline on the beneficiation of treated sewage sludge. This project will be undertaken once the status quo has been completed. The project also aims to give effect to Goal 3, Objective 1 of the WC IWMP, 2017, which aims to "Minimise the consumption of natural resources".

1.2 Scope and objective

This Status Quo Report on sewage sludge from municipal wastewater treatment works, will cover the current management practices as well as determining the challenges and opportunities that exist at municipalities with regards to sewage sludge management.

In order to obtain the relevant information, the Department developed a questionnaire which was sent via the municipal managers as part of a survey, to the managers within the respective municipal wastewater treatment departments to complete. The information received formed the basis of this Status Quo Report. Where feedback to the questionnaire was not received, information from the WC IWMP, 2017 was used. The Status Quo Report will also inform any future updates or reviews of the Department's Organic Waste Diversion Plan and Organic Waste Strategy which were developed during the 2019/20 financial year.

2 Understanding Sewage Sludge

2.1 Definition and classification

The United States Environmental Protection Agency (US EPA, 2020) refers to sewage sludge as biosolids and defines them as a product of the wastewater treatment process where the liquids and solids are separated. The solids are then treated physically and chemically to produce a semi-solid and nutrient-rich product known as biosolids. The raw sewage goes through this treatment process separating the solids and liquids before the cleaned effluent is discharged into water bodies such as the sea, streams, and estuaries (Pöykiö *et al*., 2019).

The United States of America (USA) introduced the term "biosolids" in 1991 as a definition for treated sewage sludge as opposed to raw sludge in order to promote the benefits of land use to the public (Christodoulou & Stamatelatou, 2016). According to Christodoulou & Stamatelatou (2016), the term "biosolids" is not only used in the USA but in New Zealand and Australia as well. Christodoulou & Stamatelatou (2016) regard sewage sludge as a source of renewable energy and material recovery, not as "waste" but a by-product to be post-treated for recycling purposes. As a reservoir of organic matter and nutrients, sewage sludge provides a potential substrate for a variety of possible reuse opportunities (Christodoulou & Stamatelatou, 2016). The US EPA (2020) classifies sewage sludge into Class A or B, based on the specific treatment requirements for pollutants and pathogens as well as management practices. Sewage sludge contains human faecal matter as well as products and contaminants from homes, industries, businesses, stormwater, landfill leachate in some areas, and contaminants leached from pipes (Pöykiö *et al.*, 2019).

Schedule 3, Category A of the National Environmental Management: Waste Act (NEM: WA) Amendment Act (Act No. 26 of 2014) classifies wastes from sludge as hazardous waste. Sewage sludge was identified in Annexure 3 and 4 of the National Environmental Management: Waste Act: Waste Information Regulations (2012), which lists general and hazardous waste types for reporting to the South African Waste Information System (SAWIS). Annexure 1 of the National Environmental Management: Waste Act, 2008: Waste Classification and Management Regulations (2013) identifies wastes that do not require classification (Regulation 4(1)), or assessment (Regulation 8(1) (a)) in terms of SANS 10234. Sewage sludge is not listed under item 2 of Annexure 1 and therefore requires classification and assessment in terms of SANS 10234 (DEA, 2013).

Thorpe (2016) highlights the gap in the regulatory framework concerning the classification and management of potentially pathogenic wastes such as sewage sludge. The SAN10234 primarily classifies chemical substances and mixtures (Thorpe, 2016). Sludge may not meet the hazard identification and classification criteria under SAN10234 for a hazardous waste and therefore not require a Safety Data Sheet (SDS), as a result may pose a hazard to holders and managers of the waste (Thorpe, 2016). The potential presence of pathogenic and/ or infectious agents in sludge compels classification and an accompanying safety data sheet for sludge (Thorpe, 2016).

The Guidelines for the Utilisation and Disposal of Wastewater sludge (2006), developed by the Water Research Commission, for the then Department of Water Affairs and Forestry, define wastewater sludge as the material, which is removed from wastewater treatment plants meant to treat mainly domestic wastewater, including the following products;

- Raw or primary sludge from a primary clarifier,

- Primary sludge from an elutriation process (process for separating particles based on their size, shape and density),
- Anaerobically digested sludge, both heated and cold digestion,
- Oxidation pond sludge,
- Septic tank sludge and other sludge from on-site sanitation units,
- Surplus or waste activated sludge,
- Humus sludge,
- Pasteurised sludge,
- Heat-treated sludge,
- Lime-stabilised sludge, and
- Composted sludge (Herselman& Snyman, Volume 1: 2006).

However, the guidelines do not apply to the following –

- Screenings and grit removed in the preliminary treatment processes of wastewater treatment plants,

- Solids removed from on-site sanitation systems which are mixed or blended with domestic refuse and solid waste,

- Inorganic sludge produced by potable water treatment plants,

- Inorganic brine and sludge produced by the treatment of industrial effluents or mine water, and

- Sludge and solids removed from a treatment plant that treats hazardous waste and effluents (Herselman& Snyman, Volume 1: 2006).

According to Herselman& Snyman (Volume 1: 2006), the guidelines were developed for different stakeholders, including local authorities and town or city councils that manage wastewater treatment plants to ensure the safe use and disposal of sludge. The document also provides details on a sludge classification system that is based on microbiological parameters (faecal coliforms, helminth ova), physical and stability parameters (pH, total solids, volatile solids, volatile fatty acids) as well as chemical characteristics (nutrients, metals, organic pollutants) (Herselman& Snyman, Volume 1: 2006). These parameters determine sludge utilisation based on the microbiological content, stability as well as organic and inorganic pollutants (Herselman& Snyman, Volume 1: 2006).

2.2 Sewage sludge legislative overview

Environment Conservation Act (ECA) (Act No. 73 of 1989)

Section 21 of the ECA highlights activities that the Minister may identify to have a detrimental effect on the environment and sewage disposal is listed as one of such activities in section 21 (2) (i).

Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 1: 2006

The guidelines were developed by the Water Research Commission for the Department of Water Affairs and Forestry, to assist different stakeholders including local authorities and town or city councils, that manage wastewater treatment plants to promote the safe use and disposal of sludge. The guidelines also provide a definition for wastewater sludge and a sludge classification system for sludge management options or utilisation, which is then discussed in the subsequent volumes.

Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 2: 2006

Volume 2 of the guidelines details the requirements for agricultural use of sludge.

Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 3: 2006

Volume 3 of the guidelines details the requirements for the on-site and off-site disposal of sludge.

Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 4: 2006

Volume 4 of the guidelines details the requirements for the beneficial use of sludge.

Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 5: 2006

Volume 5 of the guidelines details the requirements for thermal sludge management practices and for commercial products containing sludge.

National Environmental Management: Waste Act (NEMWA) (Act No. 59 of 2008)

Schedule 1 (Section 19), Category A of the National Environmental Management: Waste Act (NEMWA) (Act No. 59 of 2008) identifies waste management activities that require a waste management licence. The treatment of waste in sludge lagoons is such a listed activity, which requires authorisation equivalent to a basic assessment process as stipulated in the environmental impact assessment regulations made under section 24(5) of the National Environmental Management Act (NEMA) (Act No. 107 of 1998) (NEMWA, Act No. 59 of 2008).

Waste Classification and Management Regulations GN 634 (August 2013)

Annexure 1 of the National Environmental Management: Waste Act, 2008: Waste Classification and Management Regulations (2013) identifies wastes that do not require classification (Regulation 4(1)), or assessment (Regulation 8(1) (a)) in terms of SANS 10234. Sewage sludge is not listed under item 2 of Annexure 1 and therefore requires classification and assessment in terms of SANS 10234. Regulation 9 deals with the motivation for and consideration by the Minister for waste management activities that do not require a waste management licence.

National Norms and Standards for the assessment of waste for landfill disposal (August 2013)

The standards provide the requirements for the assessment of waste prior to disposal to landfill in terms of Regulation 8(1) (a) of the Waste Classification and Management Regulations (2013). The assessment requires the identification of chemical substances in the waste and the sampling as well as the analysis to determine the total concentrations (TC) and leachable concentrations (LC) of the elements and chemical substances that have been identified in the waste and specified in section 6 of these standards.

National Norms and Standards for disposal of waste to landfill (August 2013)

The standards provide the requirements for the disposal of waste to landfill in terms of Regulation 8(1) (b) of the Waste Classification and Management Regulations (2013). Waste assessed in terms of the Norms and Standards for Assessment of Waste to Landfill Disposal must be disposed to a licensed landfill as per section 4(1) of these standards. The regulation also lists timeframes for the banning of certain waste types, from disposal at landfill with the ban on liquid disposal to landfill coming into effect in August of 2019. Depending on the state of the sewage sludge leaving wastewater treatment plants, this could impact on the disposal of sewage sludge to landfill.

2.3 Health and environmental impacts

Since sludge contains pathogens, organic pollutants and heavy metals, if it is not managed properly, it could negatively impact human health and the environment.

Pathogens

When sludge is applied to land, pathogens found in the sludge may be transported through bio-aerosols downwind of the sludge storage or spreading sites (Reilly, 2001). Pathogens could also spread to water sources e.g., drinking wells, groundwater and surface water and contaminate food grown using sludge as a land application (Reilly, 2001). People making contact with areas spread with sludge could also be exposed to pathogens (Reilly, 2001). A list of pathogens and possible human health impacts are indicated in Table 1. Due to the current COVID -19 pandemic, there has been interest regarding the risk of SARS-Cov-2 contamination of sludge. According to Núñez-Delgado, 2020, it is possible for infected individuals to spread the virus through their excreta, which could lead to it spreading to wastewater and sludge. ANSES (2020) states that the risk of SARS-CoV-2 contamination is low to negligible for sludge that has undergone appropriate disinfection treatment.

Table 1: Pathogens in sewage sludge

Group	Pathogen	Disease
Bacteria	Salmonella (> 1700 strains)	Typhoid fever, salmonellosis
	Shigella spp. (4 strains)	Bacillary dysentery
	Enteropathogenic E. coli	Gastroenteritis
	Yersina entericolitica	Gastroenteritis
	Campylobacter jejuni	Gastroenteritis
	Vibrio cholerae	Cholera
	Leptospira	Weil's disease
Protozoa	Entamoeba histolytica	Dysentery, colonoid ulceration
	Giardia lamblia	Diarrhea
	Balantidium coli	Diarrhea, colonoid ulceration
	Cryptosporidium spp.	Cryptosporosis
Helminths	Ascaris lumbricoides	Ascariasis (round worm)
	Ancyclostoma duodenale	(Hook worm)
	Necator americanus	(Hook worm)

Group	Pathogen	Disease
	Taenia saginata	Taeniasis (Tape worm)
Virus	Enteroviruses (strains)	
	Poliovirus (3)	Meningitis, paralysis, fever
	Echovirus (31)	Meningitis, diarrhea, rash
	Hepatitis Type A	Infectious hepatitis
	Coxsackvirus (33)	Meningitis, respiratory disease
	Norwalk virus	Diarrhea, vomiting, fever
	Calicivirus	Gastroenteritis
	Astrovirus	Gastroenteritis
	Reovirus (3)	Respiratory disease
	Rotavirus (2)	Diarrhea, vomiting
	Adenovirus (40)	Respiratory disease

Source: Chang, n.d.

