UNIVERSITY OF KWAZULU - NATAL

Wastewater Sludge Management For Umgeni Water

By

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DECLARATION

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b) This thesis has not been submitted for any degree or examination at any other university.

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ABSTRACT

Umgeni Water is a state-owned bulk water service provider for water supply and sanitation services to water services authority in its operational area. It is constituted in accordance with the Water Services Act (Act 108 of 1997) and the Public Finance Management Act (Act 1 of 1999), The area of coverage is 21 155 square kilometres and serving 6 million people (1.64 million households) over six Water Services Authorities.

Sludge management is an important area of concern across wastewater treatment Plants at Umgeni Water. Inability to remove the sludge in the treatment plants affects the operation negatively resulting in poor performance in some treatment plants. In addition to maintaining treatment efficiency, proper sludge management is important for mitigating pathogen levels and providing opportunities for safe beneficial reuse of sludge. Sludge is characterized with respect to quantities generated (accumulation rates) and quality (helminths and heavy metals content). A review is to be conducted of appropriate sludge treatment technologies including sludge drying beds, alkaline stabilization, anaerobic digestion, and composting. These options to be valuated based on a set of selected criteria. Sludge guidelines regulate sludge disposal options as a result of the type of treatment regime, pathogen removal, and metals substance. Also disposal selections for sludge involves some form of recycling of the product, through direct land application, stabilization, composting, or pelletizing (Bloetscher, 1999).

A quantitative approach was used to explore the different sludge management strategies implemented at Umgeni Water and comparing to best practice employed by other Water Authorities. Creswell (2014), defines quantitative research as a method of understanding what factors or variables impact an outcome of the research. This is done through researchers advancing a theory to test, and they will incorporating significant analyses of the literature to identify research questions needing answers. Questionnaires were sent out to targeted sample covering the entire population of employees working on the wastewater treatment plants.

This research aimed to compare traditional sludge management options with current global trends focussing on three main areas namely, sludge beneficiation ,

compliance to environmental regulations and cost effectiveness. Recommendations for integrated approach in process design at Umgeni Water which will allow the Organization to implement sludge beneficiation in all their wastewater treatment plants.

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ABBREVIATIONS

BOD - Biological Oxygen Demand

DWS – Department of Water and Sanitation

EU – European Union

GDP – Gross Domestic Product

IMF – International Monetary Fund

km^2 - square kilometres

Ml/d – Million Litres a Day

TCLP - Toxicity Characteristic Leaching Procedure

uMDM – uMgungundlovu District Municipality

UW – Umgeni Water

WWTP – Wastewater Treatment Plants

CHAPTER ONE - INTRODUCTION

1.1 Preamble

Sewage sludge production is increasing worldwide as a result of the constantly increasing population, urban planning, and industrial developments. This sludge needs to be properly treated and environmentally managed to decrease the negative impacts of its application and disposal. According to Ghazy, et al., (2011), the main critical needs are to find and develop efficient, economical and sustainable technologies for sludge treatment. Waste and sludge management rely on various technical, ecological, economic and political factors which can influence environmental actions. Wastewater sludge is generated through the treatment processes and appropriate handling is required in order to prevent adverse influences on the environment thus minimising the risks to humans (Karius, 2011).
It is well known that the world has been reduced to a small place; there is movement of people to new places and migrating. Global companies are enforcing governance in their daily operations and as a result, people have come to expect the same high quality standards, globally (LeBlanc, 2010).

1.2 Motivation and Focus of the Study

Sludge management is a crucial component in the water value chain, however it is often ignored. Timely sludge removal from treatment systems has an important role in preventing loss of effective treatment capacity and maintaining design hydraulic retention times. Because raw wastewater sludge contains concentrated levels of pathogens, safe handling and disposal (or reuse) of this material is essential for public health protection. Sludge also contains high amounts of organic matter and nutrients, which can be beneficially reused. Therefore, proper sludge management is not only important with regards to wastewater treatment efficiency and public health but can also allow the wider community to utilise the resource value of sludge which would otherwise go to waste.

Lack of adequate sanitation is a major contributor to waterborne diseases in the developing world. Incidences of diarrheal and parasitic diseases are largely due to unsanitary conditions, which are often a result of the interaction between wastewater and drinking water. This highlights the importance of appropriate wastewater and drinking water treatment in reducing such diseases.

Though less emphasised, sludge management is also critical for controlling the spread of pathogens. Sludge, the solid waste stream generated from wastewater treatment processes, contains concentrated levels of pathogens and organic matter. The incidences of some diseases, such as helminthiasis, are closely linked to sludge and wastewater effluent management practices. The land application of inadequately treated sludge can significantly contribute to the spread of helminths.

1.3 Problem Statement

This study explores the current sludge management practices at Umgeni Water in terms of National Environmental Management Act as well as a further comparison to international trends.

1.4 Research Objectives

This study aims to :

- ascertain different processes for sludge treatment
- confirm the sludge disposal methods used at Umgeni Water
- assess the possibility of introducing sludge recycling and reuse practices
- determine the legislative impacts of wastewater sludge
- determine the financial implications to life cycle costing for sludge management.

1.5 Research Questions

- What sludge treatment processes exist at Umgeni Water?
- What processes are used in terms of sludge disposal at Umgeni Water?
- What is the possibility of sludge recycling and reuse practices being incorporated at Umgeni Water?
- What are the legislative implications in terms of wastewater sludge for Umgeni Water?

- Do different sludge management techniques have an effect on life cycle costing?

1.6 Limitations of the Study

Wastewater sludge predominantly originates from the treatment of used water from residential use and or industrial areas. Sludge is also generated when portable water is processed at waterworks. For the purpose of this study, however, sludge will refer only to wastewater sludge from treatment plants and will exclude sludge from pure industry plants. Future developments in the wastewater sector, for example, urine separating toilets, will not be covered in this study as the implementation of such would not be financially viable, for example, a new pipe network need to be constructed (Blanca Jiménez, 2008).

This study will not include the financial studies for the different systems of sludge treatment. The results will have an influence on the choice of treatment process and methods of disposing sludge. It will not focus on regulations pertaining to the working environment of the employees in the wastewater treatment.

1.7 Assumptions

With present knowledge, the opportunities seem improbable that a cost-effective sewage treatment process will be developed that does not transfer substantial amounts of the contaminant water into a condensed wet solids side-stream, thus needing off-site disposal. Wastewater treatment plants will still remain operating as sludge factories with continuous and persistent production. This operation of wastewater treatment plants will result in the sludge as a product for which quality is not entirely manageable, having no guaranteed long-term outlet and requiring treatment, transporting and disposal, all at a high cost. Wastewater sludge is thus considered as the major challenge of water contamination control and it must be given the priority it deserves (Bloetscher, 1999).

Wastewater sludge management is an international topic for which several conferences are held in order to co-ordinate research within scientific committees.

The results of such activities have highlighted the increasing understanding that despite worldwide wastewater sludge generation being on a persistent development trajectory, environmental quality standards for sludge are being made rigorous, sludge disposal sites are reducing while the economic challenges still compel for low-cost solutions to sludge disposal methods. Policy makers then have to reach an equilibrium between the favoured policy of operating wastewater sludge with respect to balanced development and practical quality standards that are reasonable in terms of costs (Hall, 2014).

1.8 The Structure Of The Study

The research consists of five chapters. The chapters are structured in a way to give a distinct view of understanding the research subject and associated theoretical material, analysis of the collected data and potential ways of overcoming the current sludge management challenges at Umgeni Water.

1.8.1 Chapter One : Introduction

Chapter 1 presents the research problem, problem statement and purpose of the study.

1.8.2 Chapter Two : Literature Review

Chapter 2 highlights theoretical background of sludge management that is a challenge for Water Services Authorities. Literature review is a fundamental process because it aids in demonstrating appreciation of the current state of knowledge on the subject. It is also a narrative of what is available on the topic by accredited scholars and researchers. The literature review will also identify controversial areas regarding the topic and assist researchers generate questions that need further research.

1.8.3 Chapter Three : Research Methodology

Chapter 3 presents a framework that was used for conducting the research. It explains sampling, data collection, analysis and processing. Data was collected by structured questionnaires schedule. It also covered the validity, reliability, and ethical considerations as well as the limitations of the study.

1.8.4 Chapter Four : Research Results and Discussion

Presentation of results , analysis and discussion of the data collected using various instruments is given in this chapter. In addition, recommendations to Umgeni Water regarding sludge management was made after the data analysis and discussion in this section.

1.8.5 Chapter Five : Recommendations and Conclusion

Chapter five consisted of recommendations to the Industry, recommendations for further research as well as illustrating the conclusion from the research findings with emphasis needs to be done to improve sludge management thus protecting the environment.

1.9 Summary

Sludge management is an essential area of interest across wastewater treatment system at Umgeni Water. Previous studies of different wastewater treatment systems have indicated the need for regular sludge removal in order to maintain treatment efficiencies. Sludge management is an emergent priority at Umgeni Water as a number of wastewater treatment systems have become critically overdue with respect to desludging. This is largely due to the lack of initial funding allocation and planning for sludge management during the design and/or take-over of treatment facilities from Municipalities. The next chapter will analyse global literature available on sludge management.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This section outlines the literature selection of wastewater treatment process which then culminates into wastewater sludge treatment process and disposal. The research will show the importance of selecting a suitable treatment process, which is an important matter before designing and implementing any wastewater treatment plant. Current wastewater sludge regulations are a constraint to its disposal options because of treatment level afforded, pathogen elimination and heavy metals content. Rojas (2012), states that sludge contents are looked at in order to identify certain challenges and opportunities in them. The pollutants in sludge content can become a problem when disposing them, hence these and their origin is highlighted.

The treatment and disposal of wastewater sludge are costly and pose an environmentally complex problem. With each Country aiming to meet one of Millennium Development Goals of waterborne toilets new sewage treatment works are constructed at the same time the environmental quality standards are becoming strict, this then poses a challenge in the world owing to the sludge generation growth (Keirungi, 2006). There is a public awareness that is constantly putting pressure on traditional disposal ways, even in the sea disposal means that are applicable for coastal areas only pressure is mounting.

According to Hall (2014), the challenge wastewater treatment utilities have is finding a technology that is innovative and cost-effective acting in response to environmental, regulatory and public demands. Reduce, recycle and re-use of waste are the desired selections for an ecological system, as opposed to incineration or disposing at a landfill site. That is not the option with sewage sludge due to a possibility of contaminants, pathogens, and faecal source. With changing water quality standards, disposal conditions for sludge and the receiving water streams are tightly controlled , the agricultural outlet may become unsustainable for water utilities due to sludge being disposed through methods offering superior security in terms of operational and financial benefits, but in the long-term might be less beneficial.

2.2 Wastewater Sludge

According to Khalid (2012) , wastewater sludge originate from different phases of the treatment process with several contents of inorganic and organic properties, both in liquid and solid phase; comprising of both beneficial and unusable elements. The beneficial elements can be utilized in various methods after the sludge has undergone a further treatment process.

2.2.1 Origin of Sludge

The world population has grown exponentially over the years, with that there is increase of potable water consumption and which ultimately becomes wastewater. Wastewater treatment is critical for both human and environmental health. The primary objective for treating used water is to obtain an effluent that can be safely returned to river streams, with minimal impact on the water quality. Increasingly, the by-products such as sewage sludge are recognized as energy sources and as a result, energy consumption is being reduced through utilization of sludge to create biogas, upgraded biogas, and/or fertilizer (Organization, 2015).
Spiller (2012), defines wastewater as having a mixture of domestic effluent having black-water (human contaminated) and grey-water (domestic contaminated) and industrial water from commercial users encompassing hospitals, industrial effluent and other urban run-off.

There are varieties of wastewater treatment systems. In some cases, final effluent may be released into the environment without any treatment. In rural communities or places where a central treatment plant is not feasible, septic tanks or on-site sewage facilities (OSSF) are used. For example, in the United States of America, approximately one-quarter of homes rely on these types of systems (Lucas, 2013). Traditionally domestic households produces large amounts of wastewater which ultimately ends up in wastewater treatment plant as large quantities of wastewater sludge (Jhansi, 2013). According to Bharadwaj (2013), the primary purpose of treating wastewater is to ensure solid particles are detached from the fluid stream. The primary stage of treatment, normally called pre-treatment is a mechanical screening that eliminates the larger particles from the wastewater. There is also a biological process where particles are removed through nitrogen and carbon. This is monitored by biological oxygen demand (BOD). Chemical treatment is also used where chemicals are added to boosts small substances to form larger particles which aids them to separate, that is called chemical precipitation. Sludge is then created when large particles combine through the separation methods. (Casey, 2006). Sludge that is formed through pre-treatment methods (mechanical, biological and chemical) is denoted as raw sludge, needing to go through further treatment.

2.2.2 Sewage Sludge Types

Effluent must be treated to required standard which is National Environmental Act (Act No. 107 of 1998), in order for it to be discharged to nearest river streams (Government Gazette, 2014). However, the residual sewage sludge needs further strict management and a number of options available for its treatment, disposal, and or beneficial re-use that needs consideration with regards to cost, viability, potential environmental impacts as well as public opinions (Smith, 2013). The features of sewage sludge vary depending on its treatment. Primary sewage sludge is the outcome of the primary settling solids from wastewater that has not undergone any treatment process. It has unfriendly features, full of pathogens, not recommended for land application (Movahedian, 2005).

Khalid (2012), states that secondary sewage sludge has undergone extensive degradation and involves a primary clarification process of biological treatment and secondary clarification.

Tertiary sewage gets produced through additional processing by chemical precipitation (use of iron, aluminum, lime and organic polymers and filtration.

The most common sludge treatment processes with related impacts on sludge properties and land application standards are briefly described in Table 2.1.

Sludge Category	**Treatment Process**	**Effect on Sewage Sludge Properties**	**Effect On Land Application Practice**
Primary	Thickening	Increases solid strength by removing water, this drops sewage sludge volume.	Reduces sewage sludge transportation costs.
Secondary	Digestion (Anaerobic and or Aerobic)	Eliminates volatile and biodegradable organic substance by changing it to soluble substance and gas. Reduction in pathogen concentrations and odour.	Reduces sewage volume, therefore lowering sludge transportation costs.
Tertiary	Alkali stabilization	Increases sewage sludge pH. Momentarily reduces biological movement. Minimizes pathogen concentrations and regulates putrescibility and odour.	High pH restraints metals when the pH levels are controlled, thus dropping heavy metal leaching and crop uptake.
	Conditioning	Improves sewage sludge dewatering characteristics. It can raise the mass of dry solids to be treated. It can improve sewage sludge compatibility and stabilization.	Sludge treated with polymer can require operational considerations at the land application site.
	Dewatering	Organic solid concentration is increased by between 15 – 40%. Handling is improved as liquid sludge is converted to damp cake.	Lowers sewage sludge transportation
	Composting	Biological activity is reduced. Degrades	Storage space needed. It can contain lower nutrient

		wastewater sludge to humus material. Sewage sludge mass is increased due to adding bulking agent.	levels than less processed sewage sludge.
	Heat Drying	Disinfects wastewater sludge. It marginally reduces potential for odour and biological activity.	Reduces volume of wastewater sludge. This lowers transportation costs.

Table 2.1 : Sludge Treatment Processes (Source : United States Environmental Protection Agency 1984)

2.3 Sludge Treatment

The purpose of sludge treatments is to:

- Decrease sludge volume to minimize internal handling and transport costs
- Lowers the number of pathogens in the sludge, and
- Prevent them from unpleasant odour.

Treatment minimizes the content of unstable reactive organic matter. Human pathogens have micro-organisms that are developed to stay in human bodies, and would not survive when excreted but can infect another human if consumed. Sludge treatment increases the biological fading off of pathogens through straining them of food and exposing them to antagonist, high temperature and or chemical environment (Evans, 2011).

Sludge undergoes different categories of treatment for economic and hygienic reasons. Sludge is treated to lower the volume, stabilize it, eliminate water content and control pathogenic organisms in it. This is conducted in different phases encompassing series of process additions in sludge handling , for example conditioning, thickening, dewatering and stabilization (Meozzi, 2011).

The process of eliminating pathogenic organisms is known as hygienization which subjects the sludge to either high temperature or a high pH. This results in high impact of minimizing pathogens. The participating micro flora that is found when composting and digesting the sludge can also pose an important function of the hygienization process. There are a number of elements adding up in the sludge and becoming contaminated to micro organisms. Hygienization is realized by numerous process treatment methods like anaerobic digestion, pasteurization, composting, and lime stabilization (Christopher, 2013).

2.3.1 Conditioning

Conditioning of wastewater sludge includes conversion of its format to remove water content. This improves additional process treatments like thickening or dewatering thus limiting the fine particle content of the rejected water. Conditioning is through mineral agents by inducing chemicals like lime or salts or organic compound that has diverse formation of polymers. Also thermal conditioning can be used whereby sludge is heated to a range of 150-200ºC in 30 to 60 minutes period. Heating to a range of 40ºC or 50ºC can also be explored resulting in a partial thermal conditioning (Dahlström, 2005).