Organic contaminants

Sewage sludge also acts as a sink for industrial and domestic chemicals that become sequestered in solids during the wastewater treatment process (Chari & Halden, 2012 in Clarke & Cummins, 2015. It is argued that even though the environmental occurrence of these contaminants is normally low, toxicologists, epidemiologists and risk assessors advise that there may still be significant and widespread environmental and human health consequences (Smith, 2009 in Clarke & Cummins 2015). Organic chemicals found in sewage sludge may have harmful effects on human health with the potential to cause adverse effects, such as reproductive damage, carcinogenicity, and metabolic and obesity diseases (Lamastra et al., 2018).

When sludge is used in crop production, persistent organic contaminants accumulate in the topsoil; repeated applications of the sludge could theoretically cause contaminants to accumulate to toxic concentrations (Clarke & Cummins, 2015. This could impact crop growth and quality, soil fertility and the food chain (Clarke & Cummins, 2015). Table 2 highlights the (theoretical) pathways by which humans can be exposed to organic contaminants along the food chain and via exposure to dust and water.

Table 2: Human exposure pathways for land-applied sewage sludge

Pathway	Human/animal exposure index
Biosolids →soil→plant→human	Lifetime ingestion of plants grown in biosolid amended soil
Biosolids →soil→human	Humans ingesting biosolids
Biosolids →soil→plant→animal→human	Human lifetime ingestion of animal products originating from biosolids amended agricultural lands.
Biosolids →soil→airborne dust→human	Human inhalation of particles (dust)
Biosolids →soil→groundwater→human	Human lifetime drinking well water
Biosolids →soil→surface water→human	Human lifetime drinking surface water

Source: Clarke & Cummins, 2015

Metals and inorganics

The metals and inorganic chemicals found in sludge that are of concern tend to accumulate is soil rather than leach (Foundation for Water Research, 2016). Heavy metals normally found in sewage include e.g., cadmium, chromium, copper, nickel, lead, zinc (Sreekrishnan & Tyagi, 1999). When sludge is applied to land these metals can make their way to humans via the consumption of the edible parts of crops (Sreekrishnan & Tyagi, 1999). The uptake of heavy metals by plants is however dependent on numerous factors e.g., solubility of the metals, pH of the soil, soil type and the plant species (Tinker 1981 and Lubben & Sauerbeck in Kacholi & Sahu, 2018). Other elements such as mercury, leave the soil via volatilization (National Research Council, 1996), a process whereby a dissolved sample is vapourised. Of concern is cadmium as it has a greater potential to enter the food chain and is toxic to humans and animals (Baizi e Silva & Camilotti, 2014).

Some studies show that the most abundant persistent organic compounds in raw wastewater at all treatment stages are likely to be Tetrachlorobiphenyl (PCB-52), Pentachlorobiphenyl (PCB-110), Heptachlorobiphenyl (PCB-180) and Heptachlor-exo-epoxide. Quintozene frequently occurs but in relatively low concentrations. Hexachlorocyclohexanes, DDT and its metabolites (DDE, DDD) and Aldrin, Dieldrin, Endrin, Isodrin are likely to be present at medium or low frequencies and in concentrations close to their detection limits. Removal percentages throughout the whole treatment process ranges from 65% to 91% for individual POP species.

2.4 Sewage sludge generation

The Water Research Commission (WRC) and the South African Local Government Association (SALGA) produced a guideline in March of 2016 titled, Wastewater Treatment Technologies, A Basic Guide. In this guide the wastewater treatment processes and technologies are detailed. Figure 1 below illustrates the treatment phases as well as the technology options for that phase. It must be noted that not all WWTWs would follow the same treatment steps or use the same technologies.

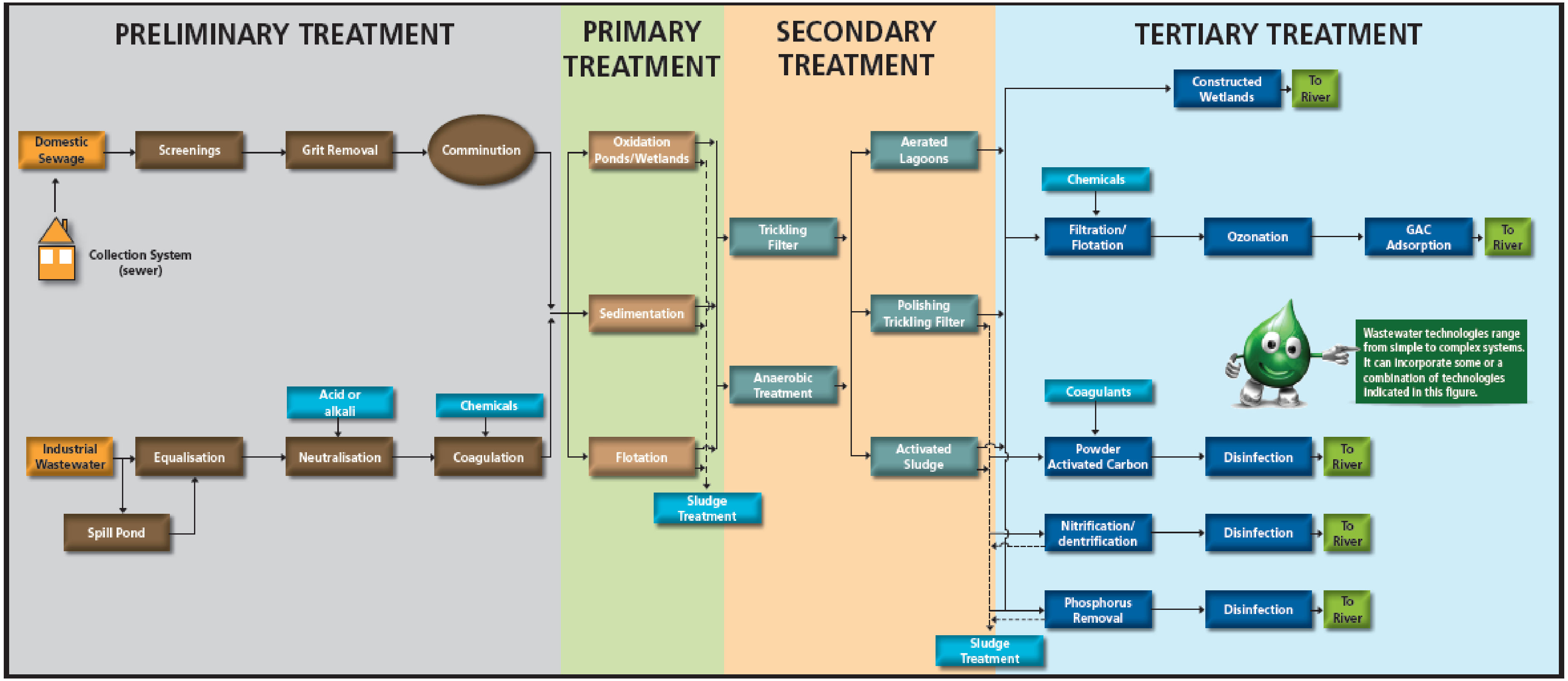

Figure 1: Wastewater treatment process

As can be seen from the Figure 1, above preliminary treatment for domestic sewage and industrial wastewater may differ. The first step in domestic sewage treatment involves the screening, either manual or mechanical, of wastewater to remove foreign materials (rags, plastic etc.), which can interfere with the treatment processes.

This is followed by a grit removal process whereby sand, silt and stones etc. are removed to protect the moving mechanical equipment from abrasion. Depending on the efficiency of the grit removal process a further process step, comminution may be required. Comminution is the reduction of solid material from one size to a smaller size by means of mechanical methods. Industrial wastewater can follow a different preliminary treatment process, depending on quality. Equalisation and/or neutralisation may be required by the addition of an acid or base. This is followed by the addition of a chemical which will act as a coagulant. These two streams (if they are separate at first) are then mixed and sent to the primary treatment process.

The primary treatment process makes use of oxidation ponds, sedimentation tanks or floatation tanks. The aim of all these processes is to maximise the separation of liquids and solids. The solids leaving the process is the first instance where sewage sludge waste is produced, and this is sent further down the process for sludge treatment. The resultant liquid stream from the primary treatment process is sent to the secondary treatment process whereby it is further separated to remove organic matter by means of a trickling filter system or for anaerobic treatment. The liquid from this process is then sent for tertiary treatment, disinfection, with the solids being sent for sludge treatment. This is the second instant whereby sewage sludge is produced, in the wastewater treatment process.

2.5 Sewage sludge treatment methods

During the wastewater treatment process, sewage sludge is produced during primary, secondary and tertiary treatment (if undertaken) (Stehouwer, 2010). The resultant sludges are referred to as primary (consisting of both organic and inorganic material), secondary (mainly organic material) and tertiary sludge, respectively (Stehouwer, 2010). Primary, secondary and tertiary sludges (if applicable) are normally combined and referred to as "raw" sewage sludge, which constitutes between 1-4% solids (Stehouwer, 2010).

Treatment of sludge is required prior to disposal/ reclamation. The main purpose of sludge treatment is:

- To reduce the volume of the sludge; this may in turn reduce handling and transportation costs;
- To reduce the number of pathogens, present in sludge; and
- To reduce malodour (Foundation for Water Research, 2016)

Figure 2, below provides an overview of the sewage sludge treatment process/s. The main treatment methods being used can be divided into volume reduction processes and stabilization processes as discussed below:

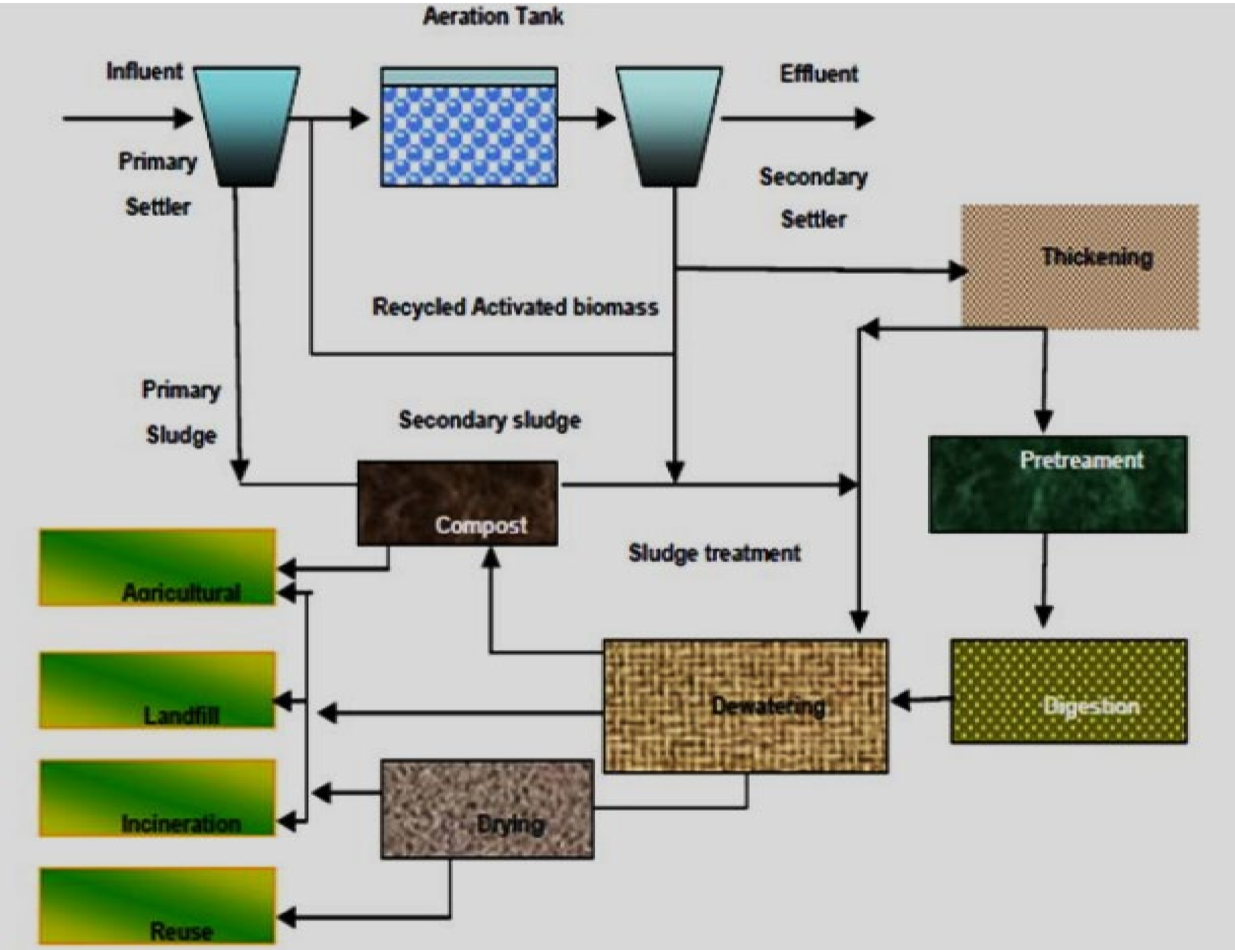

Figure 2: Sewage sludge treatment network

Source: Yapicioğlu & Demir, 2017

Volume Reduction Processes:

Reducing the volume of sludge has various benefits. These include improving efficiency of subsequent processes, reducing storage volume, decreasing transportation costs as well as operational and capital costs associated with subsequent processing (United States National Research Council, 1996; Shammas &Wang, 2007a). Volume reduction processes include sludge thickening and dewatering.

Sludge Thickening

During sludge thickening, the solids content of the sludge may be increased by 5% - 6% (Stehouwer, 2010). Different methods are used to carry out this process e.g., gravity thickening and dissolved air floatation. During gravity thickening, high-density solids settle out of liquid thereby concentrating the solids (US EPA, 2003). Primary and/or secondary sludge is fed into a circular tank, fitted with collectors or scrapers at the bottom (US EPA, 2003). Solids settle to the bottom and the scrapers move the settled solids to a discharge pipe at the bottom of the tank (US EPA, 2003). Dissolved air floatation uses air bubbles, which attach to solid particulates, causing them to rise to the surface of the liquid (Wang et al., 2007). The solids are then be collected via skimming (Wang et al., 2007).

Dewatering

During dewatering, the solids content is increased by between 15% to 30% (Stehouwer, 2010. Dewatering can be undertaken using sludge drying beds or lagoons or via mechanical dewatering. Sludge drying beds and lagoons rely on natural drainage and evaporation to remove water (US NRC, 1996). Mechanical dewatering aims to separate the sludge into its liquid and solid parts (Stauffer, n.d.). Mechanical processes used include filter presses, belt presses, vacuum filters and centrifuges (US NRC, 1996).

Sludge drying

Sludge drying is a process whereby thermal energy is provided to the sludge to evaporate water, thereby reducing the sludge volume (IWA, n.d.). Thermal drying is undertaken using either direct or indirect dryers to achieve near-complete removal of water from the sludge (US EPA, 1996).

Stabilization processes:

Sludge stabilization processes aim to stabilize the organic matter found in sludge, reducing the risk of putrefaction (decay) and reducing pathogen concentrations (de Lara et al., 2007). There are several stabilization techniques, including chemical stabilization (e.g., alkaline stabilization), biological stabilization (e.g., aerobic, anaerobic and composting processes) and thermal stabilization.

<u>Alkaline stabilization</u>

Alkaline stabilization is a type of chemical stabilization technique. The aim of chemical stabilization is to create conditions that inhibit microorganisms, thereby slowing down the degradation of organic matter and preventing odours (US NRC, 1996). Alkaline stabilization is the process whereby an alkaline material, most often hydrated lime ($CaOH_2$), is used to raise the pH of the sludge and help kill pathogens (US NRC, 1996; US AID, 2015). US AID (2015) notes that as the pH increases, the pathogen numbers decrease. It is further noted that consistently high levels of pathogen reduction occur only after a pH of 12 is reached.

<u>Anaerobic digestion</u>

Anaerobic digestion is a biological stabilization process whereby biogas (mostly methane) is produced when bacteria break down organic matter, such as sludge (US NRC, 1996; Náthia-Neves et al., 2018, Chen & Neibling, 2014). It is a natural process occurring in the absence of oxygen (Náthia-Neves et al., 2018). Bio-digesters are used to facilitate anaerobic digestion and to optimise the production of biogas, which is a low-cost energy source (Rivas-Solano et al., 2016). Anaerobic digestion increases the solids content of the sludge and reduces viable pathogens (Stehouwer, 2010).

<u>Composting</u>

Composting is a natural biological stabilization process in which microorganisms breakdown organic matter to simpler nutrients (Kootenaei et al., 2014, US NRC, 1996). Since sewage sludge contains organic matter, it is a good material for composting and can be used as fertilizer or for soil amendment (Banegas et al., 2007). Since composting is an aerobic process, wood chip or saw dust is often added to the sludge to promote aeration (US NRC, 1996). This mix is then composted at 55°C for a number of days (Stehouwer, 2010). Composting reduces the volume of the sludge and eliminates most of the pathogens (Stehouwer, 2010).

Aerobic digestion

Aerobic digestion is a process in which sludge is biologically stabilized using oxygen or air to agitate it at temperatures ranging between 15- 20°C over a period of time (US NRC, 1996; Stehouwer, 2010). Bacteria that feed on the sludge and carbon dioxide is produced during the process (Stehouwer, 2010). Aerobic digestion increases the solids content of the sludge and reduces viable pathogens (Stehouwer, 2010).

Sludge disposal:

The main disposal options for sludge are landfilling, incineration and land application. The benefit of landfilling of sludge is that it prevents the release of pollutants and pathogens into the environment by concentrating the sludge into a single location (Stehouwer, 2010). However, this only applies to situations where the landfill is properly constructed and maintained, which assists in reducing environmental risks (Stehouwer, 2010).

Incineration reduces the volume of the sludge to approximately 10-20% of the initial volume, destroys pathogens, and decomposes most of the organic material. The resulting ash is a stable, relatively inert, inorganic material, which is then landfilled (Stehouwer, 2010). Major pollutants emitted during incineration include particulate matter, metals, carbon monoxide, nitrogen oxides, sulphur dioxide and unburned hydrocarbons (US EPA, 1995).

2.6 Beneficiation of sludge

Sewage sludge has historically been viewed as a waste product because of its potential to contain high levels of contaminants i.e., pathogens and other pollutants, and has thus largely been disposed of (Usman et al., 2012). The current increasing population growth and levels of urbanisation may result in more sludge being produced. It is thus becoming increasingly unsustainable to dispose of sludge. Sustainable waste management views disposal as a last resort/ least favoured option along the waste management hierarchy (Figure 3, below). Landfilling of sludge is not always a viable option; as certain areas have limited airspace, which drives up the cost of disposal. Stricter regulations regarding landfill disposal also require that other options for managing sewage sludge be sought.

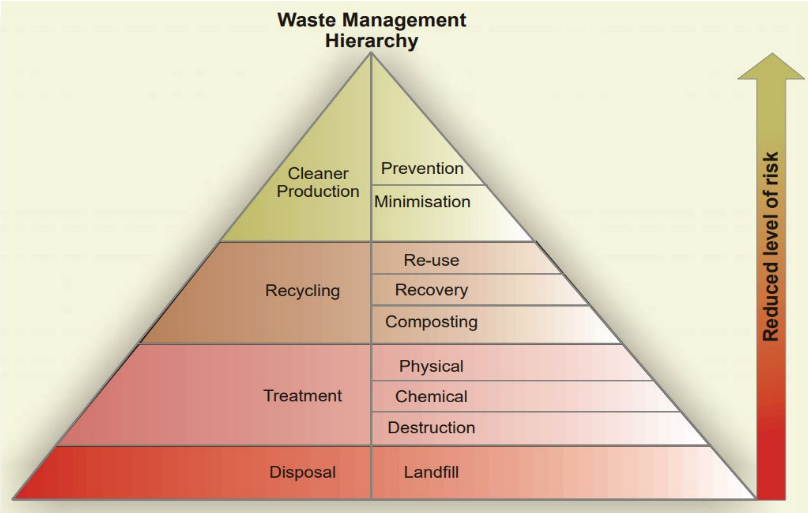

Figure 3: Waste management hierarchy

Source WRC, 2009

Currently, there is general consensus that sludge is a potential source of valuable resources and energy (WRC, 2018). During the beneficiation of sludge, it must be ensured that while the valuable components of the sludge are recovered and re-used, the negative impacts of the sludge or residues from sludge treatment are minimised (Rulkens, 2008).

Land application

Treated sewage sludge, also sometimes referred to as biosolids can be reclaimed and used in the agricultural sector. Since sludge has high organic matter content and is rich in nutrients, it may be used as a fertiliser/ soil conditioner for vegetable crops, horticultural plants and pasture (Usman et al., 2012). Applying sludge to land may improve soil texture and water holding capacity, which provides more favourable conditions for root growth and may improve the drought tolerance of plants (US EPA, 2000). Nutrients such as nitrogen and phosphorous, and organic matter found in sludge may be beneficial for plant growth and may result in a higher crop yield (Wong et al., 1995; Kauthale, 2005 in Mtshali et al., 2014). Other areas to which sludge may be applied include reclamation sites, public contact sites (e.g., parks, turf farms, highway median strips, and golf courses), lawns, home gardens and forests.

The use of sludge as a fertilizer provides several benefits over commercial fertilizers. Commercial fertilizers require large amounts of phosphorous, which is a limited resource and have large energy requirements to produce. (US EPA, 1995; UNEP, 1996 in Mtshali et al., 2014). The nutrients found in sludge are less soluble than those found in inorganic fertilizers and are thus less likely to leach into the groundwater or to runoff into surface water (US EPA, 2000). When necessary, sludge may also be combined with commercial fertilizers to obtain an optimum nutrient ratio for plant growth (Pakhnenkoa et al., 2009 in Mtshali et al., 2014). There are however risks associated with the land application of sludge, namely, the presence of contaminants e.g., heavy metals, organic pollutants and pathogens.

Green energy

Energy recovery from sludge has in recent years gained global importance and has become a key aspect in most sludge management strategies (WRC, 2018). The most widely used technology for energy recovery from sludge is anaerobic digestion (WRC, 2018). The biogas produced can be used as an energy source for the production of heat and electricity (Rulkens, 2008). The biogas may also be cleaned to produce bio-methane, which can be used as a direct substitute for natural gas (Oladejo, et al., 2019). Alternative methods for energy production include incineration, pyrolysis and gasification as indicated in Figure 4, below.

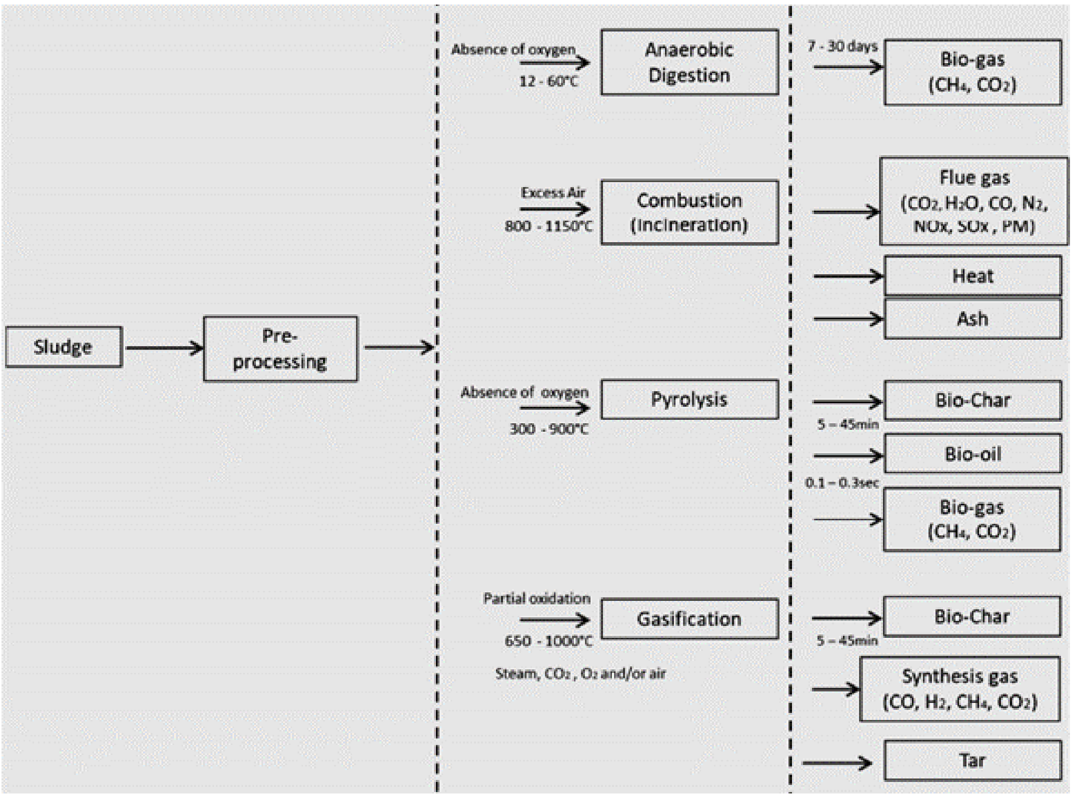

Figure 4: Sludge-energy-options

Source: Oladejo et al., 2019

Use in the construction industry

Sewage sludge can be used for a variety of purposes in the construction industry. Liew et al, (2004) undertook a study to investigate the incorporation of sludge in the production of clay bricks. It was determined that bricks with more than 30% (wt. %) sludge addition are not recommended for use, since they become brittle and that bricks with a large percentage of sludge addition cause uneven and poor surface textures. The uneven surface is as a result of the organic content of the sludge being burnt off during the firing process (Tay et al., 2002 in Johnson et al., 2014). It was however found that if sludge is replaced with sludge ash, which does not contain organic materials, the maximum sludge percentage that can be used in bricks increases to 50%. Other potential uses of sewage sludge in the construction industry identified by Johnson et al., 2014 include the production of cement-like material, use in concrete mixtures and the use of sludge in ceramic and glass production.

Other applications

The WRC Guideline for the Utilisation and Disposal Wastewater Sludge (2006) provides several additional beneficial uses of sludge e.g. rehabilitation of mine deposits, using sludge to aid the remediation of contaminated soil, using sludge as adsorbents, using sludge as a nursery growth medium, once-off high-rate land application, and to ameliorate(improve) degraded soils.

3 Sewage Sludge Management Overview

3.1 How much sewage sludge is being generated in the Province?

According to the South African State of Waste Report of 2018, compiled by the then Department of Environmental Affairs (DEA), sewage sludge is the main type of waste generated by wastewater treatment works. It is indicated that there are 824 large scale and private WWTWs in South Africa with 158 of these being in the Western Cape (DEA, SoWR: 2018). In an effort to quantify how much sewage sludge is removed from WWTWs in the Province, a data extract was gained from the Western Cape Provincial Integrated Pollutant and Waste Information System (IPWIS) for the 2019 calendar year. The reporting codes for sewage sludge are GW2101 for general waste and HW2001 for hazardous waste, depending on the classification. The extract showed that only two municipalities reported on the disposal of their sewage sludge and this was to three waste management facilities. This indicates that there is a severe lack of reporting for this waste type and is an area that needs improvement in order to gain an idea of what the potential for beneficiation is in terms of quantity.

The GreenCape Market Intelligence report of 2018 citing the Department of Economic Development and Tourism (DEDAT) study of 2016 estimated that 295 000 tonnes of sewage sludge was generated in 2016.

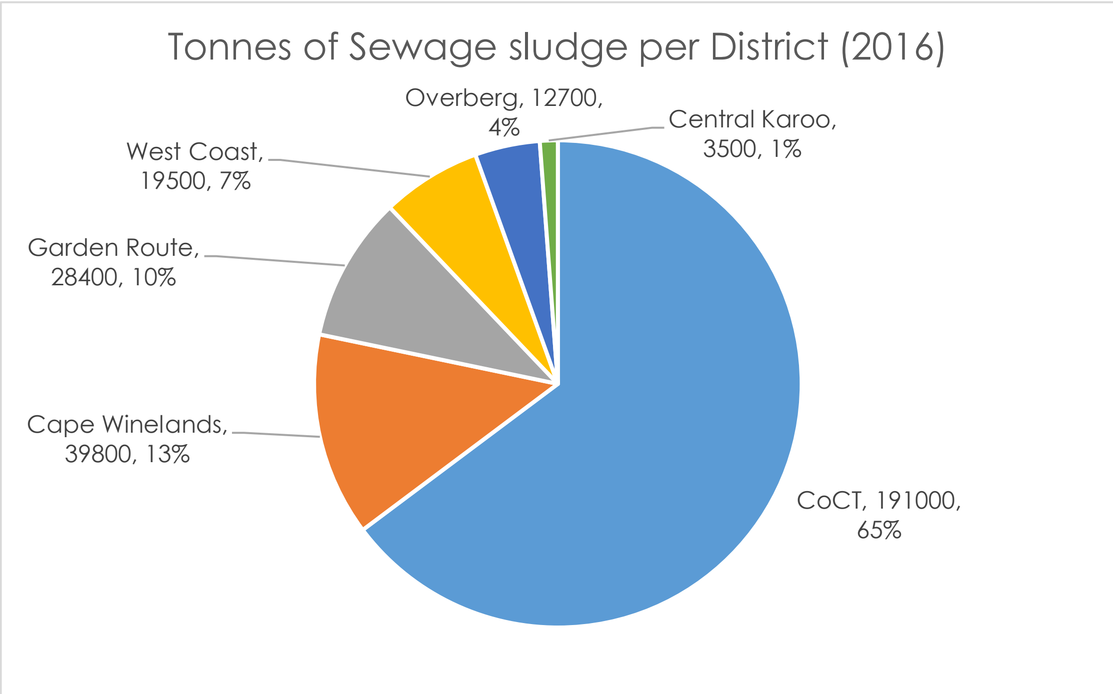

Figure 5: Tonnes of sewage sludge per District (2016)

Source: GreenCape Market Intelligence Report (2018) & DEDAT (2016)

As seen in the Figure 5, above the bulk of the sewage sludge generated in the Province is in the City of Cape Town Metro. This is as expected as the City is the most populated and home to most businesses and industry. The quanitites of sewage sludge decrease as one moves away from the City towards the borders of the Province.

With the focus on organic waste diversion and beneficiation it is important to note the portion of sewage sludge generated, in comparision to other organic waste types. Figure 6, below shows that sewage sludge makes up a significant portion of the organic waste stream in the Province.

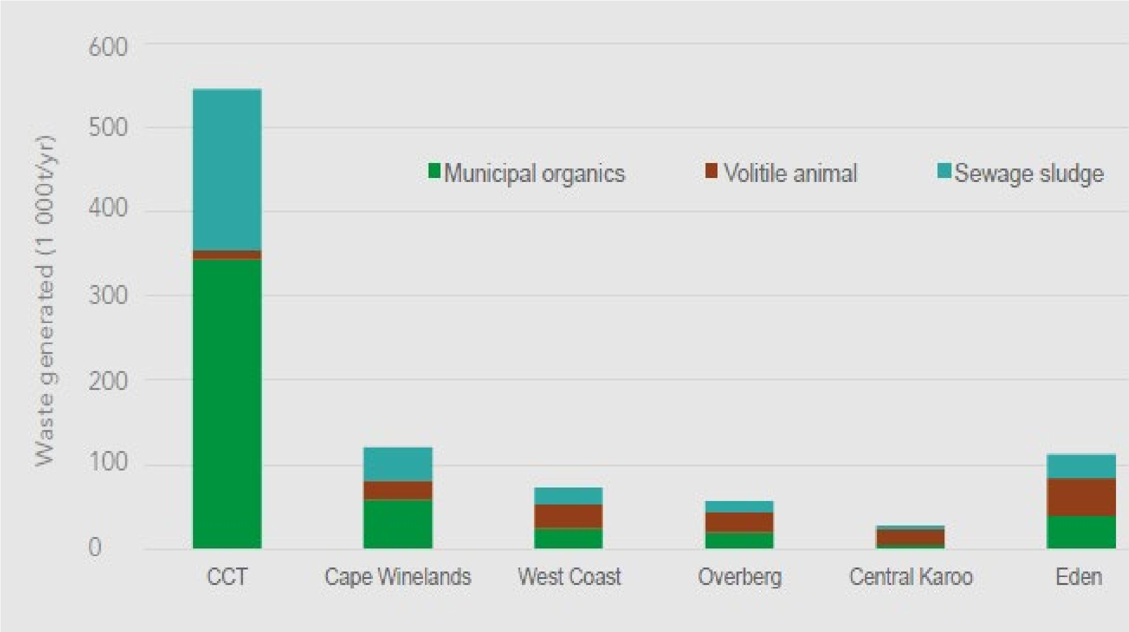

Figure 6: Organic waste and sewage sludge generated in the Western Cape

Source: GreenCape 2018 & DEDAT 2016

3.2 Management of sewage sludge per district

3.2.1 City of Cape Town Metropolitan

The City of Cape Town owns and operates 26 wastewater treatment works with a number of different treatment technologies including:

- 16 Activated Sludge WWTW;
- Marine Outfalls (with no sludge produced);
- 1 Trickling Filter Plant;
- 4 Rotating Bio-contactors (RBCs) with only residual septic tank sludge produced, which is periodically removed);
- 2 Pond Systems (with only residual sludge produced, which is periodically removed).

Therefore, there are potentially four (4) different sludge streams produced at the City's WWTWs, depending on the processes provided, namely -

1. Primary Sludge (PS), which is produced at the primary settling tanks, however, not all WWTW have these;

2. Waste Activated Sludge (WAS), which is biological sludge from the biological reactors;
3. Anaerobically Digested Sludge (ADS) which comprises of either PS, WAS or a blend of both treated or stabilised in anaerobic digesters; and the
4. Combined/ blended sludge which could contain any two or all of the above.

The sludge management methods for the City involve a combination of disposal at a hazardous landfill and application for land farming.