2.3.2 Sludge thickening

Sludge thickening is whereby the solids portion of the sludge are concentrated by reducing its water content. This assists to reduce the cost of digesting, storing, transporting and drying sludge. Sludge thickening is normally achieved using gravity settlers, dissolved air flotation, centrifuges, gravity belts and rotary drum thickeners. These processes can occupy a substantial amount of space within the wastewater treatment plant, require careful monitoring and control, and utilize large amounts of chemicals (Kandasamy, 2011).

2.3.3 Dewatering

The water content in sludge is reduced by dewatering it by various techniques. Mechanical separation is the most common method, and employs force which can either be gravity or pressure. Selection of separation methods is not always important when deciding the type of sludge to be used. Each sludge has unique dewatering properties, resulting in the water binding strongly to the solids. Proper classification of those properties is important as it gives valuable guide for evaluation of sludge dewaterability. Capillary suction time (CST) and specific resistance to filtration (SRF) are additional methods that can be used to classify the dewatering properties of sludge. However no conclusive results can be made when it comes to full compliance regarding predictions of dewatering efficiencies (Tastu, 2009).

2.3.4 Stabilisation

The sludge generated has some water content which makes handling it a challenge in terms of volume. There is then a need to thicken it in order to reduce the volume and cost for the treatments. Thickening methods vary, depending on the type of the sludge with an aim to eliminate its excess water. Flotation for chemical and biological sludge is the preferred technique, while for primary sludge the preferred method is through different sedimentation methods. Centrifugation is used for thickening or dewatering purposes (Grazia, 2011).

2.4 Storage

Storage is the method of keeping the sludge in a particular area dependent on whether it spreads or is used elsewhere. The critical area for storage of sludge is to ensure there is a balance between new sludge coming and removal of current one. Treatment works can store sludge for short-term within their primary unit system processes like clarifiers and aeration tanks and within secondary sludge treatment system in the thickeners and digesters. Sludge storage can be internal to the wastewater treatment plant or if centralization is preferred then it is stored externally.(Dahlström, 2005).The selection criteria of the appropriate method of storage relies on sludge condition, i.e. whether it is in the liquid or dewatered state depending on dryness content. During storage, they could be a development of mal-odours, due to anaerobic conditions, which can be mitigated by stabilization (Bresters, 1997).

2.5 Transportation

There is some transportation of sludge from the point where it is generated to the disposal point or where it will be used, via some form of mode. Sludge transportation is normally a substantial amount of operational costs for medium size treatment plants. Transportation modes of sludge can be by specialized trucks, tractors and pipelines (Bresters, 1997). eThekwini Metropolitan uses mainly pipeline disposal of sludge to the sea, known as marine disposal. (Olivier, 1998).

2.6 Disposal

Worldwide environmentalists are tightening sludge regulations. This then limits sludge disposal alternatives requiring improved process treatment level to be provided, pathogen removal, and metals content. Reasonable disposal options for sludge includes reusing the product, by land application, stabilization, composting, and pelletizing (Bloetscher, 1999).

In Sweden and Europe sludge is classified as waste thus disposal follows the route of waste hierarchy. The important part is that it should be treated in such a way that there is recycling of nutrients. Other uses of sludge are energy generation and material use i.e. building blocks or bituminous tar. The last choice is to dispose of it without using nutrients, energy or material (Rizzardini, 2014).

2.6.1 Deposition

Deposition is a process of transporting treated wastewater sludge to a Municipal landfill site where it is dumped. It is then mixed with other waste materials. There are restrictions in the design of landfill site with an aim of preventing ground water leakage from the landfill (Andreoli, 2014). The ground water leakage from landfill site is hazardous to environment containing heavy metals and other pollutants. Methane and carbon dioxide gases are generated by landfill due to sludge disposed there and they are harmful to the atmosphere. Some landfill sites collect these gases and the energy content utilized. There is a potential risk of increasing pathogens if the sludge was not sanitized in its previous treatment. Sludge is deposited without making use of nutrients, energy or material (Dahlström, 2005).

2.7 Incineration

Cossu (2013), states that incineration has two primary purposes namely reducing the volume of the dry sludge and to produce a sterile non-toxic residue that has no volatile substance. It gives a secure substitution when handling challenges of land scarcity accessible for waste disposal and it also assists to salvage some of the energy in the combustion process.

Sludge needs to be properly treated and dewatered before being incinerated. To incinerate the sludge without additional fuel, 40% of dry solid contents must be met. The normal dryness content of dewatered sludge is up to up to 25%. The calorific value of wastewater sludge is in the range of 10-20 MJ/kg dry solids. When sludge is incinerated, it is possible to harvest the energy in the sludge. Harvested energy can be in the form of heated water or air and can be used for either heating houses or swimming pools (Dahlström, 2005). Although incineration reduces sludge , the end product of that burned sludge is ash with approximately 30% of the dry solids. Ash is categorized as hazardous because of heavy metal content within it, and it attracts extra expense to dispose in special landfill sites; however the ash can be used as construction materials (Karimi, et al., 2011). For example, in Yokohama, Japan, 110000 m^3 of better quality soil are generated each year using 7000 m^3 of wastewater sludge as one of ingredients, tests showed end product contain similar features as sand from a pit used for road construction as backfill material (Ronald, 2010).

2.8 Global Trends In Sludge Management

Wastewater treatment and the management of sludge produced are worldwide matters, with increasing challenges, that need to control the fears of stakeholders, whether it is the operator or general public. It is known that humans produce excreta and urine, which needs to be contained and managed to protect public health and environment (Kurbiel, 2012). In the low income countries there are no estimates of quantities of wastewater sludge generated. In the developed countries there are records of indicating estimates on wastewater sludge generated, recycled or disposed. Table 2.2 displays this data (LeBlanc, 2010).

Country	**Estimated Sewage Sludge Production**	**Country Population**	**Country Level**
USA	6 514 000	298 444 000	High Income
Germany	2 000 000	82 422 000	High Income
China	2 966 000	1 313 974 000	Middle Income
Brazil	372	188 078 000	Middle Income

Table 2.2 : Estimates of Sludge Production (Source: Wastewater Sludge, And Biosolids Management: LeBlanc , 2010, pp 55)

The data indicates that high income countries have comprehensive infrastructure for wastewater treatment (e.g. secondary and tertiary treatments) and generate high volumes of wastewater sludge per person. The middle-income countries, which are less developed in terms wastewater treatment infrastructure, generally produces less wastewater sludge per person. None of the low-income countries have data on wastewater sludge generation; this is due to underdeveloped treatment and management strategies. There is an intense correlation between the affluence of a nation and commitment to developing an encompassing wastewater infrastructure with sludge management techniques. This correlation is noted through Gross Domestic Product per capita (GDP/capita) measuring the individual's wealth . High income countries can afford acceptable sanitation for all citizens, which results in a shift from public health concerns to environmental concerns (Blanca Jiménez, 2008).

2.8.1 High Income Countries

High income Countries selected for this study are Germany, Australia and United States of America. This is based on Gross Domestic Product (GDP) per capita results issued by International Monetary Fund (IMF) and the World Bank for year 2015. All three countries are within the Top 20 of the index results, the highest between three (3) being United States at number ten (10). These countries have refined their wastewater sludge Policies and Regulations. National and Provincial Governments ensures Policies, regulations and best management practices are complied with. Regulatory compositions tend to be complex and normally a high level of enforcement and compliance is required (Karius, 2011).

All human excreta is waterborne in these Countries, which then requires a collection system and treatment plant. The current motivating concerns are numerous, like additional control of pathogens and reduction releases of unwarranted nutrients, elements and chemicals to the environment. Wastewater sludge is considered to have a beneficiation component in these Countries, hence Government Policies encourage reuse. From the research conducted by them results of using wastewater sludge on soils and for electricity generation being basis for current further feasibilities in sludge re-use. There is a continuous refinement of traditional technologies and the outcomes developed into best management practices that are being shared throughout the world. Dewatering technology has advanced to a stage that makes it more efficient with the use of centrifuges, screw presses, electro-dewatering, or advanced solar drying technologies (LeBlanc, 2010).

Emphasis for wastewater sludge management operators is not necessarily the same as the ordinary public. In the developed Countries, the environmentally conscious public members have a significant responsibility in steering wastewater sludge management Policy and Regulation. There were widespread concerns recorded about chemical residues and heavy metals in the environment. These challenging tendencies form the basis for discussions on wastewater sludge management (LeBlanc, 2010).

Disposal of sludge in landfill site globally is being reviewed because of environmental implications. In Czech Republic, there is low social acceptance of landfilling, although it is the only dominant way of handling wastewater sludge. In Bulgaria only Municipal landfill disposal of sludge has been used for a longtime, however standards and regulatory arrangements for wastewater sludge reuse to soils are being developed which will have adverse implications. These countries are ranked 37 and 62 respectively, emphasizing the need for proper sludge management.

The European Union has a plan of phasing out the use of Municipal landfill sites of organic wastes, because of greenhouse gas methane emissions having potential health risks to society. Current environmental regulation seeks to minimize dependence on landfill sites for sludge disposal. In Australia, Municipal landfill disposal is not taken as a beneficial use of sludge hence programs are in place to do away with landfill disposal. There is a strong initiative from the public in United States of America to have sustainable management of wastewater sludge and re-use of nutrients and organic substances for long-term wellbeing of agricultural lands (Baietti, 2006).

2.8.2 Middle Income Countries

South Africa and Namibia represents middle-income countries in this study, Middle East is represented by Iran, Jordan and Turkey. Asia is represented by China and Russia and lastly Latin America it’s Brazil, Colombia and Mexico. Although China and Brazil are developing countries but due to their high population 1.3 billion and 205 million people respectively they do match both criteria. Their GDP/capita ranges from 102nd (Jordan) to 52nd (Turkey) as per IMF 2015. There is wastewater treatment infrastructure to certain level of service. These infrastructures serve mainly urban population. Majority of wastewater treatment is done at primary level, with secondary treatment implemented in urban areas. In rural areas, there is still use of on-site sanitation methods, while others have partial or no access to sanitation at all. The expected trend of sanitation development, which is critical to any Country's development, and provides hope for reduction of diseases and improving public health; this generates more sludge that will need to be managed. There is an increasing challenge in the Middle-income countries regarding final destination of wastewater sludge (Kellis, 2013).

China is becoming a powerhouse in the world when it comes to technological development. In 2007 China released their New Regulations that control standards for concentrations of contaminants in wastewater sludge and preferences for its management. Four types were identified namely, land use, Municipal landfill sites, production of usable materials (recycling) and incineration.
China is adopting the use of sludge in agriculture as their common management of sludge, owing to its operational simplicity and affordability. Incineration is not the preferred way because of the cost of sludge drying, however, the Regulations are tightening for land application and there is less random dumping (Dahlström, 2005).

In Brazil and Mexico, research is at an advanced stage on usage of sludge on land. In both Countries, the projects are indicating merit and have manageable risks of this method for managing wastewater sludge. In both these Countries, no data is available of the total quantities of sludge treated and also majority of the Treatment Plants have no sludge treatment systems in place. This raises concern due to the potential pollution of water sources and soil. This gets done to avoid high cost of sludge treatment system (Rojas, 2012).

In Middle Eastern Countries there are exercises being conducted in modeling a wastewater sludge management and regulatory system. This exercise aids in developing programs for materials management and regulatory controls necessary for managing wastewater sludge. Municipal wastewater sludge is not mixed with industrial waste in in these Countries, which is a positive idea. The most common sludge management are digestion, lagooning, composting, and landfilling (Seethoram, 2013).

The focus on Namibia is at Walvis Bay, which is the second largest city with a population 60,000. This city has system of anaerobic digestion and drying beds with sludge beneficiation for city parks, sports fields, and gardens (Botha, 2011).

South Africa is ranked 68th in GDP/capita and is one of the highest in African Continent. Its development has involved substantial wastewater treatment infrastructure in urban areas. Similarly to the rest of Africa, informal settlements in semi-urban parts of the Country still encounter challenges due to inadequate sanitation in place. There is a political-will to improve expenditure on wastewater infrastructure, which is in South Africa's favour. This is also witnessed through Department of Water and Sanitation's program of Green Drop Awards, awarded to the best performing Municipalities and Water Boards in wastewater treatment. South Africa has a broad spectrum of sanitation programs from areas where none exist to complex modern urban systems having challenges of current sludge management strategies (Snyman, 2007).

2.8.3 South African Trends

Snyman (2007), points out that South Africa has approximately 800 wastewater treatment plants, treating between 5 000 000 to 7 000 000 m^3/day. Table 2.3 indicates the split of wastewater treatment plants in South Africa against their treatment capacity. The details on sludge handling practices in small treatment plants is not available, hence there is suspicion that the sludge is accumulating on sites.

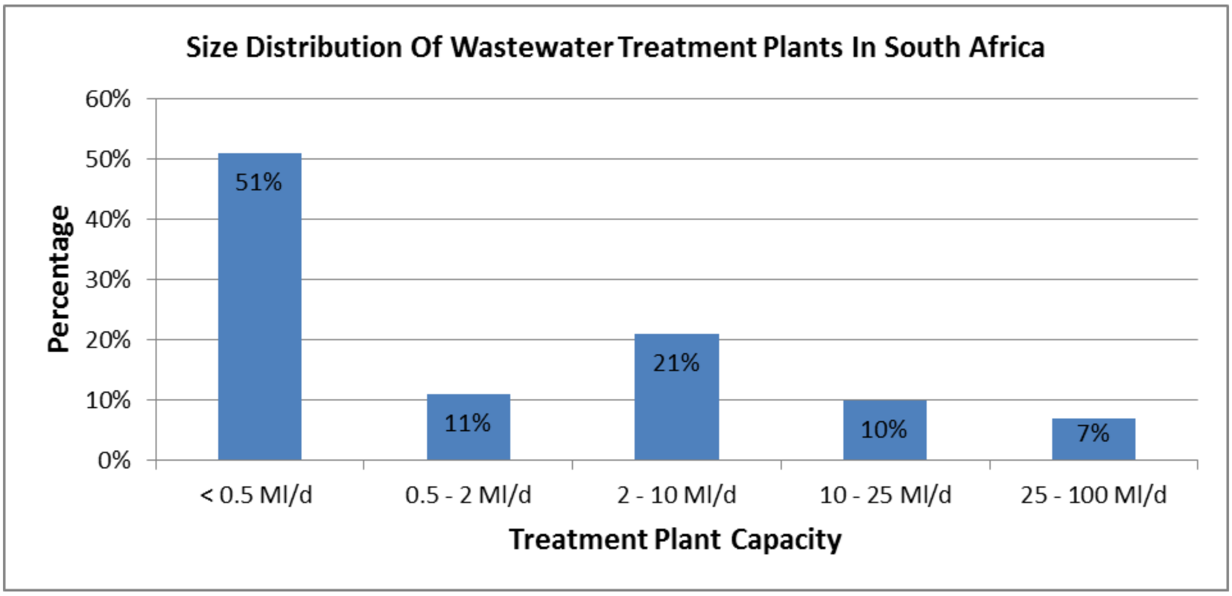


Table 2.3 : Split Of Wastewater Treatment Plant (Wastewater Sludge, And Biosolids Management : LeBlanc , 2010, pp 55.

According to S.R. Smith (2013), there is an advancement in technology for treatment of wastewater sludge which has gradually adopted the needs of public health protection, elimination of solid contents and oxygen intense composites, and removal of nitrogen and phosphorus thus protecting receiving water bodies from eutrophication. There are various range of reputable treatment technologies used by Wastewater treatment including:

- Suspended growth biological treatment processes, identical to activated sludge treatment plants;
- Fixed film biological treatment processes, similar to bio-filters/trickling filters and rotating biological contactors;
- Integrated pond treatment technologies, similar to anaerobic ponds, oxidation ponds

Table 2.4 shows the split of sludge generation for wastewater treatment plants in South Africa. The major part of sludge is anaerobically digested (primary and humus sludge) and activated sludge is estimated to be 25%. Blended sludge consists of primary and activated sludge blended during digestion.

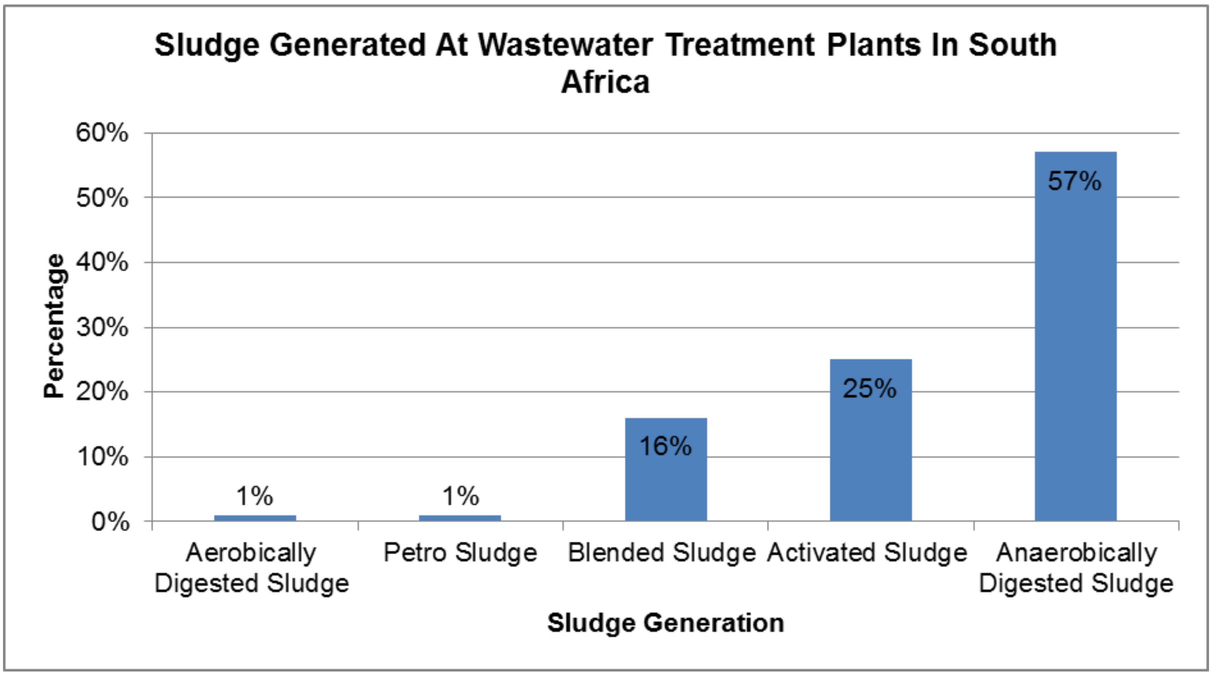


Table 2.4 Wastewater Sludge In South Africa

In South Africa most of wastewater treatment plants do not have further treatment facility of the sludge, in comparison to conventional anaerobic digestion and activated sludge aeration. Final disposal methods are dictated by on-site disposal comprising of direct land application or keeping the sludge on site (Snyman, 2007).

2.9 Umgeni Water Wastewater Treatment

Umgeni Water operates and maintains nine wastewater treatment plants with capacities varying from 0.5Ml/d to 100Ml/d, as depicted in Table 2.5 Umgeni Water has no set standard on the use of technology for sludge management as the treatment plants utilized a varied standard (Umgeni Water , 2015).

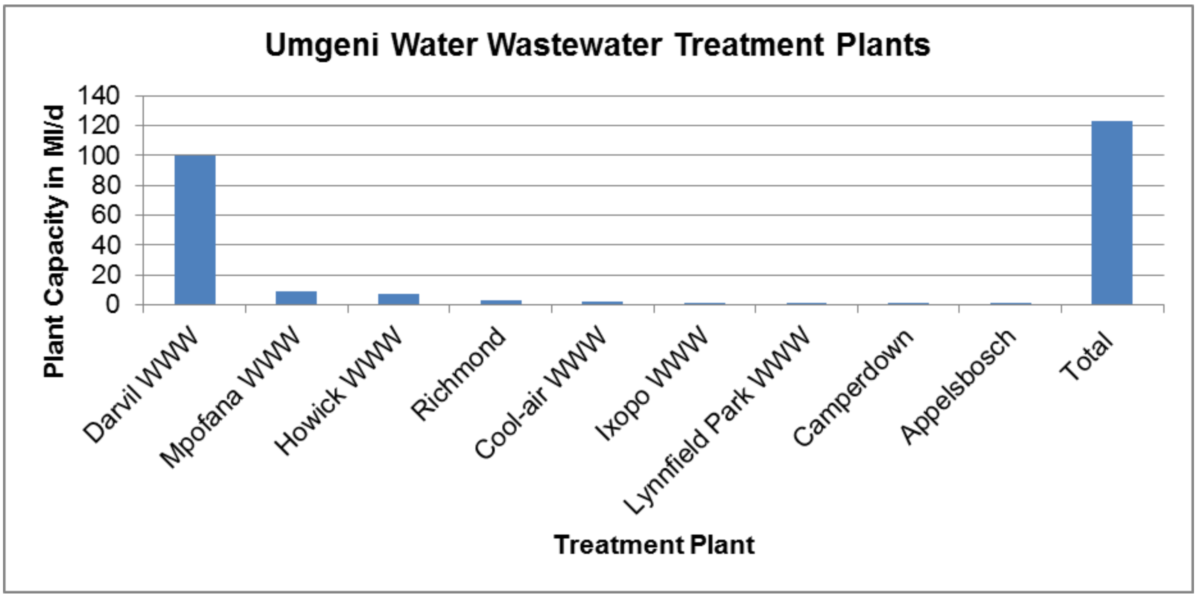


Table 2.5 Umgeni Water Wastewater Treatment Plants (Umgeni Water , 2015)

The largest treatment plant, Darvil, uses Anaerobic digestion with extended aeration. This practice has been used in municipal wastewater sludge since the early 1900s and is the most widely used sludge treatment method (Alvarez-Cohen, 2000). The benefits of using anaerobic digestion are energy generation, nutrient control, waste balancing, and decrease of pathogen. It further positively influences the reduction of greenhouse gas emissions, both directly and by offset (Bywater, 2009). The sludge for this treatment plant is disposed agriculturally through turf grass planting in a 56Ha area next to the plant.

Howick and Mpofana wastewater treatment plants use mechanical dewatering as part of sludge management. This method is normally used if the wastewater sludge is to be disposed of in a Municipal landfill site, owing to it being operationally and economically viable. The dewatering process increases the solid content and reduces the volume of sludge (Kandasamy, 2012).

Howick sludge is disposed of at a nearby landfill site owned by Local Municipality. The landfill site is not licensed to accept this type of waste. There have been instances where the landfill site refused to accept the sludge, sighting that it has odour and the water content was high. This resulted in the sludge being stockpiled on site for over six months. Mpofana sludge was disposed at a nearby landfill site but, similar problems to Howick were experienced and the sludge has been stockpiled onsite for almost two years.

Department Of Water and Sanitation Sludge Guidelines for the utilization and removal of Wastewater Sludge does not promote stockpiling of sludge onsite. The guidelines ensures that when removal of sludge is required , it is categorized and regarded as a waste and need to be managed in that way. Environmentally, these two sites faced constant complaints from nearby residents due to generation of Psychoda flies and odour.

Richmond wastewater treatment plant uses sludge lagoons for their sludge management. Although this method is economical in terms of operational costs, there are long-term negative environmental effects, due to pollution of ground water through leachate. The current lagoons are unlined and they have never been through the remediation plan in order to ensure environmental compliance. Umgeni Water is not in favor of sludge lagoons because of its environmental and safety concerns (Umgeni Water , 2015).

Cool-air treatment works sludge is stockpiled on-site for almost three years. The nearby sugarcane farmer has requested the sludge but due to it not being classified, he has not been able to receive this. The Classification of sludge is critical since there are conditions for the agricultural application of sludge (Norris, 2015).Appelsbosch, Lynnfield Park and Camperdown sludge are stockpiled on-site as there are no other correct disposal channels for them. On ad-hoc basis the sludge is taken to Msunduzi landfill site. This is not a sustainable option as there are studies of that landfill site running of space and also it is not licensed for this type of waste (Norris, 2015).

Volume 3 of the Sludge Guidelines specifically deals with legal conditions for wastewater sludge removal on land (on-site and off-site), co-disposal on landfill site and disposal to the oceanic environment. It encourages the beneficial utilization of wastewater as depicted in Figure 1 below with disposal as being the last option (Herselman, 2009).

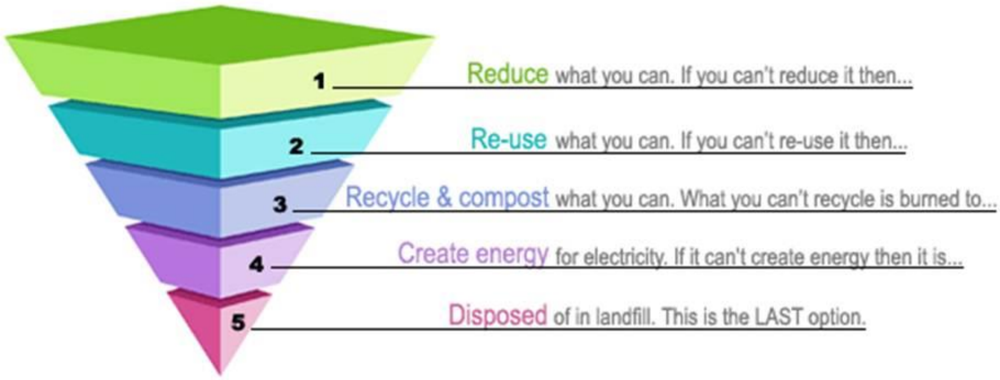


Figure 2.1 – Hierarchy Of Waste Management , 2011

Therefore, wastewater treatment plants need to provide proof of why they chose the beneficial way of handling the sludge. There should be feasibility studies conducted to implement sludge hierarchy options together with strategies to improve sludge quality, allowing beneficial use. If disposing the sludge is the only option available for management of sludge, then sludge is classified as a waste in terms of National Environmental Management Act (Herselman, 2009). Limitations and requirements should be implemented to protect the receiving water streams from possible contamination by wastewater sludge. The restrictions and requirements are more rigorous with declining sludge quality and the exposure of the receiving water streams to contamination (Snyman, 2007).

If one looks at Umgeni Water treatment plants, there is evidence of no uniform methodology on sludge management; some of the disposal options might be affected by changes in Environmental Legislation. When that happens, penalties might be imposed to Umgeni Water. The only approved methodology of disposal currently in use is the dedicated land disposal where the disposal site is within the boundaries of the treatment plant, this is Darvil treatment plant (Westgate, 2013).

2.10 Sludge Classification

Classification of wastewater sludge is vital prior to the sludge disposal process because of risk of toxic elements accumulating on the ground. Furthermore, this poses potential health hazards due to pathogens in the wastewater sludge. The content of the wastewater sludge depends on primary pollution load of the treated water, the treatment process applied both to wastewater and sludge. Sludge treatment influences its composition (Khalid, 2012).

Sewage sludge can display differences in their properties depending on the source and prior treatment, however, based on history, their characterization only provides qualitative information. Many limits have been initiated and tests improved to determine detailed properties of sludge with regards to particular methods of treatment (Bresters, 1997).

Conventional categorization limits can be arranged in physical, chemical and biological limits:

- Physical limits details the information on sludge processing and handling.
- Chemical limits encompasses both the presence of nutrients and toxic compounds, making it essential for agricultural purposes.
- biological limits highlights the microbial activity and organic/pathogens existence, thus permitting the safety of use to be evaluated.

2.10.1 Umgeni Water Sludge Classification

According to a report by Northeast Colorado (2011),the purpose sludge classification is to introduce and conduct a public health program that is aimed for necessary or desirable protection of public health against diseases that could be as a result of coming to contact with hazardous sludge and preservation of the environment. Umgeni Water in 2015 conducted the classification of sludge at eight wastewater treatment works. The terms of reference for the project was to classify wastewater sludge in terms of the Department of Water and Sanitation (DWS) guideline series Guidelines for the Utilization and Disposal of Wastewater Treatment Works Sludge (2006) Volumes 1-5 (Norris, 2015).

2.10.2 Sludge Classification Results

The sludge was assigned a label based on the outcomes of the analysis. According to the analytical data, the majority of the classification was C3a which describes an unstable sludge with poor microbiological treatment but with low metal and organic pollutants. Cool Air and Camperdown (B3a) showed a moderate biological contamination with unstable sludge. Finally Appelsbosch and Mpofana (C1a) achieve a higher stability as they showed a vector reduction of over 38%. Table 2-2 indicates the sludge classification results for Umgeni Water.

Site Name	Classification
Appelsbosch	C1a
Cool Air	B3a
Mpofana	C1a
Howick A	C3a
Howick B	C3a
Ixopo	C3a
Richmond	C3a
Camperdown	B3a

Table 2.6 : Umgeni Water Sludge Classification (Norris, 2015)

2.10.2.1 Sludge Management Options

Based on the classification outcome, each beneficial use was assessed. There were no unrestricted consumptions identified, hence restrictions and requirements are outlined.

2.10.2.1.1 Appelsbosch and Mpofana WWTW

The beneficial use of this material is limited by the low nutrient status of the sludge which varies from 0.56% - 1.4% N (Ammonia), 0.12% - 0.28% P (Phosphorus) and 0.26% – 0.06% K (Potassium). Restrictions apply to the microbiological content and vegetables which are eaten raw, touched or are below the sludge and harvested parts underneath the soil surface may not be cultivated in these soils. The low metal content results in other uses being preferred and as such the sludge is qualified in terms of the pollutant class. The microbiological and stability presents no issues with regards to the disposal of the sludge (Norris, 2015).

The disposal options require additional analysis of sludge samples using a Toxicity Characteristic Leaching Procedure (TCLP). There is no beneficial use commercially available for this sludge due to microbiological risk. Leaching is a natural activity by which water soluble materials ,are washed out from soil or wastes. The leached out chemicals, are then called leachate(s) and they could be a source of contamination of surface and ground water (Chezom, 2013).

2.10.2.1.2 Howick, Ixopo and Richmond WWTW

Due to stability, these sludges cannot be used in agricultural applications. The low metal content results in other uses being preferred. The microbiological and stability present, result in qualified suitability of the sludge. The landfills do not accept unstable sludge and the microbiological risk results in restrictions or monitoring requirements. No beneficial use is available for this sludge due to microbiological risk and stability acceptability (Norris, 2015).

2.10.2.1.3 Cool Air and Camperdown WWTW

The low metal content results in other uses being preferred and as such the sludge is a qualified no in terms of the pollutant class. The landfills do not accept unstable sludge and the microbiological risk results in restrictions or additional monitoring requirements (Norris, 2015).

2.11 Impacts of Current And Future Sludge Management

2.11.1 Waste Pyramid

Wastewater sludge generation will never be escaped since it is part of a human value chain, hence legislation on effluent quality standards worldwide are being made stricter to reduce nutrient emissions. Also sludge production cannot be decreased because of its human origin, technologies implemented only reduces its mass for disposal. Use of wastewater sludge on agricultural land to exploit the resource’s usefulness of organic substance and nutrients remain the most preferred method because it reduces the use of incineration where possible (Hall, 2011).

2.11.2 Financial Implications

The disposal of sludge entails positive and cautious management, but the handling of disposal is dependent on associated costs with regards to circumstances. The common trend previously in developed Countries has been to make sludge disposal easy, while complying with legislation; there has been significant increase in European Union (EU) and national environmental legislation (Bharadwaj, 2013).

There is a need for developing a cost-effective sewage treatment process that does not transfer high amount of the pollutant load into a concentrated wet solids side-stream requiring off-site disposal. The wastewater treatment plants will remain functioning as sludge factories with constant and unstoppable output. The end quality of sludge will also remain not entirely controllable due to type of wastewater being received. This has no permanent long-term outlet and generally requires processing, transport and disposal costs of which at is sometimes estimated to be half the total cost of operating the treatment works. Sludge is frequently considered as the main problem of water pollution control (Hall, 2014).

2.12 Summary

Fulazzaky (2013), state that developing countries, especially South Africa is being confronted with increased challenges of sludge management due to increasing water demands from population growth, improved standard of living , urbanization as well as economic and industrial developments. These challenges of sludge management are due to increased quantity and the extent of sludge handling technology method with respect to operating problems. Umgeni Water is not excluded in this growth as it has acquired additional wastewater treatment plants from Water Services Authorities.

Selection of a suitable disposal method is centred upon the classification of the sludge according to Sludge Guidelines, whereby classification is divided into three categories namely the microbiological class (A, B or C), stability class (1, 2 or 3) and pollutant class (a, b or c). Hence sludge can be classified B1a' type. The guidelines thereafter refer the type of sludge to the ideal treatment method by choosing an appropriate management (Snyman, 2007).

Costs are a critical component of choosing sludge management. They may differ subject to local circumstances and capacity of the treatment plant. In order to identify the correct evaluation of different options for sludge treatment and disposal, a consideration of annual costs, which are guided by three factors, namely capital outlay, operating costs and disposal or re-use of the sludge (Meozzi, 2011).

Following on from here, the next chapter will discuss the research methodology undertaken to explore sludge management options for Umgeni Water incorporating best practices.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

Most research textbooks symbolize research as a multi-stage procedure that one need to follow in order to have a comprehensive research project. As Saunders, Lewis and Thornhill (2009,p10) pointed out the exact number of stages differs, but normally encompass formulating and expounding a topic, literature review , research design, data gathering, data analysis and writing up .Research is a hands-on action that requires responses from participants. Business research aim is to solicit information about business in a methodical way and hence provide management with information to aid informed decision making. Research methodology affords an instrument for management to gather information needs of important decision makers. Business research is a management instrument that organizations utilize to mitigate indecision. Business research critically define significantly the crucial basics that business research should obtain and under what guiding principles this research design and methodology will be undertaken (Coldwell, 2004).

It is crucial to carry out a systematic analysis of detected information so as to obtain answers with a view to introducing suitable differences for effective sludge management philosophy (Bougie, 2015). This research study followed a structured framework with a set of philosophies and utilised procedures, methods, and techniques which have been tested for validity and reliability. The study was intended to be impartial and objective. This chapter comprises of discussion on strategies for research design, research methodology, sampling strategy, data collection instruments, and data analysis used.

3.2 Research Design and Rationale

Research design details a plan and strategy of how the outcomes of the study will be aligned to research questions or problems. This plan is an encompassing program of the research. It contains a framework indicating what the researcher's role is from writing the hypotheses and to operational consequences to the final analysis of data (Kumar, 2014).