Table 3: Current Sludge Management methods at the CoCT WWTWs

Name of WWTW	Effluent sources	Management Methods (Disposal/Beneficiation)
Athlone	Industrial & residential	Disposed to Cape Flats WWTW inlet works via sewer
Borcherds Quarry	Industrial & residential	PS and WAS mechanically dewatered together on site. Combined/ blended cake disposal at a hazardous landfill
Cape Flats	Mainly residential	PS and WAS anaerobically digested, the digested sludge is dried in sludge lagoons and disposed of at a hazardous landfill
Gordons Bay	Mainly residential	Disposed to the Macassar WWTW inlet works via sewer
Bellville	Industrial & residential	WAS mechanically dewatered on site and disposed of to land farming
Zandvliet	Industrial/ residential	
Wildevoelvlei	Mainly residential	
Scottsdene	Mainly residential	
Fisantekraal	Mainly residential	
Kraaifontein	Mainly residential	
Macassar	Industrial/ residential	
Melkbos	Mainly residential	WAS dried on solar drying beds/ slabs and disposed of to land farming
Wesfleur (Domestic)	Mainly residential	
Wesfleur (Industrial)	Mainly residential	
Mitchells Plain	Mainly residential	PS and WAS separately mechanically dewatered on site. PS to hazardous landfill, WAS to land farming
Potsdam	Industrial & residential	
Simons Town (Biological trickling filters)	Mainly residential	PS and humus anaerobically digested. Digested sludge dried on solar drying beds. Dry sludge disposed of to landfill or land farming once or twice annually.

The City provided a list of the sludges with quantities and all sludge tonnages are provided as dry tonnes with average monthly values for 2019. The Athlone, Borcherds Quarry, Mitchells Plain and Potsdam WWTWs were the only facilities with primary sludge values of 650, 251, 7& 186 dry tonnes/ month respectively. The Athlone, Bellville, Borcherds Quarry, Fisantekraal, Gordons Bay, Kraaifontein, Macassar, Melkbos, Mitchells Plain, Potsdam, Scottsdene, Wesfleur (Domestic), Wesfleur (Industrial), Wildevoelvlei and Zandvliet facilities produced waste activated sludge valued at 543, 269, 86, 171, 11, 54,167, 27, 108, 299, 88, 30, 25, 83& 726 dry tonnes/ month respectively. The Cape Flats and Simons Town (biological trickling filters) produced anaerobically digested sludge at 850 & 3 dry tonnes/ month respectively. The Camps Bay Outfall, Green Point Outfall, Groot Springfontein Ponds, Hout Bay Outfall, Klipheuwel RBC, Llandudno RBC, Millers Point RBC, Oudekraal RBC and Philadelphia Ponds either do not produce sludge or do not produce sludge regularly.

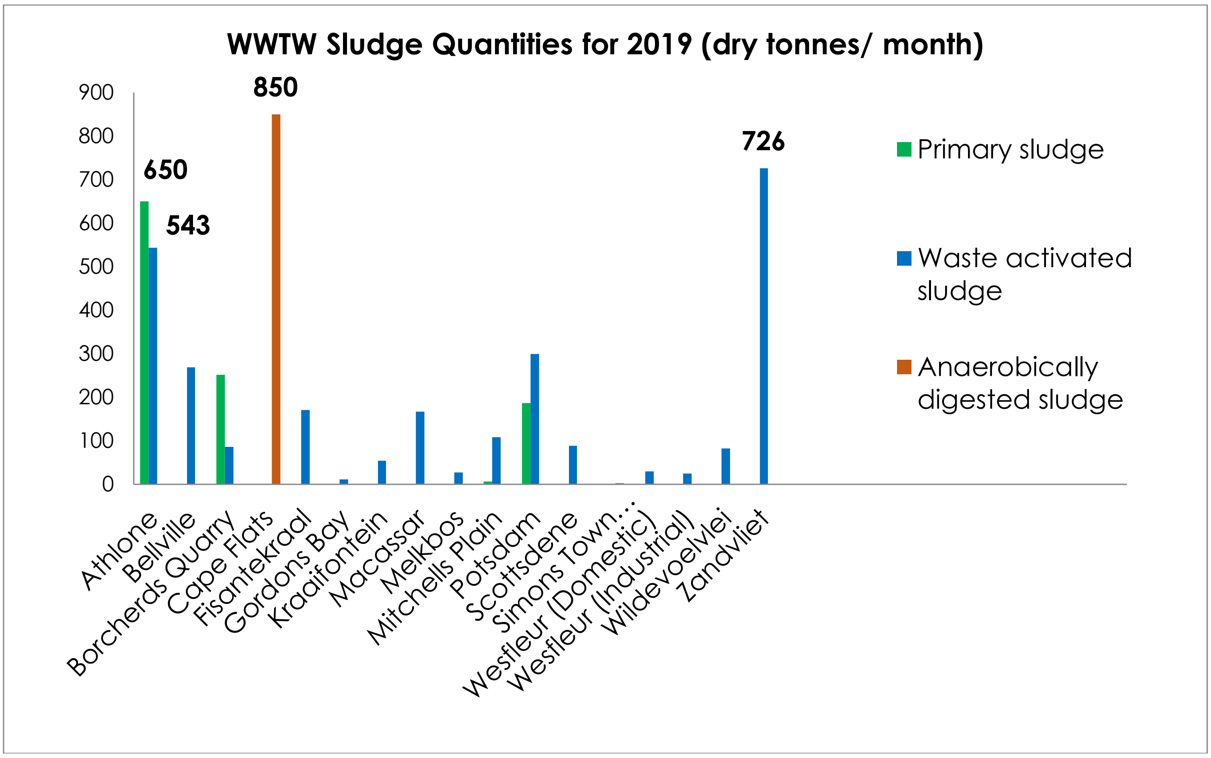

Figure 7: Quantities of sludge generated in the 2019 reporting period (CoCT)

The challenges and opportunities experienced by the City include the following:

- Overall challenges with sludge disposal –
  - — Service providers do not respond to the section of the beneficiation of sewage sludge included in the sludge transport and disposal tenders;

— The primary sludge is still going to a hazardous landfill; and

— The City may run out of suitable agricultural land for land application in 5 – 10 years' time.

- Regarding opportunities with sludge, the City is planning to install three (3) Biosolids Beneficiation Facilities (BBFs), namely –

— The Southern BBF will have 145 dry tonnes per day capacity and should be completed in 2024;

— Either the Northern or Eastern BBF with approximately 100 dry tonnes per day capacity; and a

— Third future BBF installation to be provided as and when required.

The BBFs are intended to reduce sludge quantities, produce a beneficiated and pasteurised class A1 product; and recover Nitrogen & Phosphorous as well as produce steam for the hydrolysis step and electricity from the methane gas.

When the Southern BBF is completed, primary sludge will be prioritised and the remainder of the capacity will be filled with waste activated sludge. Any remaining waste activated sludge will still go for application to land farming until the second BBF is installed. According to the City, even when the BBFs are installed, there will still be a challenge with the uncertainty as to the final destination of the beneficiated biosolids, but the options include -

- Requesting service providers to tender separately for further processing and disposal of the beneficiated biosolids;
- Including the specifications in the initial operations and management tender of the facility; and
- Packaging and marketing the product in-house e.g., the Washington DC Municipality employs a similar combination of technologies where they package and market their beneficiated solids as a commercial product to households, garden centres, other municipalities and farmers. This is done in-house and is providing an additional revenue stream for the Washington DC Municipality.

The City has contracted Green Cape to assist with a project to source potential sludge users and uses (primary, WAS, digested and beneficiated). The project will run for a

12-month period and the City is hoping for further insight into re-use applications of the municipality's sludges –

- In the interim while the first BBF is being constructed;
- When both beneficiated solids and WAS are being produced (i.e. while the second BBF is being constructed); and ultimately; and
- When just beneficiated solids are being produced.

Appendix A provides an example of the classification, microbiological parameters, physical and chemical characteristics of the primary and waste activated sludge from 12 of the 17-wastewater treatment works that produce sludge in the City of Cape Town, 2016- 2019.

3.2.2 Garden Route District Municipality

The Garden Route local municipalities have provided data for 25 wastewater treatment works with sludge management methods involving a combination of irrigation, disposal at landfill and natural evaporation.

The Oudtshoorn Municipality is currently stockpiling the sludge on-site, which has been classified and is planning to issue a tender within six (6) months to source a service provider to sell the dry sludge. The George Municipality does not have stockpiling space for sludge and have initiated a process to run a pilot project to further treat the dried sludge for commercial purpose by partnering with an external service provider. The project is still in at a planning stage and final approval to proceed with implementation is pending compliance with Supply Chain Management regulations.

The challenges in Hessequa Municipality include the following:

- Insufficient dry beds, tertiary aerobic pond capacity and power outages;
- Dry beddings, limited oxidation dams as the dams are full in winter; as well as; and
- Plant capacity versus demand.

The Municipality plans to ensure that water quality is suitable for irrigation use at local sport grounds and the irrigation system will be upgraded for use by farms as well as a golf club. The Bitou Municipality is planning usage for composting while Kannaland Municipality is challenged with pollution at the point of waste disposal but hopes farmers will use the sludge for composting. The Knysna Municipality is challenged with limited space at disposal sites and Mossel Bay Municipality is waiting for tender approval and cost to remove sludge from their site.

Table 4: Current Sludge Management methods within the GRDM

Municipality	Name of WWTW	Effluent sources	Management Methods (Disposal/Beneficiation)
Oudtshoorn	Dysselsdorp	Residential	Under investigation
	Oudtshoorn	Residential/ Industrial	
	De Rust	Residential	
George	Outeniqua	Schaapkop River	Belt press
	Gwaing	Gwaing River	
	Kleinkrantz	Sand Dunes	Sludge drying beds
	Uniondale	Irrigation purpose	
	Herolds Bay (Oxidation ponds)	Evaporation dams	Empty primary ponds every second year, the sludge is dried and taken to the Gwaing WWTW
	Haarlem	Irrigation purpose	Empting of septic tanks once a year and the sludge is taken to the Uniondale WWTW
Hessequa	Riversdale	Industrial	Usage for nearby Golf Club irrigation
	Stillbaai	Residential	Beneficiation
	Jongensfontein	Residential	Natural evaporation and for Irrigation purposes
	Melkhoutfontein	Residential	
	Albertinia	Residential	Usage for nearby Golf Club irrigation and Rugby field
	Gouritsmond	Residential	Natural evaporation in summer and transportation to the Albertinia plant in winter
	Heidelberg	Heidelberg	Irrigation for nearby farms
Bitou	Ganse Vlei	Residential	Sludge ponds
	Kurland	Residential	
Kannaland	Ladismith	Industrial& Residential	Landfill
	Zoar	Residential	
	Calitzdorp	Residential	
	Van Wyksdorp	Residential	
Knysna	Knysna	Residential	Disposal at a flower nursery
Mossel Bay	Regional	Industrial& Residential	Composting- SS-Organics
	Pinnacle Point	Industrial& Residential	

Mossel Bay Municipality had the highest average tonnes per month deposited sludge at 260 and Kannaland Municipality had the lowest quantity at 2 tonnes per month (Figure 8), below.