It can be either qualitative, quantitative or mixed method. Differences in philosophical perspectives in each paradigm combined with the aims of a study, determine the focus, approach and mode of enquiry which, in turn, determine the structural attributes of a study design. Qualitative research focuses on the understanding, explaining, exploring, discovering and clarifying situations, feelings, perceptions, attitudes, values, beliefs and experiences of a group of people. It is then a subjective research and requires naturalistic and interpretive approach, for example collecting qualitative data through interviews and questionnaires (Creswell, 2014).

Harwell (2014),defines quantitative research as being based on conventional scientific methods, that generate numerical data and seeks to establish causal relationships or association between two or more variables, using statistical methods to test the strength and meaning of the relationships. The positivist ontology according to Edirisingha (2012) , considers that the world is external and that each research has a single objective reality to any or situation irrespective of the researcher's perspective or confidence. Positivist researchers stay removed from the participants of the research by building a space, which is important in continuing to be emotionally impartial to make pure differences between reason and feeling. The goal of positivist researchers is to make time and perspective free simplifications.

The study looked at the technology used for sludge treatment, volumes of sludge, type of sludge and operating conditions of the area where sludge was produced by each treatment works. Available wastewater sludge management options were also looked at as well as the financial implications of proposed management options. Conclusions were drawn centred around on the business case.

Research design is not linked to any specific technique of collecting data or any form of data. Any research design can as standard, utilize any form of data collection method and can be either quantitative or qualitative or mixed method. Research design signifies the format of a survey focussing on the logical content rather than a logistical one (Marshall, 2006).

3.2.1 Methods and Instruments Of Data Collection

There are two main methods for collecting information about a condition, person , problem or occurrence. Data for this study was gathered through two main methods. These are primary and secondary data. Secondary data refers to information gathered by other researchers for some other purpose. They comprise raw and analysed data. Secondary resources can be documents for example earlier research conducted by government departments or private companies. Secondary data include both qualitative and quantitative data. In primary data collection, the individual researcher conducting the study collects the data through qualitative, quantitative methods and mixed methods. This data is unique to the researcher and until it is published, no one else has access to it (Kumar, 2014).

In conducting this study primary and secondary sources of data were used to obtain the study objectives. The questionnaire was the method of data collection issued to a target population. The questionnaire was designed to focus on these themes viz. demographic information, wastewater sludge knowledge, sources of sludge, sludge treatment process. The questions on demographic information focussed on the age of the respondent, length of service in the organization and highest qualification. These were such to assess the relation of understanding in response to technical dimensions that followed.

The questions on wastewater sludge knowledge measured the understanding towards wastewater sludge with emphasis on the environmental protection. Sources of sludge questions were assessing the understanding of sources of sewage inflows that results in sludge, mainly whether the inflows were domestic , industrial and or combination that the participants treatment works receives. Sludge treatment process focussed on whether Umgeni Water has a standard treatment process across all treatment plants or has a variety.

3.2.1.1 Primary Sources Of Data

A closed-ended question is method of restricting respondents with a list of answer alternatives to choose from. Usually the answers are presented in multiple choices, with a single answer or more than one , but can also be in scale format, where participant decide to rate the situation along the scale continuum, similar to Likert questions (Bougie, 2015).

Closed ended questioning for the study was chosen because it is easy to analyse since choices are given. Every answer was given a number to allow statistical interpretation. The questions were more specific thus communicating similar meanings. Access to primary data was not restricted as the researcher is employed by Umgeni Water in the wastewater department. Actual treatment technologies and sludge disposal strategies were made available so as to achieve the targets of the study.

3.2.1.2 Secondary Sources Of Data

Within this study any secondary data source was assessed for opinion and correctness to ensure the understanding is valid for the study. Secondary sources include journals, internet, books (Bukowska, 2009). For literature review, international conference papers, journal articles and other dissertations indicating best practices enabled information needed for achievement of the study objectives (Coldwell, 2004).

3.3 The Research Philosophy

Kumar (2014), states that a research study is either exploratory or formal The critical differences in these philosophies is the intensity of structure and the pressing intention of the study. Exploratory studies incline towards unrestricting structures with the aim of uncovering future research responsibilities. The prime purpose of exploration is to create hypotheses or questions for further research (Schindler, 2013).

The research design creates the master-plan for the gathering, measurement, and evaluation of data. It creates a plan and structure for investigation envisaged to solicit responses to research questions. The degree to which this research design was formulated was exploratory study. The research was quantitative because it collected data using a structured questionnaire which concentrated on specific research questions. It is a positivist research method. This includes low level of contribution from the researcher and high number of respondents (Edirisingha, 2012). The results were deliberated using both qualitative and quantitative tools.

3.4 Data Collection Methods

3.4.1 Research Setting

Research setting discusses the area where data is collected. The study focused on the nine (9) wastewater treatment plants that Umgeni Water owns and those being operated and maintained on behalf of uMgungundlovu District Municipality and Msunduzi Local Municipality. The treatment plants are situated in the Midlands Region of KwaZulu-Natal (Umgeni Water , 2015).

3.4.2 Target Population

Population is a collection of persons, objects, or items from which samples are taken for measurement. The target population covers participants of a group that a researcher is concerned in studying. The outcomes of the study are uniform to this population, because they share the same behaviours (Marshall, 2006).Nine (9) wastewater treatment plants formed the target population from which 50 participants were selected. These wastewater treatment plants have varying capacities and are also exposed to differing operating conditions (Umgeni Water , 2015).

3.4.3 Sampling Techniques

A sample is a sub-section of the population, which is chosen to partake in a study (Creswell, 2014). Establishing a sample size is a critical concern because having a large sample size may be time consuming and needing both resources and funds, while a small sample size may lead to erroneous results (Delice, 2010).

Saunders (2009),defines two general types of sampling namely the probability and non-probability. Probability sampling, the likelihood of any one member or element of the population being selected, is known. In non-probability sampling, the precise number of elements in the population is unknown as a result the likelihood of selecting any one member of the population, remains unknown.

Simple random	There is an equal chance for each population member of being chosen into the sample.
Systematic	An element of the population is selected at the beginning with a random start and following the sampling fraction selects every element.
Stratified	Population is separated into sub-populations or strata and simple random sample on each strata is used.
Cluster	Population is separated within heterogeneous sub-groups.

Table 3.1 : Probability Methods (Source : Barreiro, 2014)

Having identified the wastewater section of Umgeni Water as the subject of investigation for sludge management, the selection of participants had to be conducted.

Some of the pertinent questions that were asked at this stage were:

- Who are the participants?
- Where are the participants from?
- How many participants should be included in the sample?
- How should these participants be selected?

This group comprised of Operations, Engineering and Scientific Services. They were selected independently on a random sample from each stratum (one random sample from Operations and another random sample from Engineering and Scientific Services).

The wastewater Section of Umgeni Water has a staff complement of 90 staff members. Over and above that are the support Sections namely Asset Management, Engineering and Scientific Services with 20 dedicated staff members in total. The total population in the wastewater plant is therefore 110, however, a sample size was limited to 50 participants (Umgeni Water , 2015).

Every sampling technique has advantages and disadvantages; however the best option, in this case, was Stratified Random Sampling. Stratified random sampling assisted in drawing a random sample, to allow the sample to be representative of the population on key characteristics of interest (Bougie, 2015).

3.4.4 Research Instruments

To obtain information on the sludge management for Umgeni Water, a set of questionnaires was used. Questionnaires are attached as Appendix A. The following aspects were focussed on to allow a fare distribution of skill and experience.

- **Demographic section:** The first section, consisting of questions 1 to 3, was aimed at drawing up a profile of participants in terms of the duration that the participants have worked in wastewater, their age, and their highest qualification.
- **Wastewater sludge knowledge:** This focussed on the participant's knowledge of sludge management and its impact on the environment and the legislations thereof.
- **Sources of sludge:** It was critical to understand the origin of the influent entering the treatment plants so that the appropriate technology can be implemented as well as understanding how to handle the sludge thereafter.

- **Section D of questionnaire:** This covered sludge treatment processes from preliminary operations of sludge, thickening, stabilization conditioning, disinfection, dewatering, and disposal. There are various sludge treatment processes implemented for each treatment plant. Understanding these treatment processes ensured that the proper planning is in place.

3.5 Ethical Considerations

Saunders (2009), states that ethical matters will arise as the research is being planned and the researcher seeks to contact Company and individuals to collect, analyse and report the data. In the structure of research, ethics guides the correctness of the behaviour in relation to the rights of those who become the subject of the study, or are affected by it. In any research it is unethical to gather information without awareness of the participants, their preparedness and stated consent.

In this research, the purpose and intention of it was explained and how it might affect them directly or indirectly. It was also explained that the consent was voluntary. Permission to conduct the research within Umgeni Water was granted by the General Manager – Operations.

3.6 Validity and Reliability

The two major criteria to be considered when appraising a measurement tool are validity and reliability. Validity quantifies what actually needs to be measured, this incorporates face validity, content validity, criterion validity and concurrent validity (Schindler, 2013).

The content validity of the questionnaire was achieved by structuring the measurement questions in the questionnaire in such a manner that they adequately covered the content of investigation. Criterion validity was achieved by structuring the questions in such a manner that predictions could be made.

Reliability is concerned with accuracy and precision of a measurement technique. There are three types of reliability namely parallel forms of reliability, test-retest reliability and inter-rate reliability (Schindler, 2013).

The questionnaire was designed for reliability by ensuring there was no interference between unrelated variables.

3.7 Limitations of the study

The interviewer used a structured questionnaire, which was homogenous and open-ended. This accelerated prompt interviews, but didn't promote broad in-depth investigation.

Another limitation is that the researcher may have been biased in the study as the researcher is part of the organization, some assumptions and predeterminations exist. This was an unavoidable result because of knowing the organizational operation well.

3.8 Summary

This Chapter detailed the research design and showed the plan of implementing it during the study. The design indicated the methodology and procedures for collection, measurements and data analysis. The research approach was such that it gives results, conclusion and recommendations in Chapter 5 and will provide a solution to the problem statement in Chapter 1. The next chapter discusses the data analysis and results.

CHAPTER FOUR

Presentation and Discussion of the Results

4.1 Introduction

This chapter details the summary of the experiential findings of the study obtained across collection of primary data. The data acquired was statistically analysed using SPSS and is presented by graphs, tables and discussions. The results are exhibited in distinctive sections addressing the objectives of the study. Descriptive statistics are arranged in the form of frequencies and percentages thus presenting the results that address the variables.

4.2 Demographics

This section highlights the demographic features of the respondents who contributed in this study. Demographic data affords a detailed environment in which the research took place, including common variables that will be compared with the key variables concerning the research questions. A total of 40 participants responded against a target population of 50. This equated to 80% response rate. The acceptable standard for questionnaires is between 70 – 80 % response rate (Nulty, 2013).

4.2.1 The Respondents Age

Table 4.1 indicates the respondent's age employed by Umgeni Water that were sampled for this study.

Age of Respondents	No. of Respondents	Percentage
20 to 29 years old	13	33%
30 to 39 years old	14	35%
40 to 49 years old	7	17%
50 to 59 years old	5	12%
60 years and above	1	3%
Total	**40**	**100%**

Table 4.1 Respondents Age

It is clear from Table 4.1 that age group thirty to thirty nine years old represented the majority (35%) of the respondents, while age groups from twenty to twenty nine years old and forty to forty nine years old of the respondents, represented 33% and 17 % each respectively. The age groups fifty to fifty nine years old represented 12 % of the respondents, and the age group sixty years old and above represented 3 % of the respondents.

4.2.2 The Respondents Length of Service

Table 4.2 illustrates the length of the respondent's employment duration at Umgeni Water.

Length of Service	No. of Respondents	Percentage
0 to 1 year	5	13%
1 to 5 years	15	37%
5 to 10 years	7	18%
10 to 15 years	5	12%
15 years and above	8	20%
Total	**40**	**100%**

Table 4.2 Respondents Length of Service

It is evident from Table 4.2 that the majority (37%) of the respondents length of service was more than one year, followed by 20 % whose length of service was more than 15 years. 18 % of the respondents length of service was five to ten years, 13 % for up to a year, and 12 % for ten to fifteen years length of service.

4.2.3 The Respondents Highest Academic Qualification

Figure 4.1 illustrates the highest academic qualification of the respondents.

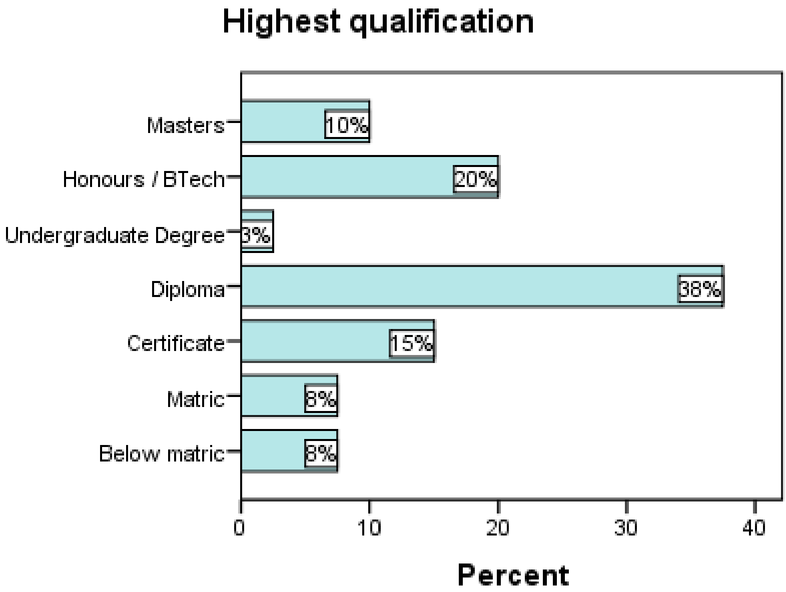


Figure 4.1 Respondents Highest Qualification

Figure 4.1 showed that the largest number of respondents (38%) had Diplomas, followed by Honours and Bachelor of technology qualifications (20%). Respondents (15%) had certificate qualifications, 10 % had masters qualifications and 8% each had matric or below matric qualifications.

4.3 Objective One: To ascertain what different processes of sludge treatment exists at Umgeni Water

According to Khalid (2012), wastewater sludge originates from different phases of the treatment process with several contents of inorganic and organic properties, both in liquid and solid phase; comprising of both beneficial and unusable elements. Accordingly it is important to understand from a knowledge basis the existence of the different sludge treatment processes.

4.3.1 The Need for Developing a Strategic Approach towards the Global Impact of Sludge on the Environment

The respondents were asked to indicate whether they agreed or disagreed with a need for developing a strategic approach towards the global impact of sludge on the environment.

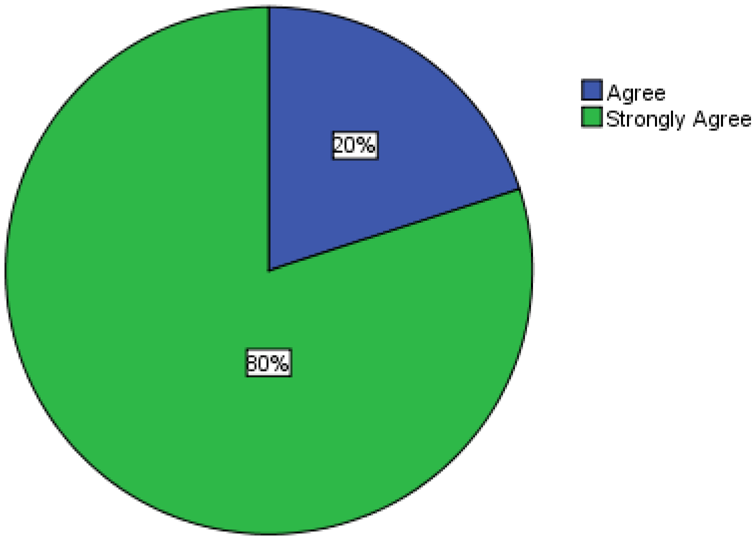


Figure 4.2 Sludge having a Global Impact on the Environment

It is clear from Figure 4.2 that the highest number of the respondents (80%) strongly agreed that there was a need for developing a strategic approach towards sludge having a global influence on the environment while 20 % of the respondents agreed. Kurbiel (2012) stated that wastewater treatment and the management of sludge produced are worldwide matters, with increasing challenges that need to control the fears of stakeholders, whether it is the operator or general public. It is known that humans produce excreta and urine, which needs to be contained and managed to protect public health and environment (Kurbiel, 2012). The finding supports the view of Kurbiel (2012).

4.3.2 The Different Wastewater Treatment Process Outcomes

The respondents were asked to indicate whether they agreed or disagreed that the different wastewater treatment processes resulted in different sludge produced.