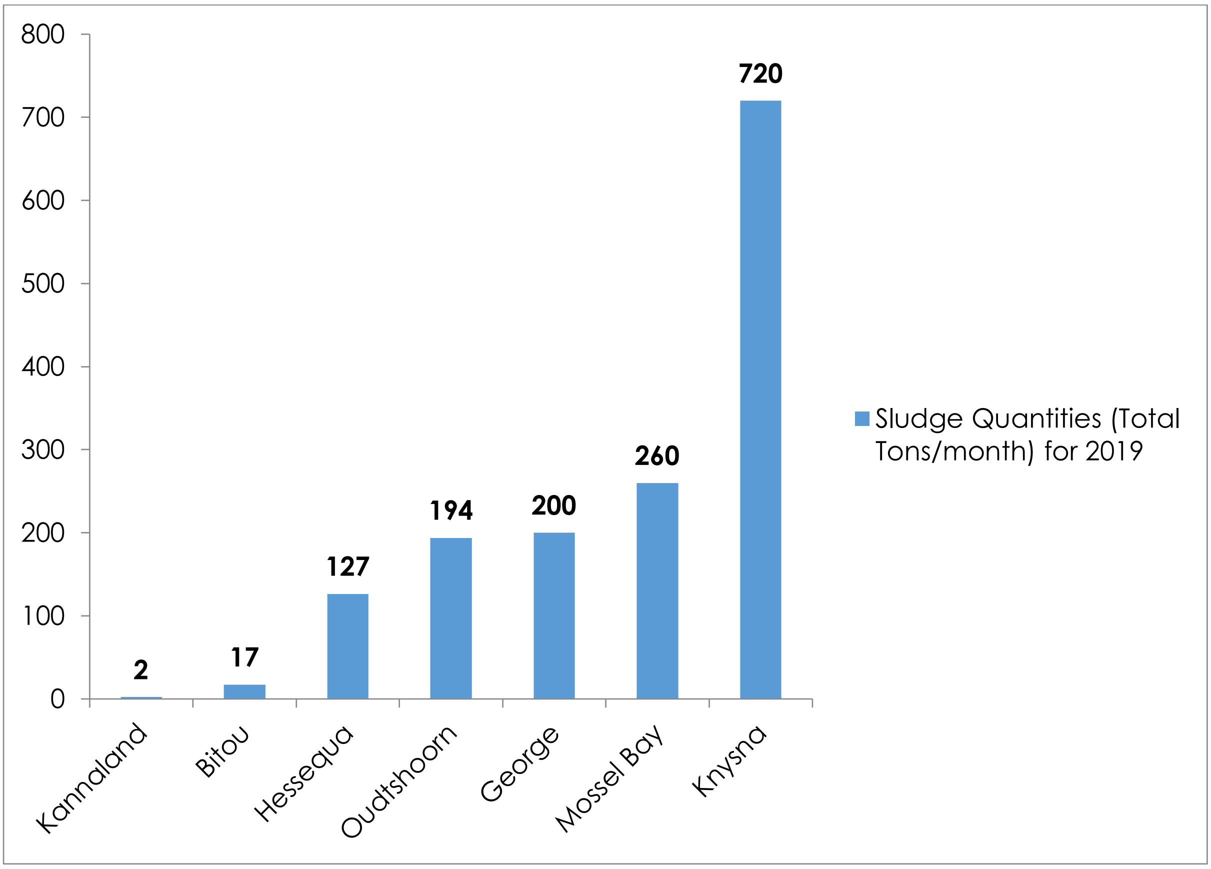

Figure 8: Quantities of sludge generated in the 2019 reporting period (GRDM)

3.2.3 Overberg District Municipality

The Overberg local municipalities have provided data for 18 wastewater treatment works with sludge management methods involving a combination of disposal at landfill and land farming application. The Cape Agulhas Municipality has challenges that include staff shortages, poor effluent quality as well as biological and hydraulic overloads but are planning for an upgrade in the 2021/ 2022 financial year.

The continued disposal of sludge to landfill is problematic in Overstrand Municipality due to the new regulations and the municipality views the composting of sludge as a potential option once the new Norms and Standards are published. Theewaterskloof Municipality is challenged with convincing the agriculture sector regarding the applicability of sludge to land and that the sludge can be mixed with greens to produce compost with the development of a composting facility in the town.

The challenges in the Swellendam Municipality include the absence of a dedicated waste site, no budget, vehicles, lifting machines or personnel and there is no plan in place to deal with the challenges. The Swellendam Municipality submitted data for accumulated sludge (297 066 tonnes/ month) for the 2019 reporting period, however it is likely that this sludge was stockpiled over a longer period as the value is too high to be the average monthly disposal from 2019 alone. Overstrand Municipality had the highest average tonnes per month of disposed sludge at 256.

Table 5: Current Sludge Management methods within the ODM

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
Cape Agulhas	Bredasdorp	Industrial& residential	Waste license being applied for (onsite disposal)
	Struisbaai	Industrial& residential	Onsite sludge disposal
	Arniston	Residential	Water license required
	Napier	Residential	New license with upgrade
Overstrand	Hermanus	Industrial/ Residential	Screenings disposed of at Vissershok WMF. Sludge disposed of at Karwyderskraal Landfill.
	Hawston	Industrial/ Residential	Screenings transported to Hermanus WWTW disposed of at Vissershok WMF with Hermanus screenings. Sludge disposed of at Karwyderskraal Landfill.
	Kleinmond	Industrial/ Residential	Screenings transported to Hermanus WWTW disposed of at Vissershok WMF with Hermanus screenings. Sludge disposed of at Karwyderskraal Landfill.
	Stanford	Industrial/ Residential	Screenings transported to Gansbaai WWTW disposed of at Vissershok WMF with Gansbaai screenings. Sludge disposed of at Gansbaai Landfill.
	Gansbaai	Industrial/ Residential	Screenings disposed of at Vissershok WMF.

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
			Sludge disposed of at Gansbaai Landfill.
	Eluxolweni (Pearly beach)	Residential	Screenings transported to Gansbaai WWTW disposed of at Vissershok WMF with Gansbaai screenings. No sludge disposed/ oxidation pond system.
Swellendam	Klipperivier	Industrial/ Residential	None
Theewaterskloof	Grabouw	Industrial& residential	Composting and Land application on site.
	Villiersdorp	Industrial& residential	Disposal/ application to land.
	Botrivier	Residential	
	Riviersonderend	Residential	
	Greyton	Residential	
	Genadendal	Residential	
	Caledon	Industrial& residential	

3.2.4 West Coast District Municipality

The West Coast local municipalities have provided data for 23 wastewater treatment works and the sludge is mainly used for agricultural purposes as shown in Table 6, below. However, this excludes the 4 WWTWs for Matzikama Municipality, which were taken from the WC IWMP as the municipality did not provide current data. Saldanha Bay Municipality had the highest average tonnes per month deposited sludge at 5 469 and the sludge quantities for Matzikama and Cederberg municipalities are unknown.

The Bergrivier Municipality keeps sludge on site as they find it costly to dispose of it at a hazardous landfill but indicates that their quantities are too minimal for feasible projects. Saldanha Bay Municipality is challenged with sludge lagoons that require long drying times resulting in bad odour and an unpleasant sight, stockpiling of sludge and transportation to the Laingville WWTW due to limited draw-off capacity.

Saldanha Bay Municipality is looking into agricultural benefits (farming) and usage as capping material. In Cederberg Municipality, sludge dams are insufficient, and they have challenges with ponds and inlet works but see opportunity in recycling and re-use of the final effluent. Cederberg Municipality is in the progress of reallocating and upgrading of WWTW to eliminate risks. The Swartland Municipality has the following challenges –

- Elevated levels of CODs from food processors, abattoirs and dairy farms;
- Power cuts and storms;
- Old and dysfunctional infrastructure as well as ineffective and outdated control systems;
- Dysfunctional dewatering plant; and
- Inoperable WAS pumps due to cable theft.

Table 6: Current Sludge Management methods within the WCDM

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
Bergriver	Porterville	Residential	None – Kept on site in ponds
	Piketberg	Residential	
	Velddrif	Residential	
	Dwarskersbos	Residential	
	Eendekuil	Residential	
Saldanha Bay	Langebaan	Residential	None
	Saldanha	Residential/ Industrial	Currently taken by West Coast Bio Organics for Agricultural use
	Vredenburg	Residential/ Industrial	Request by West Coast Bio-organics to use for Agri-culture
	Laingville	Residential	Currently used by sport grounds and neighbouring agriculture
	Shelly point	Residential	None
	Paternoster	Residential	
	Hopefield	Residential	
Swartland	Malmesbury	Industrial and residential	Agricultural use. Sludge is produced from the dewatering plant and is removed from site daily. It is transported to farms within a 10km radius from the plant.
	Riebeek Valley	Residential effluent	Agricultural use. Sludge is produced from the dewatering plant and is removed from site daily. It is transported to farms within a 15km radius from the plant.
	Moorreesburg	Industrial and residential	Sludge treatment is achieved with sludge drying beds. Dried sludge is stockpiled and disposed to the nearest hazardous landfill on a regular basis
	Darling	Industrial and residential	Sludge is wasted manually with a vacuum truck and discharged directly to the oxidation-evaporation ponds.
Matzikama	Ebennaeser	N/A	Sludge is buried after drying.

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
	Klawer		
	Koekenaap		
	Lutzville		

3.2.5 Cape Winelands District Municipality

The Cape Winelands local municipalities have provided data for 15 wastewater treatment works and sludge management involves a combination of landfill disposal as well as land farming application as shown in Table 7, below. However, this excludes the 6 WWTW for Langeberg and Breede Valley municipalities, which were taken from the WC IWMP as the municipalities did not provide current data. The Stellenbosch Municipality had the highest average tonnes per month deposited sludge at 4 378 and the sludge quantities for Langeberg and Breede Valley Municipalities are unknown.

The Stellenbosch Municipality has a challenge with disposal costs but views further treatment to reduce pathogens can enhance the sludge application. Two (2) out of four (4) belt presses are defunct in Drakenstein Municipality but they intend to engage in the marketing of sludge. In Witzenberg Municipality, the drying of sludge during the winter period, stockpiling of dried sludge and the cleaning of sludge dams is a great challenge, but the Municipality sees opportunity for agricultural purposes based on the classification of the sludge.

Table 7: Current Sludge Management methods within the CWDM

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
Stellenbosch	Stellenbosch	Residential& Industrial	Land application
	Wemmershoe k	Residential& Industrial	
	Klapmuts	Residential& light industrial	
	Pniel	Residential& light industrial	Stock Piling
	Raithby	Residential	Land application
Witzenberg	Ceres	Residential& Industrial	Disposal to landfill site
	Wolseley	Residential	Disposal in sludge dams
	Tulbagh	Residential	Disposal to landfill site

Municipality	Name of WWT Works	Effluent sources	Management Methods (Disposal/Beneficiation)
	Op die Berg	Residential	
Drakenstein	Paarl	Residential& Industrial	Land application, Agriculture
	Pearl Valley	Residential	
	Wellington	Residential& Industrial	Sludge pumped to Paarl WWTW
	Hermon	Residential	Oxidation pond system, no sludge produced
	Gouda	Residential	
	Saron	Residential	Land application, Agriculture
Langeberg	Ashton		Sludge removed by farmers and used for agricultural purposes. Excess sludge disposed by municipality.
	Bonnievale		Sludge stockpiled near drying beds and removed by farmer for land application.
	McGregor		Sludge stockpiled prior to collection for disposal at Ashton WWTW.
	Robertson		Sludge stockpiled near drying beds and removed by farmer for land application.
	Montagu		Maturation pond systems, no disposal of sludge.
Breede Valley	De Doorns		Sludge is treated, classified and stockpiled prior to been taken by farmer.

3.2.6 Central Karoo District Municipality

Laingsburg is the only municipality in the Central Karoo district that submitted data for 1 WWTW, while data for 7 WWTW in Beaufort West and Prince Albert municipalities were taken from the WC IWMP. Sludge management involves a combination of landfill disposal as well as land farming application as shown in Table 8, below.

The Laingsburg Municipality has a temporary dam that was created on site to dry sludge removed from the existing anaerobic dam with an approximate value of 3 000m^3, which is equivalent to 2 163 tonnes/ month. No disposal takes place in Laingsburg Municipality.

Sludge quantities for Prince Albert Municipality are unknown but the sludge is manually removed by handmade tools and safely disposed of in trenches on site. In Beaufort West Municipality, sludge has been stockpiled in lagoons for 20 years at (15 000m^3), which is approximately 10815 tonnes/ month stored in lagoon (20-year period).

Table 8: Current Sludge Management methods within the CKDM

Municipality	Name of WWT Works	Effluent sources	Sludge Quantities (Tonnes/month) for 2019	Management Methods (Disposal/Beneficiation)
Laingsburg	Laingsburg	Residential (no industrial areas)	A temporary dam was created on site to dry out the sludge that was removed from the existing anaerobic dams (approximately 3 000 m^3) or ~2163 tonnes/ month	No disposal took place
Prince Albert	Klaarstroom		Sludge quantities unknown	Sludge is manually removed by handmade tools and safely disposed of in trenches on site.
	Leeu-Gamka			
	Prince Albert			
Beaufort West	Beaufort West			Sludge is stockpiled on site and then given to different users to be used as compost.
	Merweville		No sludge generated yet. Oxidation ponds with very low inflows.	No sludge generated yet. Oxidation ponds with very low inflows.
	Murraysburg		Sludge quantities unknown	Oxidation ponds have not been de-sludged.
	Nelspoort		Sludge quantities unknown	In the process of drying the oxidation ponds, which will help determine which method can be used to dispose of sludge.

4 Conclusion

Based on the feedback gained it is evident that there are various infrastructural and operational challenges that municipalities, as owners of the WWTWs, face. Many of which can have a direct or indirect impact on how sewage sludge is currently managed. Below is a summary of the sewage sludge management methods currently used by WWTWs.

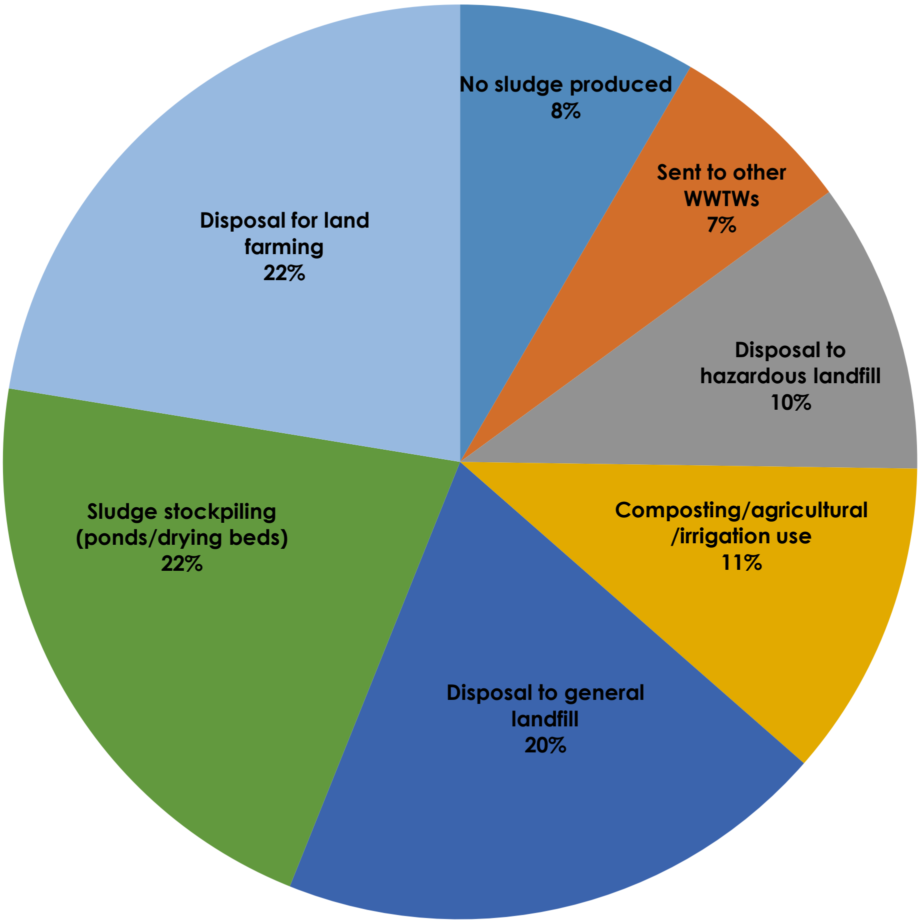

Figure 9: Sewage sludge management methods

As illustrated in the Figure 9, above the most common methods of sewage sludge management is disposal or stockpiling. Be it for land farming, sludge stockpiling or disposal to a general or hazardous landfill. All of these options are dependent on there being land available for these applications. With the shortage of landfill airspace across the Province and the aim to divert organic waste from landfill, more beneficiation options for treated sewage sludge needs to be considered. There are some encouraging examples whereby 11% of WWTWs currently divert their sewage sludge for composting/ agricultural and irrigation purposes. These localised solutions can be learnt from and where possible applied in other areas across the Province.

To plan effectively for the management of any waste type it is important to understand the quantity, quality and location of such waste. As mentioned in section 3.1, reporting to the IPWIS for sewage sludge is very poor thus making it difficult to determine the exact amount of sewage sludge available in the Province. The quality of sewage sludge produced is key in determining the end use options. Where municipalities have tested their sludge, they have diverted it for use in composting as well as agricultural and irrigation purposes. Some municipalities have indicated that their sludge is of a good enough quality to be used for farming and/or composting however they have been unable to convince prospective end users of its applicability.

There is a need to stimulate business interest in sewage sludge. Municipalities are encouraged to get their treated sewage sludge tested and compare microbiological parameters (faecal coliforms, helminth ova), physical and stability parameters (pH, TS, VS, VFA) as well as chemical characteristics (nutrients, metals, organic pollutants), as these parameters determine sludge utilisation based on the microbiological content, stability as well as organic and inorganic pollutants. These parameters should be compared to guidelines values and their sludge product accordingly marketed.

5 References

Baizi e Silva, A. R. and Camilotti, F. 2014. Risk of heavy metals contamination of soil-plant system by land application of sewage sludge: a review with data from Brazil. Available: https://www.intechopen.com/books/environmental-risk-assessment-of-soil-contamination/risks-of-heavy-metals-contamination-of-soil-pant-system-by-land-application-of-sewage-sludge-a-revie[2020, August 2].

Banegas, V., Moreno, J. L., Garcia, C., León, G. and Hernández, T. 2007. Composting anaerobic and aerobic sewage sludges using two proportions of sawdust, Waste Management, 27(10): 1317-1327.

Chang, A. C. n.d. Land application of sewage sludge.: pathogen issues. Available: https://inis.iaea.org/collection/NCLCollectionStore/_Public/29/009/29009787.pdf [2020, August 2].

Chen, L. and Neibling, H. 2014. Anaerobic digestion basics. Available: https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1215.pdf [2020, August 2

Christodoulou A. & Stamatelatou K. 2016. Overview of legislation on sewage sludge management in developed countries worldwide. Water Science and Technology 2016; 73:453–462.

Clarke, R. M. and Cummins, E. 2015. Evaluation of "classic" and emerging contaminants resulting from the application of biosolids to agricultural lands: a review. Human and Ecological Risk Assessment, 21:2 492-513. Available: https://www.researchgate.net/publication/302697753_Evaluation_of_'classic'_and_emerging_contaminants_resulting_from_the_application_of_biosolids_to_agricultural_lands_a_review [2020, August 2].

De Lara, A. I., Andreoli, C. V., Lopes, D. D., Mortita, D. M., Pegorini, E. S., Fernandez, F., de Santos, H. F., Pinto, M. A. T., von Sperling, M., Luduvice, M., Goncalves, R. S., da Silva, S. M. C. P. and Soccol, V. T. 2007. Sludge treatment and disposal, in Andreoli, C. V; von Sperling, M. and Fernandes (eds). Biological waste treatment series, vol. 6. Available: https://sswm.info/sites/default/files/reference_attachments/ANDREOLI%20et%20al%202007%20Sludge%20Treatment%20and%20Disposal.pdf [2020, August 2].

Department of Environmental Affairs (DEA). 2008. National Environmental Management: Waste Act (NEMWA) (Act No. 59 of 2008). DEA, Pretoria.

Department of Environmental Affairs (DEA). 2014. National Environmental Management: Waste Amendment Act (NEMWA) (Act No. 26 of 2014). DEA, Pretoria.

Department of Environmental Affairs (DEA). 2012. National Environmental Management: Waste Act (59/2008): National Waste Information Regulations. Government Notice R. 625.

Department of Environmental Affairs (DEA). 2013. National Environmental Management: Waste Act (59/2008): Waste Classification and Management Regulations. Government Notice R.634 of 23 August 2013. Pretoria.

Department of Environmental Affairs and Development Planning. 2017. Western Cape Integrated Waste Management Plan. Department of Environmental Affairs and Development Planning.

Department of Environmental Affairs. 2018. South Africa State of Waste. A report on the state of the environment. Final draft report. Department of Environmental Affairs, Pretoria. 112 pp.

Department of Human Settlements, 2019. The Neighbourhood Planning and Design Guide. Section K, Sanitation. Pretoria: Department of Human Settlements.

Department of Economic Development and Tourism. The Western Cape Waste Economy Business Case: Gap Analysis Cape Town: DEDAT 2016.

Foundation for Water Research, 2016. Sewage sludge: Operational and Environmental Issues. Available: http://www.fwr.org/sludge.pdf [4 August 2020]

French Agency for Food, Environmental and Occupational Health & Safety (ANSES). 2020. Sewage sludge produced during the COVID-19 Epidemic Can Only Be Applied to Fields After Disinfection. Available: https://www.anses.fr/en/content/sewage-sludge-produced-during-covid-19-epidemic-can-only-be-applied-fields-after [August 2020]

GreenCape Market Intelligence Report, Waste. 2018. Available: https://www.greencape.co.za/assets/Uploads/20180622-GreenCape-Waste-MIR-FA-LR.pdf [September 2020].

Herselman, J., Snyman, H. G. 2006. Guidelines for the Utilisation and Disposal of Wastewater Sludge. Volume 1: Management Options. WRC Report No. TT 261/06. Pretoria: Water Research Commission.

International Water Association. n.d. Sludge drying overview- Treatment methods and applications. Available: https://www.iwapublishing.com/news/sludge-drying-overview-treatment-methods-and-applications [2020, August 2].

Johnson, O. A., Napiah, M. and Kamaruddin, I. 2014. Potential uses of waste sludge in the construction industry. Research Journal of Applied Sciences, Engineering and Technology 8(4): 565-570. Available: https://www.researchgate.net/publication/272944348_Potential_uses_of_Waste_Sludge_in_Construction_Industry_A_Review [2020, August 4].

Kacholi, D. S. and Sahu, M. 2018. Levels and Health Risk Assessment of Heavy Metals in Soil, Water, and Vegetables of Dar es Salaam, Tanzania. Journal of Chemistry, vol. 2018. Available: https://www.hindawi.com/journals/jchem/2018/1402674/ [2020, October 30].