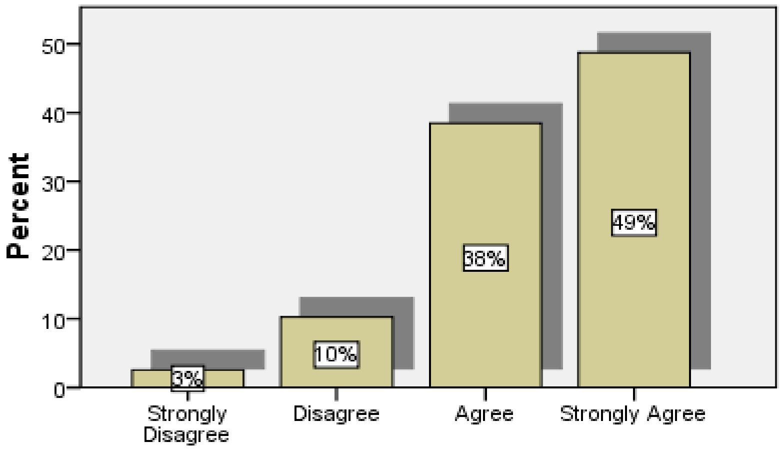


Figure 4.3 Different Wastewater Treatment Processes

Figure 4.3 showed the respondents (49%) strongly agreed that different wastewater treatment processes would result in the different types of sludge produced, 38% agreed while 10% and 3% of the respondents disagreed or strongly disagreed that different wastewater treatment processes would result in the different types of sludge produced. According to Movahedian (2005) that the features of sewage sludge vary depending on its treatment. Primary sewage sludge is the outcome of the primary settling solids from wastewater that has not undergone any treatment process. Khalid (2012), states that secondary sewage sludge has undergone extensive degradation and involves a primary clarification process of biological treatment and secondary clarification. The findings supports the views of Movahedian (2005) and Khalid (2012).

4.3.3 The Different Sources of Sludge

The respondents were required to indicate whether they knew the origin of the influent that was received at their treatment plants.

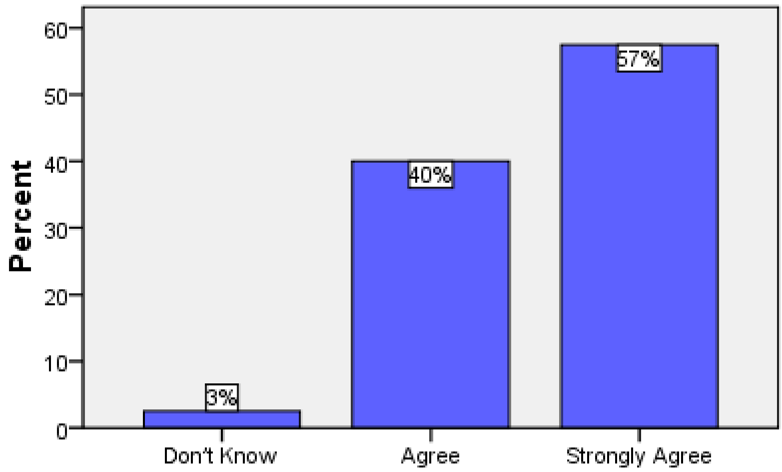


Figure 4.4 Origin of Influent

Figure 4.4 highlights that 57% and 40% of the respondents strongly agreed and agreed respectively that they knew the origin of the influent received at their treatment plants, while 3% of the respondents had no such knowledge. This finding is unique to this study thus it contributes to the profile of this study.

4.3.4 Domestic Influent

The respondents were asked to indicate if the influent received was purely domestic.

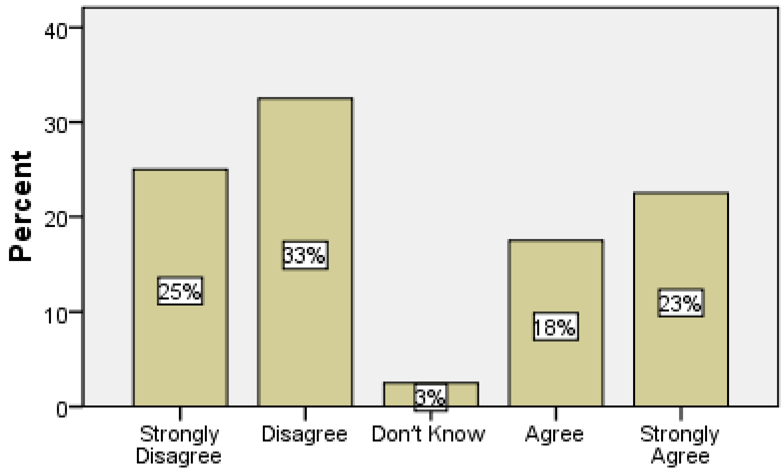


Figure 4.5 Domestic Influent

It is evident from Figure 4.5 that 25% and 33% of the respondents strongly disagreed and disagreed that the influent produced was domestic, 23% strongly agreed, 18%

agreed while 3% did not know that the influent received was purely domestic. This finding is unique to this study thus it contributes to the profile of this study.

4.3.5 Industrial Influent

The respondents were asked to indicate if the influent received was industrial.

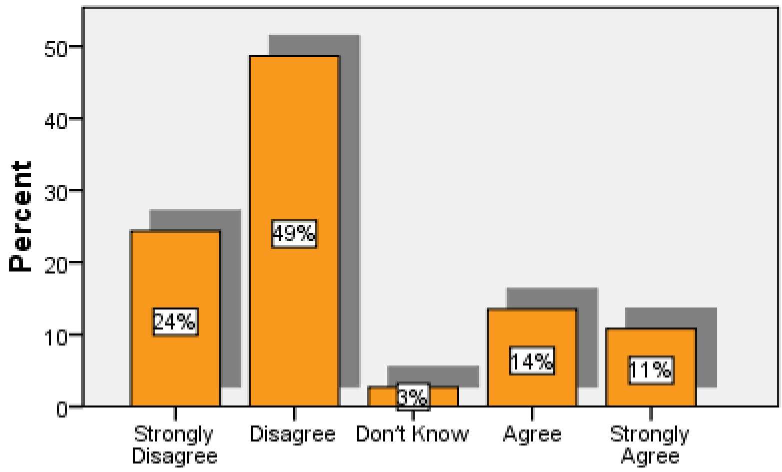


Figure 4.6 Industrial Influent

It is evident from Figure 4.6 that 24% and 49% of the respondents strongly disagreed and disagreed of the notion that influent produced being industrial, 11% strongly agreed, 14% agreed while 3% did not know that the influent received was industrial. This finding is unique to this study thus it contributes to the profile of this study.

4.3.6 The Division of Influent between Domestic and Industrial

The respondents were asked to indicate if the influent received was the split between domestic and industrial.

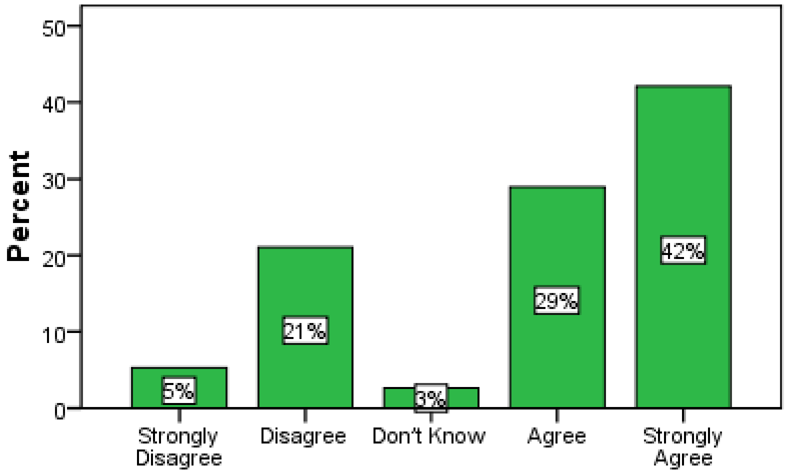
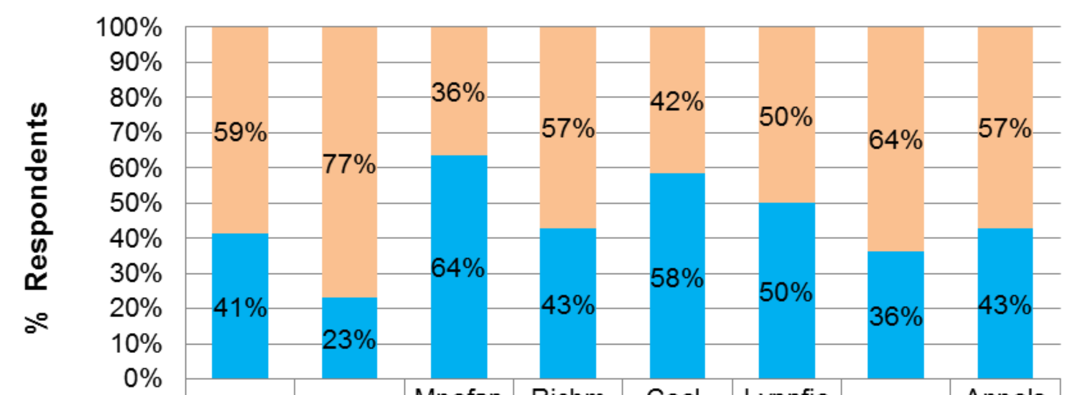


Figure 4.7 Influent Split between Domestic and Industrial

It is evident from Figure 4.7 that 42% and 29% of the respondents strongly agreed and agreed that the influent produced was a split between domestic and industrial, 5% strongly disagreed, 21% disagreed while 3% did not know that the influent received was a split between domestic and industrial. Spiller (2012), defines wastewater as having a mixture of domestic effluent having black-water (excreta, urine and faecal) and greywater (kitchen and bathing) and industrial water from commercial users encompassing hospitals, industrial effluent and other urban run-off. The findings supports the view of Spiller (2012).

4.3.7 Preliminary Operations for sludge treatment

The respondents were asked to indicate the initial operation of sludge treatment for their treatment plants.



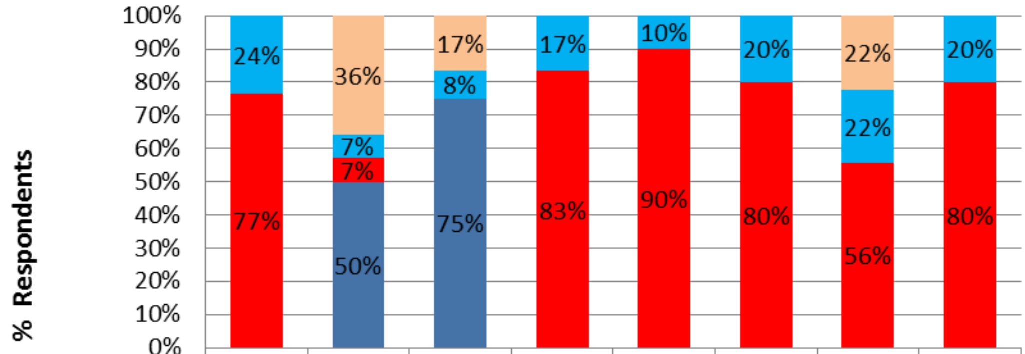
	Darvil	Howick	Mpofan a	Richm ond	Cool-Air	Lynnfie ld	Ixopo	Appels boch
Sludge Degritting	59%	77%	36%	57%	42%	50%	64%	57%
Sludge Storage	41%	23%	64%	43%	58%	50%	36%	43%
Sludge Bending								
Sludge Grinding								

Figure 4.8 Preliminary Sludge Treatment

It is evident from Figure 4.8 that 59 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Darvil while and 41 % believed that it was sludge storage, 77 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Howick while and 23 % believed that it was sludge storage, 36 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Mpofana while and 64 % believed that it was sludge storage, 57 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Richmond while and 43 % believed that it was sludge storage, 42 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Cool-Air while and 58 % believed that it was sludge storage, 50 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Lynnfield while and 50 % believed that it was sludge storage, 64 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Ixopo while and 36 % believed that it was sludge storage and 57 % of respondents believed that sludge de-gritting was the preliminary operation for sludge treatment at Appelsbosch while and 43 % believed that it was sludge storage. According to Andreoli (2014) sludge de-gritting addresses ineffective grit removal prior to dewatering. Sludge de-gritting decreases grit brought by wear on the sludge dewatering system and reduces grit build-up in the digestion process prior to the start of sludge treatment. The study supports the view of Andreoli (2014).

4.3.8 Thickening Sludge Treatment of Plants

The respondents were asked to indicate the thickening sludge treatment for their respective treatment plants.



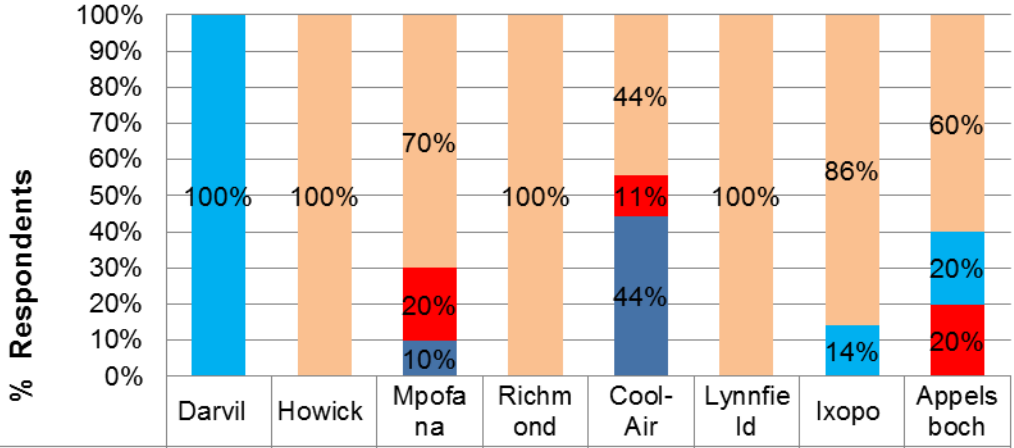
	Darvil	Howick	Mpofana	Richmond	Cool-Air	Lynnfield	Ixopo	Appelsboch
Centrifugation		36%	17%				22%	
Floatation Thickening	24%	7%	8%	17%	10%	20%	22%	20%
Gravity Thickening	77%	7%		83%	90%	80%	56%	80%
Rotary Drum Thickening		50%	75%					

Figure 4.9 Thickening Sludge Treatment

It is clear from Figure 4.9 that 74% of the respondents believed that gravity thickening was used at Darvil while 24% felt it was floatation thickening. The respondents (50%) believed that rotary drum thickening was used at Howick while 36%, 7% and 7% felt that it was centrifugation, floatation and gravity thickening respectively. The respondents (75%) believed that rotary drum thickening was used at Mpofana while 17% and 8% felt that it was centrifugation and floatation thickening that was used. The respondents (83%) felt that gravity thickening was used at Richmond while 17% felt it was floatation thickening. The respondents (90%) believed gravity thickening was used at Cool-Air while 10% believed it was floatation thickening. The respondents (80%) believed gravity thickening was used at Lynnfield while 20% felt it was floatation thickening. The respondents (56%) believed that gravity thickening was used at Ixopo, 22% felt it was centrifugation while the other 22 % believed it was floatation thickening. The respondents (80%) believed gravity thickening was used at Appelsbosch while 20% believed it was floatation thickening. Sludge thickening is whereby the solids portion of the sludge are concentrated of reducing its water content. This assists to reduce the cost of digesting, storing, transporting and drying sludge. Sludge thickening is normally achieved using gravity settlers, dissolved air flotation, centrifuges, gravity belts and rotary drum thickeners (Kandasamy, 2011). The findings supports the view of Kandasamy (2011).

4.3.9 Stabilising of the Treated Sludge at Plants

The respondents were asked to indicate the stabilising method for the sludge treatment at their treatment plants.



	Darvil	Howick	Mpofana	Richmond	Cool-Air	Lynnfield	Ixopo	Appelsboch
Aerobic Digestion		100%	70%	100%	44%	100%	86%	60%
Anaerobic Digestion	100%						14%	20%
Lime stabilization			20%		11%			20%
Heat Treatment			10%		44%			

Figure 4.10 Stabilization of the Treated Sludge

It is evident from figure 4.10 that 100% of the respondents believed that anaerobic digestion stabilising method was used at Darvil, 100% of the respondents felt that aerobic digestion stabilising method was used at Howick, Richmond and Lynfield plants. The respondents (70%) believed that aerobic digestion stabilising method was used at Mpofana, while 20% and 10% felt it was lime stabilization and heat treatment that was used at the plant. The respondents (44%) each believed that aerobic digestion and lime stabilising methods was used at Cool-Air, while 11% felt it was heat treatment that was used at the plant. The majority of respondents (86%) believed that aerobic digestion stabilising method was used at Ixopo while 14%

believed it was anaerobic digestion stabilization was used at the plant. The respondents (60%) believed that aerobic digestion stabilising method was used at Appelsboch, while 20% felt it was anaerobic digestion and another 20% felt it was lime stabilization method that was used the plant. According to S.R.Smith (2011) that the major part of sludge is anaerobically digested in 57 % wastewater treatment plants in South Africa. Aerobic digestion accounts for only 1% wastewater treatment plants in South Africa. The largest treatment plant, Darvil, uses anaerobic digestion with extended aeration. This practice has been used in municipal wastewater sludge since the early 1900s and is the most widely used sludge treatment method (Alvarez-Cohen, 2000). The findings of this study is that the majority of treatment plants of Umgeni water uses Aerobic digestion which is contrary to the study carried out by S.R.Smith (2011). The findings also support the study carried out by Alvarez-Cohen (2000).

4.3.10 The Condition of the Treated Sludge at Plants

The respondents were asked to indicate the conditioning method for the sludge treatment at their treatment plants.

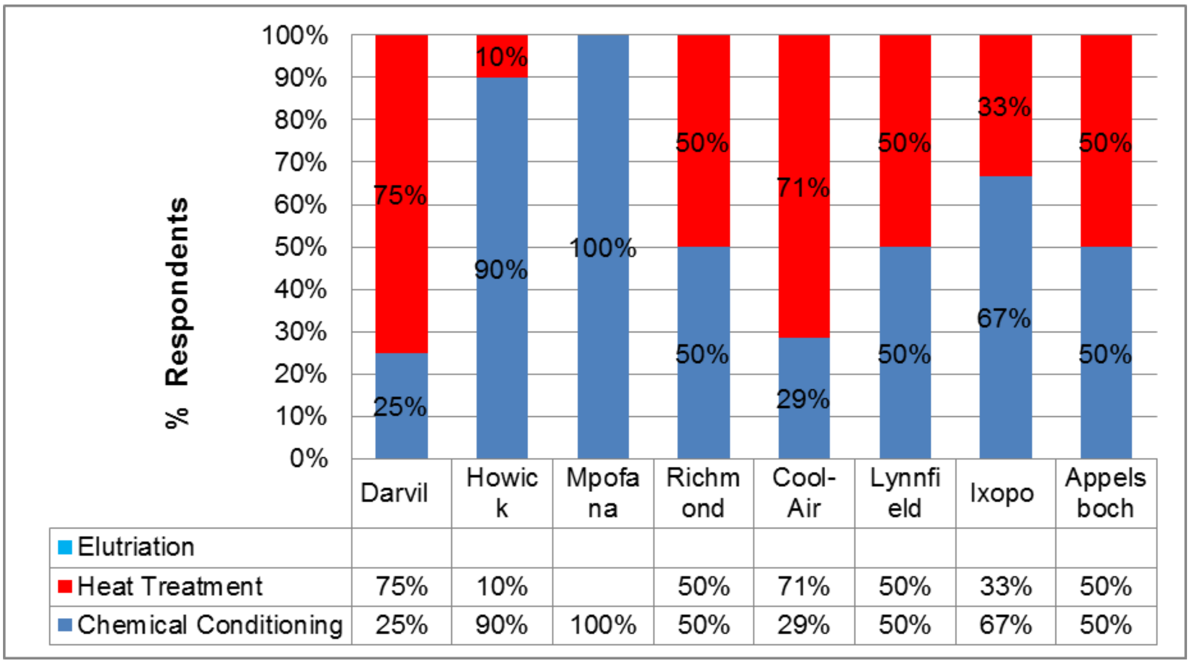
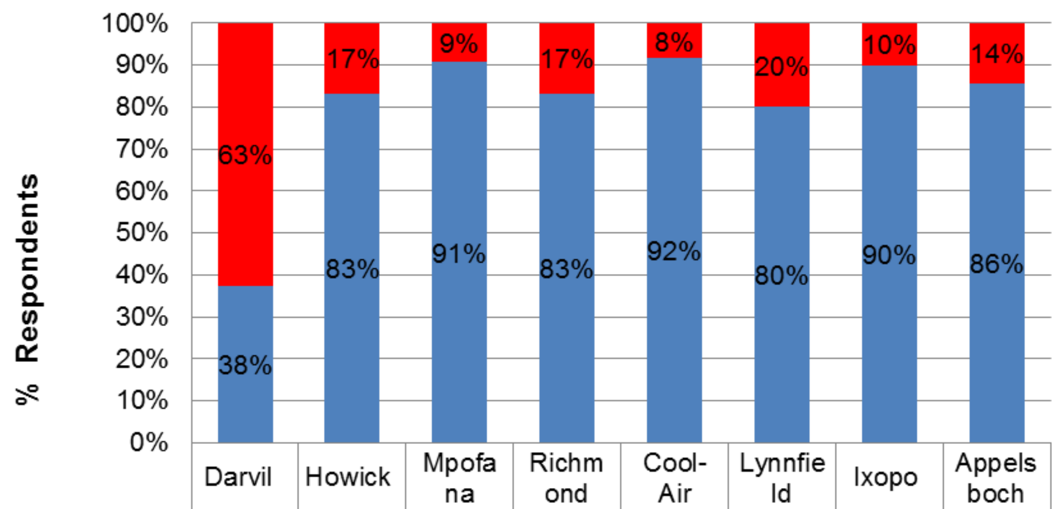


Figure 4.11 Conditioning of Sludge

It is evident from figure 4.11 that the majority (75%) of respondents felt that heat treatment was utilised for conditioning at Darvil while 25% felt it was chemical conditioning method. The majority (90%) of respondents indicated that chemical conditioning was utilised at Howick while 10% felt it was the heat treatment method. The majority (100%) of respondent's believed that chemical conditioning was utilised at Mpofana. The majority (71%) of respondents indicated that heat treatment was utilised for conditioning at Cool-Air while 29% felt it was chemical conditioning method. The Respondents (50%) each felt that heat treatment and chemical conditioning was used at Lynnfield. The respondents (67%) indicated that chemical conditioning was used at Ixopo while 33% felt that heat treatment was used. The Respondents (50%) each felt that heat treatment and chemical conditioning was used at Richmond and Appelsbosch. According to Dahlström (2005) conditioning is through mineral agents by inducing chemicals like lime or salts or organic compound that has diverse formation of polymers and thermal conditioning whereby sludge is heated to a range of 150-200ºC in 30 to 60 minutes period. The finding supports the opinion of Dahlström (2005) as both heat treatment and chemical conditioning is carried out at Umgeni Water sludge plants.

4.3.11 The Disinfection of the Treated Sludge at Plants

The respondents were asked to indicate the disinfection method for the sludge treatment at their treatment plants.



	Darvil	Howick	Mpofa na	Richm ond	Cool-Air	Lynnfie ld	Ixopo	Appels boch
Pasteurization	63%	17%	9%	17%	8%	20%	10%	14%
Long Term Storage	38%	83%	91%	83%	92%	80%	90%	86%

Figure 4.12 Disinfecting of Sludge

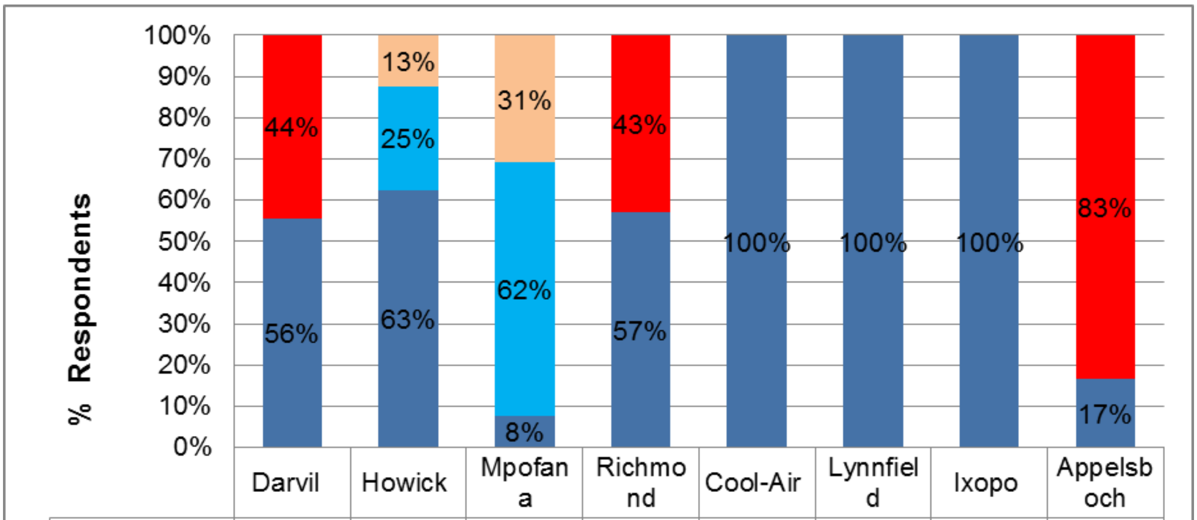
It is evident from figure 4.12 that (63%) of respondents indicated that pasteurisation was utilised for disinfecting sludge at Darvil while 38% felt it was long term storage disinfection. The majority (83%) of respondents indicated that long term storage disinfection was utilised at Howick while 17% felt it was pasteurisation. The majority (91%) of respondent's believed that long term storage disinfection was utilised at Mpofana while 9 % felt it was pasteurisation.

The majority (83%) of respondents believed that long term storage disinfection was utilised at Richmond while 17 % felt it was pasteurisation. The respondent's (92%) believed that long term storage disinfection was utilised at Cool-Air while 8 % felt it was pasteurisation. The majority (80%) of respondent's believed that long term storage disinfection was utilised at Lynnfield while 20 % felt it was pasteurisation. The majority (90%) of respondent's believed that long term storage disinfection was utilised at Ixopo while 10% felt it was pasteurisation.

The majority of respondents (86%) felt that long term storage disinfection was utilised at Appelsbosch while 9 % felt it was pasteurisation. Christopher (2013) states that there are a number of elements adding up in the sludge and becoming contaminated to microorganisms, therefore hygienization is realized by numerous process treatment methods like anaerobic digestion, pasteurization, composting, and lime stabilization. The study supports the views of Christopher (2013), however the finding of sludge being stored over the long term indicated that pasteurisation is mostly carried out at the Darvil plant when compared to all the other plants. This finding is exclusive to the study and therefore adds to the profile of this study.

4.3.12 Dewatering Sludge Treatment at Plants

The respondents were asked to indicate the dewatering method for the sludge treatment at their treatment plants.



	Darvil	Howick	Mpofana	Richmond	Cool-Air	Lynnfield	Ixopo	Appelsboch
Belt Presses		13%	31%					
Centrifuge		25%	62%					
Lagoon	44%			43%				83%
Drying Bed	56%	63%	8%	57%	100%	100%	100%	17%

Figure 4.13 Dewatering of Sludge

It is evident from Figure 4.13 that respondents (56%) indicated that drying bed dewatering process was used at Darvil while 44% felt it was lagoon dewatering method. The respondents (63%) indicated that drying bed dewatering process was used at Howick while 25% and 13% felt it was centrifuge and belt presses dewatering methods. The respondents (62%) indicated that centrifuge dewatering process was used at Mpofana while 8% and 31% felt it was drying bed and belt presses dewatering methods. The respondents (57%) indicated that drying bed dewatering process was used at Richmond while 44% felt it was lagoon dewatering method. The majority (100%) of respondents indicated that the drying bed dewatering process was used at Cool-Air, Lynnfield and Ixopo plants. The respondents (83%) felt that the lagoon dewatering process was used at Appelsboch while 17 % felt that it was the drying bed process. According to Kandasamy (2011) reducing the water content of sludge is normally achieved using gravity settlers, dissolved air flotation, centrifuges, gravity belts and rotary drum thickeners. The majority of respondents indicated that the drying beds method was commonly in use by Umgeni Water, this finding is exclusive to the study and hence contributes to the profile of this study. Seethoram (2013) describes lagooning as one of the most common sludge management treatments. The finding of the study supports the views of Kandasamy (2011) and Seethoram (2013).

4.4 Objective Two: To confirm the sludge disposal methods used at Umgeni Water

According to Andreoli (2014) that the disposition process of waste water sludge includes the transporting of the treated wastewater sludge to a Municipal landfill site where it is dumped or mixed with other waste materials. Reasonable disposal options for sludge includes reusing the product, by land application, stabilization, composting, and pelletizing (Bloetscher, 1999).

4.4.1 Understanding The Source of Influent Enhances Sludge Treatment and Disposal

The respondents were asked to indicate whether they agreed or disagreed that knowing the source of influent can enhance sludge treatment and disposal.

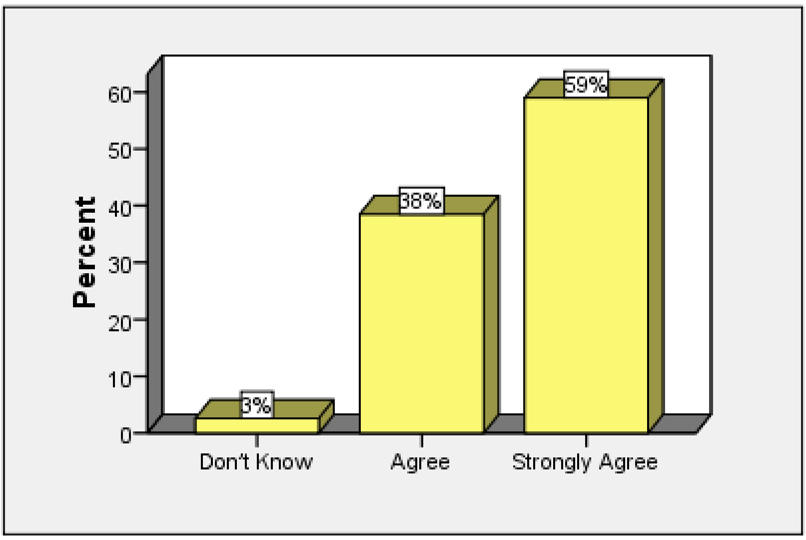


Figure 4.14 Enhancing Sludge Treatment and Disposal

Figure 4.14 showed that 59% and 38% of the respondents strongly agreed and agreed respectively that knowing the source of influent can enhance the sludge treatment and disposal, while 3% of the respondents had no such knowledge. According to Khalid (2012), wastewater sludge originates from different phases of the treatment process with several contents of inorganic and organic properties, both in liquid and solid phase; comprising of both beneficial and unusable elements. The beneficial elements can be utilized in various methods after the sludge has undergone a further treatment process. The study supports the view of Khalid (2012).

4.4.2 The Sludge Disposal Method at the Treatment Plants

The respondents were asked to indicate what sludge disposal method was utilised at their treatment plant.

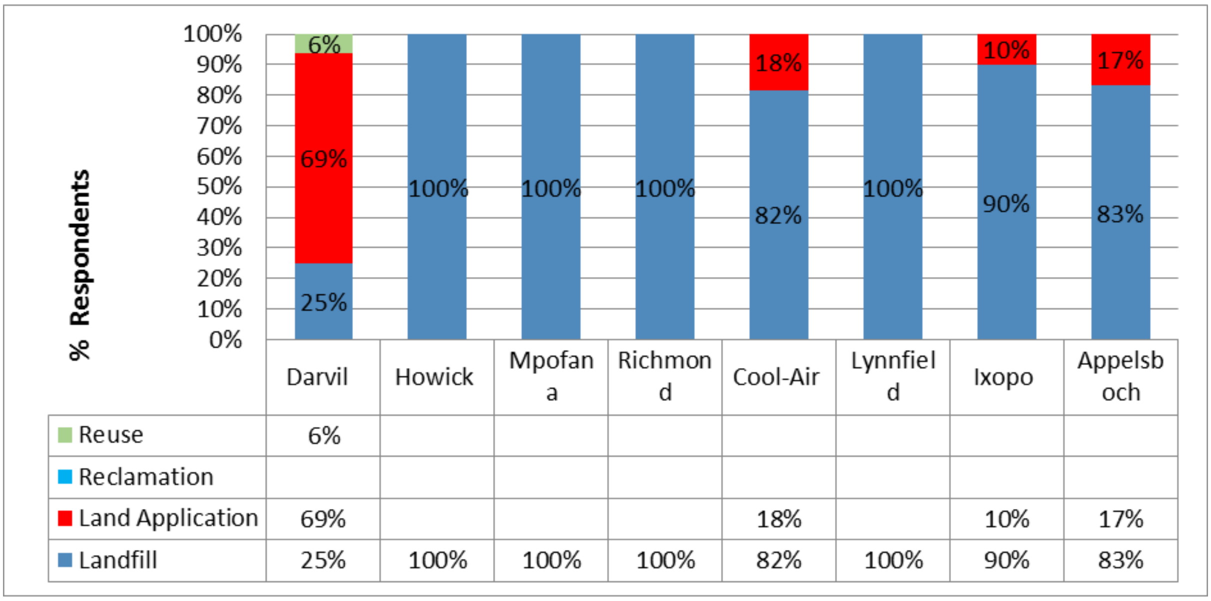


Figure 4.15 Sludge Disposal Methods

It is evident from Figure 4.15 that 69% of the respondents indicated that land application sludge disposal method was used at Darvil, 25 % felt that it was landfill method and 6% felt that it was re-use method. 100% each of respondents indicated that the landfill method was used at Howick, Mpofana, Richmond and Lynfield plants. The respondents (82%) believed that the landfill method was used at Cool-air while 18% believed it was land application that was used. The respondents (90%) believed that the landfill method was used at Ixopo while 10 % believed it was land application that was used. The respondents (83%) believed that the landfill method was used at Appelsbosch while 17% believed it was land application that was used. Bloetscher (1999) describes land application as one of the reasonable disposal options for sludge. Andreoli (2014) states that one of the disposition methods of treated wastewater sludge is a process of transporting it to a Municipal landfill site where it is dumped with other waste materials. The study supports the views of both Andreoli (2014) and Bloetscher (1999).

4.5 Objective Three: To assess the possibility of introducing sludge recycling and reuse practices at Umgeni Water

According to Bloetscher (1999) environmentalists worldwide are tightening sludge regulations and promoting sludge disposal alternatives. Reasonable disposal options for sludge includes reusing the product, by land application, stabilization, composting, and pelletizing.