Kootenaei, F. G., Aminirad, H. and Ramezani, M. 2014. Composting of sewage sludge and municipal solid waste. Nature Environment and Pollution Technology 13(3):553-558. Available: https://www.researchgate.net/publication/287352128_Composting_of_sewage_sludge_and_municipal_solid_waste [2020, August 4].

Lamastra, L., Suciu, N. A. and Trevisan, M. 2018. Sewage sludge for sustainable agriculture: contaminants' contents and potential use as a fertilizer. *Chemical and Biological Technologies in Agriculture*. 5 (10): 2-6. Available: https://link.springer.com/article/10.1186/s40538-018-0122-3 [2020, August 4].

Liew, A. G., Idris, A., Wong, C. H. K., Samaad, A. A., Noor, M. J. M. M. and Baki, A. M. 2004. Incorporation of sludge in clay brick and its characterisation. Waste Management. 22 (4): 226-233. Available: https://www.researchgate.net/publication/8253882_Incorporation_of_Sewage_Sludge_in_Clay_Brick_and_its_Characterization

Mtshali, J. S., Tiruneh, A. T. and Fadarin, A. O. 2014. Characterisation of sewage sludge generated from wastewater treatment plants in Swaziland in relation to agricultural uses. Resources and Environment 4(4): 190-199, DOI: 10.5923/j.re.20140404.02 [2020, August 4].

Náthia-Neves, G., Berni, M., Dragone, G., Mussatto, S. I. and Forster-Carneiro, T. 2018. Anaerobic digestion process: technological aspects and recent developments. *International Journal of Environmental Science and Technology*. 2033-2046. Available: https://www.researchgate.net/publication/325156429_Anaerobic_digestion_process_technological_aspects_and_recent_developments [2010, August 4]

Núñez-Delgado, A. 2020. What do we know about the SARS-CoV-2 coronavirus in the environment? Science of the Total Environment. 727. https://doi.org/10.1016/j.scitotenv.2020.138647

Oladejo, J., Shi, K., Luo, X., Yang, G. and Wu, T. 2019. A review of sludge-to-energy recovery methods. Energies, 12 (1):1-38. Available: https://www.mdpi.com/1996-1073/12/1/60 [2020, August 4].

Pöykiö R., Watkins G. & Dahl O. 2019. Characterisation of municipal sewage sludge as a soil improver and a fertilizer product. Ecological Chemistry Engineering S 2019; 26 (3): 547 – 557.

Reilly, M. 2001. The case against land application of sewage sludge pathogens. The Canadian Journal of Infectious Disease, 12(4): 205–207. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2094820/ [2020, August 4].

Republic of South Africa. 1989. Environmental Conservation Act (ECA) (Act No. 73 of 1989). Pretoria.

Rivas-Solano, O., Faith-Vargas, M. and Guillén-Watson, R. 2016. Biodigesters: chemical, physical and biological factors related to their productivity. Tecnología en Marcha. 29(5): 47-53.

Rulkens, W. 2008. Sewage sludge as a biomass resource for the production of energy: Overview and assessment of the various options. Energy & Fuels, 22, 9-15. Available: https://sswm.info/sites/default/files/reference_attachments/RULKENS%202007%20Sewage%20Sludge%20as%20a%20Biomass%20Resource.pdf [2020, August 4].

Shaddel, S., Bakhtiary-Davijany, H., Kabbe, C., Dadgar, F., and Osterhus, S.W. 2019. Sustainable Sewage Sludge Management: From Current Practices to Emerging Nutrient Recovery Technologies. Sustainability. 11(3435):1-2.

Shammas, N. K. and Wang, L. K. 2007. Gravity Thickening, in Wang, L. K.; Shammas, N. K., Hung, Y. T. (eds). Biosolids treatment processes. Handbook of Environmental Engineering, vol 6., Humana, Totowa, NJ,

Smith, S. R. 2009. Organic contaminants in sewage sludge (biosolids) and their significance for agricultural recycling. Philosophical Transactions of the Royal Society A. 367(1904):4005–4041.

Sreekrishnan T.R. and Tyagi R.D. 1999. Metal removal from sewage Sludge: Bioengineering and Biotechnological Applications. In: Prasad, M. N. V. and Hagemeyer, J. (eds). Heavy Metal Stress in Plants. Springer, Berlin, Heidelberg. Available:
https://link.springer.com/article/10.1186/s40538-018-0122-3 [2020, August 4].

Stauffer, B. undated. Mechanical dewatering. Available: https://sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/sludge-treatment/mechanical-dewatering [2020, August 4].

Stehouwer, R. 2010. What is sewage sludge and what can be done with it? Available: https://extension.psu.edu/what-is-sewage-sludge-and-what-can-be-done-with-it [2020, August 4].

Tesfamariam, E.H., Badza, T., Demana, T., Rapaledi, J., and Annandale, J.G. 2018. Characterising Municipal Wastewater Sludge For Sustainable Beneficial Agriculture Use. (WRC report; no. TT 756/18). Gezina, South Africa: Water Research Commission.

Thorpe B. K. 2016. Implementing the Waste Classification and Management Regulations and Associated Standards for the Assessment and Disposal of Waste to Landfill: An Industry Perspective. Proceedings of the 23rd WasteCon, 17-21 October 2016, Emperors Palace, Johannesburg, South Africa.

United States Agency for International Development. 2015. Implementer's guide to lime stabilization for septage management in the Philippines. Available: https://www.pseau.org/outils/ouvrages/lcp_pawd_usaid_implementer_s_guide_to_lime_stabilization_for_septage_management_in_the_philiippines_2015.pdf, accessed [2020, August 4].
United States Environmental Protection Agency. 1995. Compilation of air pollutant emissions factors. Available: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-

factors#:~:text=Compilation%20of%20Air%20Pollutant%20Emissions%20Factors%20(AP%2D42),-AP%2D42%2C%20Compilation&text=It%20contains%20emissions%20factors%20and,group%20of%20similar%20emitting%20sources.&text=The%20Fifth%20Edition%20of%20AP%2D42%20was%20published%20in%20January%201995 [2020, August 4]

United States Environmental Protection Agency (US EPA). 2020. https://www.epa.gov/biosolids/basic-information-about-biosolids (Accessed 8 September 2020)

United States Environmental Protection Agency. 1996. Biosolids technology factsheet: heat drying. Available: https://www.epa.gov/sites/production/files/2018-11/documents/heat-drying-factsheet.pdf [2020, August 4].

United States Environmental Protection Agency. 2003. Biosolids technology fact sheet: gravity thickening. Available: https://nepis.epa.gov/Exe/ZyNET.exe/P10053EB.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2000+Thru+2005&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C00thru05%5CTxt%5C00000021%5CP10053EB.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL#

United Stated National Research Council. 1996. Use of reclaimed water and sludge in food crop production. Available: https://www3.epa.gov/npdes/pubs/mstr-ch3.pdf [2020, August 4]

Usman, K., Marwat, S. K., Ghulam, S., Khan, M. U., Khan, N., Khan, M. A., and Khalil, S. A., 2012. Sewage sludge: An important biological resource for sustainable agriculture and its environmental implications. Available: https://www.researchgate.net/publication/276491335_Sewage_Sludge_An_Important_Biological_Resource_for_Sustainable_Agriculture_and_Its_Environmental_Implications. [2020, August 4].

United States Environmental Protection Agency. 2000. Biosolids technology fact sheet: Land application of biosolids. Available: https://www3.epa.gov/npdes/pubs/land_application.pdf [2020, August 4].

Wang, L. K., Shammas, N. K., Selke, W. A. and Aulenbach, D. B. 2007. Flotation thickening. In Biosolids treatment processes. In: Wang, L. K., Shammas, N. K., Hung, Y. T. (eds). Handbook of environmental engineering, vol 6. Humana, Totowa, NJ, Available: online https://link.springer.com/chapter/10.1007/978-1-59259-996-7_3, viewed [2020, August 2].

Water Research Commission .2006. Guideline for the utilisation and disposal of sludge. Volume 1: Selection of management options. Available: http://sawic.environment.gov.za/documents/270.pdf [2020, August 4].

Water Research Commission, 2009. Guideline for the utilisation and disposal of sludge. Volume 3: Requirements for the on-site and off-site disposal of sludge. Available: http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20349%20web.pdf [2020, August 4].

Water Research Commission, 2016. Wastewater treatment technologies, A Basic Guide. Available: http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20651%20-%2015.pdf [2020, September 10]

Water Research Commission, 2018. Energy recovery from wastewater sludge- a review of appropriate emerging and established technologies for the South African Industry. Available: http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20752-18.pdf [2020, August 4].

Yapicioğlu, P. S. and Demir, O. 2017. Life cycle assessment of sewage sludge treatment- an overview. Available: https://www.researchgate.net/publication/322759900_Life_Cycle_Assessment_of_Sewage_Sludge_Treatment-An_Overview [2020, August 10]

6 Sign-off

I hereby approve the Sewage Sludge Status Quo Report.

Signature

Eddie Hanekom
Director: Waste Management

Date: 12 March 2021

7 Appendix A

Category	Constituent (unit)	Primary sludge				Waste activated sludge			
		Min	Median	Max	Mean	Min	Median	Max	Mean
Classification	Microbiological Class	C	B	B	B	C	B	A	B
	Stability Class	1	2	2	1.8	1	2	2	1.6
	Pollutant Class	a	a	a	a	a	a	a	a
Physical Characteristics	pH	5.74	6.12	7.01	6.3	5.09	5.89	6.79	5.9
	Total Solids (%)	8.3	16.85	22.2	16.7	8.4	14.05	41.6	17.7
	Volatile Solids (%)	6.8	13.8	19.9	14.0	6.9	11.85	27	13.2
	Volatile Fraction (%)	76.3	82.7	92.1	83.7	49.1	79.9	92.5	77.8
	Volatile Fatty Acids (%)	0.01	0.02	0.02	0.018	0.01	0.02	0.02	0.018
Nutrients	TKN (mg/kg as N)	4 550	8 904.5	27 796	10 309	3 821	8 578.5	26 037	9 904
	TP (mg/kg as P)	35	250.5	845	330.3	236	707	12 339	1 742.7
	Potassium (mg/kg as K)	2 650	7 297.5	32 679	9 082.9	958	6 489	59 172	10 256.5
Metals and Micro elements	Arsenic (mg/kg as As)	<1	<1	<1	<1	<1	<1	<1	<1
	Cadmium (mg/kg as Cd)	0.42	1.55	7	2.8	<1	<1	61.3	3.7
	Chromium (mg/kg as Cr)	4	51.6	180	73.3	<1	47.1	820	114.6
	Copper (mg/kg as Cu)	21	111.5	363	120.8	38.3	129.5	790	175.7
	Lead (mg/kg as Pb)	1	25.1	102	33.3	<1	15.15	95.9	18.7
	Mercury (mg/kg as Hg)	0.005	<1	<1	<1	<1	<1	<1	<1
	Nickel (mg/kg as Ni)	3.9	33	61.3	31.3	<1	11	293	29.4
	Zinc (mg/kg as Zn)	173	632.5	2 409	990.3	125	494.5	3 762	718.3
Microbiological Quality	Faecal Coliforms (organisms per g)	2 400	3 334 500	8 063 000	3 799 117	57	10 200	8 063 000	1 267 887
	Total Viable Helminth Ova (ova/g)	0	1.5	5	2	0	4	25	5.3
Stability (O'Shaunessy's formula)	Class	1	2	2	1.8	1	2	2	1.5
	Volatile solids reduction (%)	0	6.9	14.3	6.5	0	23.8	81.6	29.5

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