4.5.1 Wastewater Treatment Plant Forms Part of Ecological System

The respondents were asked to indicate whether wastewater treatment plant (WWW) formed part of an ecological system

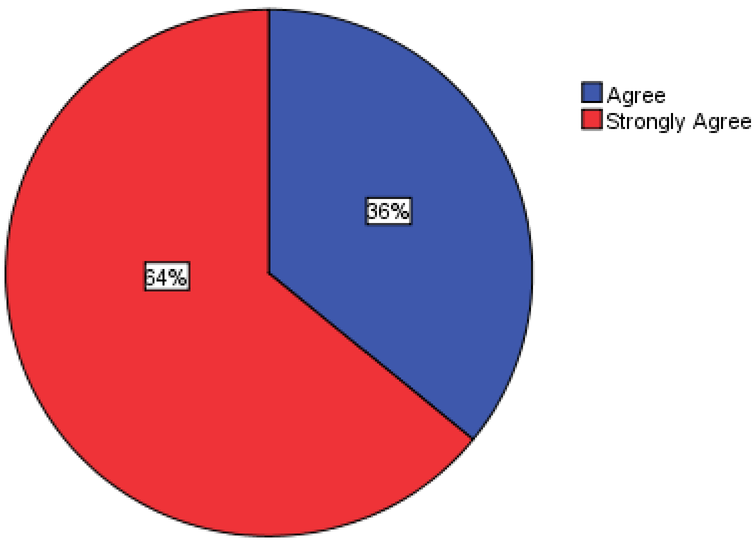


Figure 4.16 Wastewater as part of the Ecology

It is evident from Figure 4.16 that the respondents (64%) strongly agreed and 36% of the respondents agreed that the wastewater treatment plant formed part of the ecological system. According to Hall (2014), the challenge of wastewater treatment utilities is finding technology that is innovative and cost-effective which responds to environmental, regulatory and public demands. Reducing, recycling and re-using wastes are the desired selections for an ecological system, as opposed to incineration or disposing at a landfill site. The study supports the view of Hall (2014).

4.6 Objective Four: To determine the legislative impacts of wastewater sludge

The treatment and disposal of wastewater sludge are costly and pose an environmentally complex problem. With each Country aiming to meet one of Millennium Development Goals of waterborne toilets new sewage treatment works are constructed at the same time the environmental quality standards are becoming strict, this then poses a challenge in the world owing to the sludge generation growth (Keirungi, 2006).

4.6.1 Sludge Management and Disposal is Governed by Legislation

The respondents were asked to indicate whether sludge management and disposal is governed by legislation.

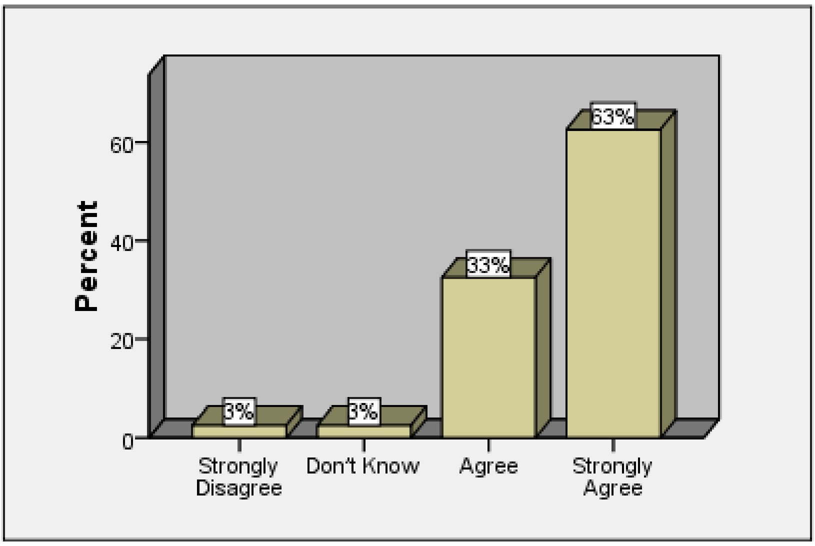


Figure 4.17 Understanding of Legislation in the Disposal of Sludge

It is evident from Figure 4.17 that 63% and 33% of respondents strongly agreed and agreed that sludge management and disposal was governed by legislation. The respondents (3%) disagreed that sludge management and disposal was governed by legislation and 3% of respondents did not know if sludge management and disposal was governed by legislation. The Department of Water and Sanitation Sludge

Guidelines for the utilization and removal of Wastewater Sludge Volume 3 specifically deals with legal conditions for wastewater sludge removal on land (on-site and off-site), co-disposal on landfill site and disposal to the marine environment. The findings support the legislative condition of Department of Water and Sanitation Sludge Guidelines for the utilization and removal of wastewater sludge.

4.6.2 Sludge Management Challenges to the Environment

The respondents were asked to indicate whether sludge by-products from the wastewater treatment and disposal thereof was one of the most challenging environmental problems in wastewater treatment process.

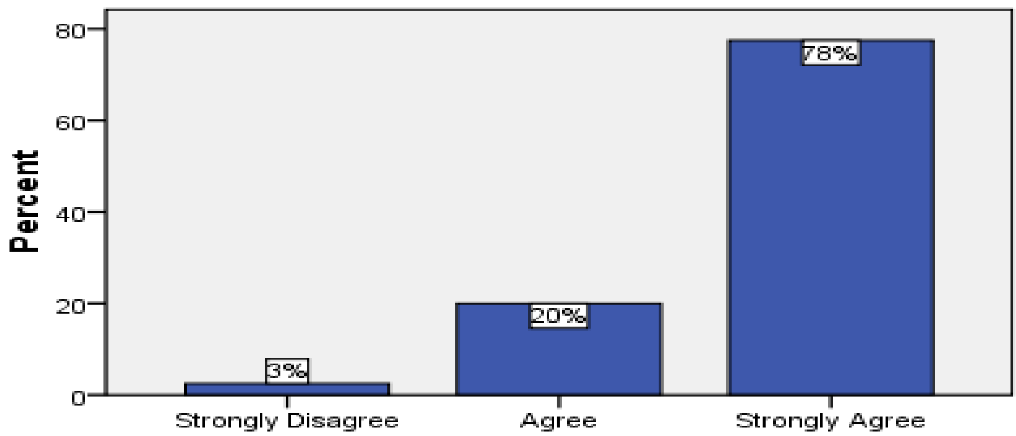


Figure 4.18 Sludge and its Environmental Challenges

It is clear from figure 4.18 that the majority (78%) of respondents showed that they strongly agreed and 20% agreed that sludge by-products from the wastewater treatment and its disposal was one of the most challenging environmental problems in wastewater treatment process. 3% of respondents disagreed that sludge by-products from the wastewater treatment and its disposal was one of the most challenging environmental problems in waste water treatment processes. According to Snyman (2007) wastewater treatment plants need to provide proof of why they chose the beneficial way of handling the sludge. There should be feasibility studies conducted to implement alternate options and efforts to improve the sludge quality, should that be the limiting factor for beneficial use. If disposal is the only alternative management option for sludge, it is then classified as a waste. Restrictions and requirements should be applied to protect the receiving water streams from possible contamination by wastewater sludge. The restrictions and requirements are more stringent with declining sludge quality and the vulnerability of the receiving water streams (Snyman, 2007). The findings support the view of Snyman (2007).

4.7 Objective Five: To determine the financial implications to life cycle costing of sludge management

The disposal of sludge entails positive and prudent management, but the simplicity or complexity of disposal is much dependent on associated costs with regards to circumstances. Sludge is a product of which the quality is not accurately controllable due to its origin. This has no secure long-term outlet and generally requires processing, transport and disposal costs of which it can be half the total cost of operating the treatment works (Hall, 2014).

4.7.1 Sludge Management and Company Productivity Strategy

The respondents were asked to indicate whether company strategy provided greater value and productivity with regards to sludge management.

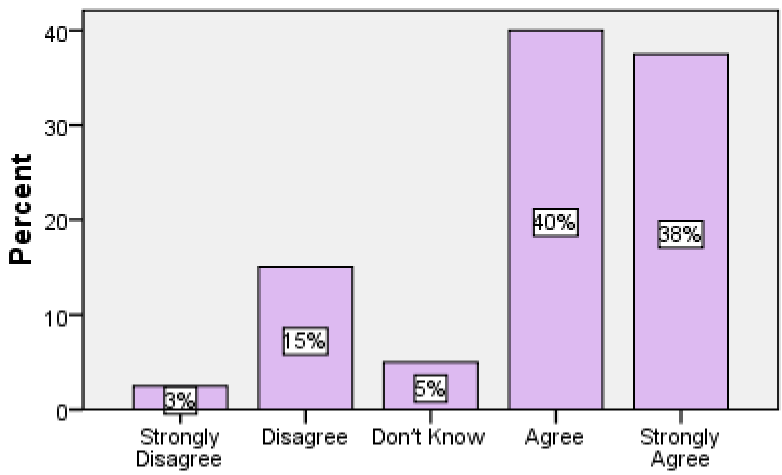


Figure 4.19 Company Strategy for Sludge Management

It is apparent from figure 4.19 that 38% and 40% of the respondents strongly agreed and agreed respectively that Company strategy provided greater value and productivity with regards to sludge management. 3% and 15% of the respondents strongly disagreed and disagreed that company strategy provided greater value and productivity with regards to sludge management while 5 % had no knowledge of this. Meozzi (2011) argues that costs are a critical component of choosing sludge management. They may differ subject to local circumstances and capacity of the treatment plant. In order to identify the correct evaluation of different options for sludge treatment and disposal, a consideration of annual costs, which are guided by three factors, namely capital outlay, operating costs and disposal or re-use of the sludge. The study supports the argument by Meozzi (2011).

4.8 Summary

The significant findings of this study are that Umgeni Water utilises various methods of sludge waste management which is costly. There is strong indication that there are numerous factors impacting on the volume of sludge generated and that there have been satisfactory attempts made by Umgeni Water to effectively minimize hazardous sludge being disposed in a landfill site. The findings have shown that regulatory challenges in water and sanitation requirements play an important role in alternative environmentally friendly sludge disposition strategies. The following Chapter completes this study by specifying recommendations and comments on the study limitations.

CHAPTER FIVE

Conclusions and Recommendations

5.1 Introduction

The growth of wastewater treatment technology combined with the execution of robust environmental legislation has effectively protected the aquatic system from pollution in many countries of the world. However, sewage sludge, as the by-product of the wastewater treatment process, is also produced at the same time. Unlike the other types of waste, clean-production technology can be implemented to minimize the quantity of sludge, sewage sludge is not avoidable and its generation will continue to increase along with wastewater discharge and treatment rate (Karius, 2011) .

In order to stabilise the sludge the three common methods used are anaerobic digestion, composting or thermal drying. These methods has the potential of reducing the content of pathogens which may constitute a risk when disposing sludge. The literature has indicated that sewage sludge is now becoming a global environmental concern because of its increasing generation and high contents of organic waste and pathogens, as well as heavy metals. Careful treatment and proper disposal is a priority to protect human and environmental impacts against this potential toxic waste (Andreoli, 2014).The treatment and reduction of the volume of sludge at Umgeni Water treatment plants in this study appear ineffective, there is evidence of no uniform methodology on sludge management and the disposal options.

This chapter concentrates on the findings of the research study, its limitations, recommendations from it and also suggestions for further studies that could be conducted in the field of sludge management.

5.2 Key Findings and Conclusions

The main aim of the study was to ascertain different processes of sludge treatment, confirm the sludge disposal methods used at Umgeni Water, and assess the possibility of introducing sludge recycling and reuse practices. The study further explored the legislative impacts of wastewater sludge treatment and the financial implications of life cycle costing of sludge management. The review of the literature indicated concern over the methodology uniformity of sludge management and the challenges in disposal options which is affected by changes in Environmental Legislation. The literature further revealed that proper sludge management is not only important with regards to wastewater treatment efficiency and public health but can also allow the wider community to utilise the resource value of sludge which would otherwise go to waste. The exploration of wastewater sludge management at Umgeni Water revealed that there is an urgent need to look at implementing global best practices in sludge management thus meeting changing environmental regulations.

The main research question and sub-research questions were formulated in a way that aligned them to the objectives of this study. The results showed that there are various factors impacting on the volume of sludge generated and that Umgeni Water need to effectively enhance their efforts to improve the reduction of landfill sludge waste disposal.

5.2.1 Objective One

The outcomes for objective one suggest that there are different processes utilised by the various Umgeni Water treatment plants for sludge management. Influent is obtained from both industrial and domestic sources. Sludge de-gritting activity was commonly done prior to the sludge dewatering. The purpose of sludge de-gritting was to address the ineffective grit removal. Additional findings identified that sludge generation is a global phenomenon that has an immense effect on the environment when being disposed of. It is evident from the findings of this study that Umgeni Water treatment plants have no standardisation in treatment and stabilising sludge. The Darvil treatment plant is the only treatment plant utilising anaerobic digestion stabilising methodology.

5.2.2 Objective Two

From the findings of objective two, it can be noted that the major challenge for Umgeni Water is to reduce the disposal of sludge to Municipal landfill sites. All eight treatment plants disposes sludge through landfill sites which has an adverse impact on the environment and human inhabitancies. It is evident from this study that there are alternative sludge methods adopted to limit the impact to the environment. Re-use and reclamation methods of sludge disposal are not considered as alternate options. Additional findings indicate that the beneficial elements of sludge can be utilized in various methods after the sludge has undergone a further treatment process but through firstly understanding the sources of sludge.

5.2.3 Objective Three

It is evident from the findings of objective three, that Umgeni Water has a challenge of wastewater treatment utilities that responds to environmental, regulatory and public demands. Reducing, recycling and re-using wastes are the desired selections for an ecological system, as opposed disposing at a landfill site.

5.2.4 Objective Four

Given the findings obtained in objective four, it is clear that the treatment and disposal of wastewater sludge is costly and poses an environmentally complex problem. The study has proven that regulations for the utilisation and removal of wastewater sludge are becoming stringent, this then poses a challenge to the sludge generation growth.

5.2.5 Objective Five

Based on the outcomes of objective five, it is clear Umgeni Water has been negatively impacted by operating costs, due to the capacity of the treatment plants. The correct evaluation of different options for sludge treatment and disposal is affected by annual operational costs, which are guided by capital outlay and disposal or re-use of the sludge.

Summary of the results and findings of the study advocates that the objectives of the study have been accomplished, and that it provides considerable and valuable information to Umgeni Water and other Government entities. These results could be commissioned to develop a strategy for alternate sludge re-use and recycle programs.

5.3 Recommendations To Improve Current Conditions

The recommendations suggested are centred on research findings, review of relevant literature and discussions.

5.3.1 The Treatment of Sludge

It is clear from the results of the study that the Umgeni Water sludge treatment plants does not utilise a standard for the treatment of sludge. The Darvil treatment plant is the only one amongst all nine plants that processes sludge using the anaerobic digestion method and the other plants use aerobic digestion. The majority of wastewater treatment plants in South Africa have no further treatment of the sludge, in comparison to conventional anaerobic digestion and activated sludge aeration. Final disposal methods are still dictated by on-site disposal comprising of direct land application and or stockpiling of the sludge on site (Snyman, 2007). Umgeni Water should play a more technological role in investigating more reputable treatments wastewater sludge treatment which may include:

- Suspended growth biological treatment processes, like activated sludge plants
- Fixed film biological treatment processes, like bio-filters/trickling filters and rotating
- Biological contactors; and
- Mixed pond treatment technologies, like anaerobic ponds and oxidation pond

Department of Water and Sanitation in conjunction with Department of Environmental Affairs should make have incentives for Umgeni Water for innovative technological initiatives of reducing sludge disposal through direct land application and or stockpiling.

5.3.2 Reducing Impact to the Environment

The main long-term objective of sludge treatment and disposal is to contain the residues of the wastewater treatment without major impact on the environment. That will then allow sludge to be stored temporarily, treated, processed and re-used for landscape or in agriculture. Wastewater treatment and the management of sludge produced are worldwide matters, with increasing challenges that need to control the fears of stakeholders, whether it is the operator or general public (Kurbiel, 2012). Findings of this study identified that sludge generation is a global phenomenon that has an immense effect on the environment when being disposed of, Umgeni Water plants are stockpiling sludge. Anaerobic digestion allows an opportunity to produce 100 percent renewable energy from biodegradable waste. Research clearly indicates the most sustainable way to treat waste is to collect it weekly for treatment by anaerobic digestion. Strong support in the new waste strategy requires initiatives to start fulfilling this potential, with the extensive introduction of food waste collections and the transformation of all eight Umgeni Water treatment plants to anaerobic digestion plants. Anaerobic digestion can provide a low technology approach to primary wastewater treatment resulting in energy production and better fertilizer properties than the raw waste (United States Environmental Protection Agency, 1984).

5.3.3 Combined Treatment and Disposal Concept For Sewage Sludge

It is evident from the findings of this study that there must be a strategy of introducing sludge recycling and reuse practices. Reduction, re-use and recycling, recovery and disposal are the major components of waste management strategy (Volume 3 of the Sludge Guidelines). However, this concept’s main objective is to achieve a material cycle society. Reduction is the preferred method and the most effective usage of a matter with small consumption of resource and the smallest amount of waste discharged. When discharged products are utilized in the same manner or in another manner, that is termed re-use. Recycling suggests to upgrading waste into new products and can be applied in two forms, recycling at cause of the production or recycling of waste material. Recovery is about using the waste to realize a beneficial outcome. These concepts should part of the overall waste management strategic objectives of Umgeni Water plants.

5.3.4 Avoidance and Treatment of Sludge Management Concept

It is clear from the findings of this study that the main target of sludge management is to decrease the generation of waste and to augment the establishment of waste treatment and disposal. Snyman (2007), recommends that the strategy for sludge management should first target to reduce both the production (quantity) and pollutant concentration (quality) at the level of the producer. Waste prevention and encouraging effective recycling methods are key drivers in reducing negative impact of waste on the environment. The recycling approach promotes the idea that every item of waste not to be seen as a source of pollution to be reduced, but also as a potential resource to be exploited (Blanca Jiménez, 2008).

There are limited possibilities to avoid sludge generation. The discharge of industrial and commercial wastewater can be reduced if there is pre-treatment prior to discharging to Municipal sewer networks, this is a requirement by Department of Water and Sanitation. Therefore, stringent legal enforcement is required to implement penalties in the form of polluter pays principle and with clean-up costs borne by the Company that caused the damage. With these controls, mainly the concentration of pollutants can be minimized and observed. Further reduction can be reached through pre-treatment prior to disposing to sewer system.

5.3.5 Umgeni Water should consider the following

The sewage sludge treatment solution should indicate the following parameters to be proper in practice:

- Minimum investment, operation and maintenance costs
- Small land requirements
- Enable to fulfil the legal requirements
- In the long run, simple to operate with small elementary maintenance efforts, skills required for operation and supervision are basic as possible
- Low estimated risk of failures
- Low-technology solution, relative-easy in handling, simple understanding for

semi-skilled locals

- Proven technology and construction with local material
- Durable construction and proceeding elements
- Universally applicable for different inputs and varying climatic conditions
- Low energy demand (low pumping effort, use of gravity, hydraulic pressure, slope)
- Achievable uniformity of solids, safe hygienic quality of solids, required quality of liquid effluent
- Cost effective by-products (biogas, energy, fertilizers, compost, biosolids etc.)
- Fully safeguarded sludge management (odour, leachate, without human health risks)

These systems can be centralized wastewater treatment plants with higher treatment capacity, decentralized wastewater treatment plants with minimal treatment capacities, septic tanks for individual users, sewerage and wastewater channel residues, or similar ones.

5.4 The limitations of this study

The collected statistics were limited to Umgeni Water treatment plants in the uMgungundlovu District Municipality and Msunduzi Local Municipality areas.

This study was conducted by a first-time researcher, which might have been also a limiting factor.

It is clear that there has been significant studies conducted abroad around the topic of wastewater sludge. There is limited research information on the topic in South Africa especially in Water Service Authorities in KwaZulu Natal. The literature reviewed in this study is limited to that dealing sludge treatment plants in South Africa.

5.5 Recommendations For Further Potential Studies

The current study had limited timespan given this could have resulted in some characteristics being overlooked. Possible studies that could be undertaken further are.

- As the research study only focused on Umgeni Water wastewater treatment plants, the other treatment plants around the Country should be assessed and their results compared to the findings of this study.
- This study focused on Umgeni Water Plants in the uMgungundlovu District Municipality, future research could also include a provincial evaluation of wastewater treatment plants in other Water Service Authorities.
- Wastewater treatment plants should be studied to verify infrastructure alignment to water and sanitation regulations.
- The impact of stockpiling sludge has on the environment and people.

5.6 Summary

The research achieved the objectives of this study and established that timely sludge removal from treatment systems has an important role in preventing loss of effective treatment capacity and maintaining design hydraulic retention times. It has also been proven that the lack of financial resources to upgrade treatment plants has an adverse effect of sludge volume reduction. It has further been proven that stock piling of sludge occurs at treatment plants. Sludge recycling and re-use measures have a direct impact on the environment. The study has proven that there is no standard method used for sludge treatment amongst the treatment plants. It has been further highlighted the need for more collaboration between Umgeni Water and other Government Entities in getting financial resources to technologically upgrade treatment plants in order to reduce sludge disposal into landfill sites.

REFERENCES

Alvarez-Cohen, W. & Nazaroff, G., 2000. *Environmental Engineering Science.* 3rd ed. New York: John Wiley and Sons.

Andreoli, C. & Fernandes, F., 2014. Sludge Treatment and Disposal. *Biological Wastewater Treatment Process,* 6(4), pp. 1-242.

Baietti, A., 2006. *Characteristics Of Well Performing Public Water Utilities,* Netherlands: World Bank.

Barreiro, P., 2014. *Survey Sampling Methods.* [Online]
Available at: http://www.rgs.org
[Accessed 01 10 2016].

Barz, M., 2009. Sewage Sludge From Wastewater Treatment As Energy Source. *International Journal of Renewable Energy,* 4(1), pp. 1-11.

Bharadwaj, S. D. & Jogdhankar, S. R., 2013. Automatic Wastewater Treatment Process To Reduce Global Warming. *International Journal of Environmental Science: Development and Monitoring,* 4(2), pp. 65-69.

Bhattacharya, M., 2009. *Wastewater Sludge Managment Options For Umgeni Water,* Massachusetts: Massachusetts Institute of Technology.

Blanca, J. & Pay, D., 2008. *Wastewater, Sludge and Excreta Use in Developing Countries: An Overview,* Accra: International Water Management Institute.

Bloetscher, D., Meeroff, E. & Fred, E., 1999. Sludge Management, Processing, Treatment, and Disposal. *Florida Water Resources Journal,* 3(5), pp. 23 - 25.

Botha, P., 2011. *Wet Sanitation Collection,Conveyance And Treatment Systems,* Windhoek: Republic Of Namibia.

Bougie, U. S. a. R., 2015. *Research Methods for Business.* 6th ed. United Kingdom: John Wiley and Sons.

Bresters, A. R., 1997. Sludge Treatment and Disposal. *Environmental Issues Series,* 3(7), pp. 9-53.

Bukowska, A., 2009. Sampling techniques in metalexicographic research. *International Journal of Lexicography,* 1(21), pp. 1258-1269.

Bywater, A., 2009. *A Review of Anaerobic Digestion Plants on UK Farms - Barriers, Benefits and Case Studies,* Stoneleigh Park,Warwickshire: Royal Agricultural Society of England.

Casey, T. J., 2006. *Unit Treatment Processes in Water and Wastewater Engineering,* Dublin: Aquavarra Research Limited.

Chezom, D. et al., 2013. Comparative Study of Different Leaching Procedures. *International Journal of Engineering Research and General Science,* 1(2), pp. 69-76.

Christopher, M., 2013. *Municipal Wastewater Management in Kawempe Division, Kampala Capital City Authority,* Kampala: Tampere University of Applied Sciences.

Coldwell, D. & Herbst, F., 2004. *Business Research.* 1st ed. New York: Juta & Company.

Cossu, R., 2013. International Journal of Integrated Waste Management, Science and Technology. *Nuclear and Chemical Waste Management,* 3(2), pp. 23-54.

Creswell, J., 2014. *Research design: Qualitative, Quantitative, and mixed Method Approaches.* 4th ed. United States of America: Sage Publications.

Dahlström, C. & Nilsson, H., 2005. *Treatment and Disposal Methods for Wastewater Sludge in the Area of Beijing, China,* Beijing, China: Department of Water and Environmental Engineering.

Delice, A., 2010. The Sampling Issues in Quantitative Research. *Educational Sciences : Theory & Practice,* 10(4), pp. 2001-2018.

Department of Environmental of Affairs., 2011. *National Waste Management Strategy.* Pretoria: GCIS.

Edirisingha, P., 2012. *Interpretivism and Positivism (Ontological and Epistemological Perspectives),* Newcastle upon Tyne, UK: Northumbria University.

Encyclopedia, 2008. *A Dictionary of Nursing.* Los Angeles: Oxford University Press.

Evans, T., 2011. *Sewage Sludge: Operational and Environmental Issues,* Marlow , UK: Foundation For Water Research.

Fulazzaky, J., Mohamad, A. & Gany, A., 2013. *Challenges of sludge management in developing countries towards sustainable environment with particular reference to Indonesian condition.* Penang, World Engineering.

Ghazy, M., Dockhorn, T. & Dichtl, N., 2011. Economic And Environmental Assessment Of Sewage Sludge Tretament Processes Application In Egypt. *International Water Technology Journal,* 1(2), pp. 102 - 119.

Goswami, S., Jayant, K. & Ajaygiri, K., 2014. Characterization, Treatment and Disposal of Sludge: A Review. *International Journal for Research in Applied Science & Engineering Technology (IJRASET),* 2(XXI), pp. 516 - 517.

Government Gazette, 2014. *National Environmental Management: Waste Amendment Act, 2014.* Cape Town: Government Press.

Grazia, B., Laura, C. & Librici, V., 2013. Treatment And Disposal Of Sewage Sludge: Comparative. *Environmental Engineering and Management Journal,* 12(11), pp. 7-10.

Hall, J., 2014. Ecological and Economical Balance For Sludge Management Options. *Technology and Innovative Options Related To Sludge Management,* 1(2), pp. 115 - 171.

Harwell, M., 2014. Opportunities and Challenges in Designing and Conducting Inquiry. In: J. P. Bean, ed. *Research Design in Qualitative/Quantitative/Mixed Methods.* Minnesota: Sage Publishers, pp. 147-181.

Herselman, J. & Snyman, H., 2009. *Guidelines for the Utilisation and Disposal of Wastewater Sludge,* Pretoria: Water Research Commission.

Jhansi, S. C. & Mishra, K. S., 2013. Wastewater Treatment and Reuse:Sustainability Options. *The Journal of Sustainable Development,* 10(1), pp. 1-15.

Kandasamy, S. & Vigneswaran, J., 2012. Sludge Treatment Technologies. *Encyclopedia of Life Support Systems,* 2(4), pp. 132-150.

Karimi, A. R. et al., 2011. Selection of wastewater treatment process based on the analytical hierarchy process and fuzzy analytical hierarchy process methods. *Int. J. Environ. Sci. Tech,* 8(2), pp. 267 - 280.

Karius, R., 2011. *Developing an integrated concept for sewage sludge treatment and disposal from municipal wastewater treatment systems in (peri-) urban areas in Vietnam.* Pratzschwitzer: Technische Universität Dresden.

Keirungi, J., 2006. *The Design And Assessment Of An Integrated Municipal Waste Beneficiation Facility,* Grahamstown: Rhodes University.

Kellis, M., 2013. Review Of Wastewater Reuse In The Mediterranean Countries Focusing On Regulations And Policies For Municipal And Industrial Applications. *Global NEST,* 15(3), pp. 333 - 350.

Khalid, U., Sarfaraz, K., Said, G. & Muhammad, L., 2012. Sewage Sludge: An Important Biological Resource fo rSustainable Agriculture and Its Environmental Implications. *American Journal of Plant Sciences,* 2(3), pp. 1708-1721.

Khunene, J., 1998. *The Roles and Responsibilities of Local Government and Related Institutions,* Pretoria: Department of Water and Sanitation.

Kumar, J., 2014. *Research Methodology - A Step by Step Guide.* 3rd ed. Los Angeles: Sage Publications.

Kurbiel, J. & Żeglin, K., 2012. *Trends In Development Of Wastewater Sludge Technology,* Warszawska: Cracow University of Technology.

LeBlanc, R., 2010. *Global Atlas Of Excreta, Wastewater Sludge, And Biosolids Management:Moving Forward The Sustainable And Welcome Uses Of A Global Resource,* Kenya: United Nations Human Settlements Programme.

LeBlanc, R., Matthews, P. & Roland, P., 2010. *Sludge, And Biosolids Management : Moving Forward The Sustanable And Welcome Uses Of A Global Resource,* Kenya: United Nations Human Settlements Programme.

Lucas, G., Benjamin, B., Wagner, K. & Kyna, B., 2013. Estimating On-site Sewage Facility Density and Distribution Using Geo-Spatial Analyses. *Journal of Natural & Environmental Sciences,* 4(1), pp. 14-21.

Marshall, C. & Rossman, G., 2006. *Designing Qualitative Research.* 4th ed. Los Angeles: Sage Publications.

Mema, V., 2012. *Impact Of Poorly Maintained Wastewater And Sewage Treatment Plants : Lessons From South Africa,* Pretoria: Council for Scientific and Industrial Research.

Meozzi, P., 2011. Sludge Treatment and Disposal - Management Approaches and Experiences. *European Environment Agency,* 11(7), pp. 1-9.

Morrison, B., Murphy, D. & Robert, D., 2012. *medical-dictionary.thefreedictionary.com.* [Online]
Available at: http://medical-dictionary.thefreedictionary.com/helminthiasis
[Accessed 25 October 2015].

Movahedian, A. & Bina, M., 2005. Effects of aeration rate and detention time on thermophilic aerobic digestion of mixed sludge and its dewaterability. *International Environ. Sci Tech,* 2(2), pp. 105-111.

Norris, J., 2015. *Umgeni Water Sludge Classification Report.* Pietermaritzburg: Terratest Pty (Ltd).

Northeast Colorado , 2011. *Land Application of Classified Sludge Regulations,* Colorado: Northeast Colorado Health Department.

Nulty, D., 2013. The adequacy of response rates to online and paper surveys: what can be done?. *Assessment & Evaluation in Higher Education,* 33(3), pp. 301-314.

Olivier, J., 1998. *eThekwini Metropolitan Wastewater Management,* Durban: eThekwini Metropolitan.

Organization, W. H., 2015. *Water Sanitation Health.* [Online]
Available at: http://www.who.int/water_sanitation_health/en/
[Accessed 10 October 2015].

Pirofski, L., 2012. *BMC Biology.* [Online]
Available at: http://www.biomedcentral.com
[Accessed 15 October 2015].

Rizzardini, C. & Goi, D., 2014. Sustainability of Domestic Sewage Sludge Disposal. *Sustainability,* 6(3), pp. 2424-2434.

Röhrs, L., Fourie, A. & Blight, G., 2011. Effects of sewage sludge and refuse composition on the rate of degradation and leachate quality of co-disposed waste in a water-deficient environment. *Water SA,* 24(2), pp. 137-145.

Rojas, F., 2012. *Living without sewage in Latin America The Business of Collecting Fecal Sludge in four Latin American Cities,* Guatemala City: World Bank Water and Sanitation program.

Rudd, A., Boxall, B. & Murray, A., 2010. Wastewater Management. *Environmental Health Perspectives,* 120(9), pp. 1222 - 1232.

Sanitation, D. o. W. a., 2012. *Green Drop Progress Report,* Pretoria: Government Communication and Information System.

Saunders, M., Lewis, P. & Thornhill, A., 2009. *Research Methods For Bussiness Students.* 5th ed. London: Prentice Hall Financial Times.

Schindler, D., Cooper.R & Pamela, S., 2013. *Business Research Methods.* 12th ed. New York: McGraw Hill.

Seethoram, C., 2013. Wastewater Treatment and Reuse:Sustainability. *Consilience: The Journal of Sustainable Development,* 10(1), pp. 1-15.

Sekaran, U. & Bougie, R., 2015. *Research Methods for Business.* 6th ed. United Kingdom: John Wiley and Sons.

Singh, A., Masuku, S. & Micah, B., 2014. Sampling Techniques & Determination Of Sample Size In Applied Statistics Research : An Overview. *International Journal of Economics, Commerce and Management, United Kingdom,* 2(11), pp. 1-22.

Smith, S., 2013. Management, Use and Disposal Of Sewage Sludge. *Encyclopedia of Life Support Systems,* 4(13), pp. 1-10.

Snyman, H. G., 2007. Management of Wastewater and Faecal Sludge in Southern Africa. *Research Gate,* 2(1), pp. 81 - 88.

Snyman, H. & Herselman, J., 2009. *Guidelines for the Utilisation and Disposal of Wastewater Sludge,* Pretoria: Water Research Commission.

Stake, R., 2010. *Qualitative Research - Studying How Things Work.* New York ed. New York: Guildford Press.

Strydom, S. & Wilma.T., 2010. *A CSIR perspective Of Water In South Africa,* Pretoria: CSIR.

Tastu, Y., 2009. *Evaluation Of Sludge Dewatering Properties,* Sweden: Water and Environmental Engineering, Department of Chemical Engineering,Lund University.

Umgeni Water , 2015. *2014/15 - Annual Report.* Pietermaritzburg: Umgeni Water.

Westgate, T., 2013. *Detailed Feasibility Study For Sludge Disposal To Existing Lands.* Pietermaritzburg: Hatch - Goba.

William, D.,1984. *Sludge Treatment Processes.* United States Environmental Protection Agency

Yu, C. & Fen, T., 2007. Mixed Methods Sampling: A Typology With Examples. *Journal of Mixed Methods Research,* 1(1), pp. 77-99.

Zohrabi, M., 2013. Mixed Method Research: Instruments, Validity Reliability and Reporting Findings. *Theory and Practice in Language Studies,* 3(2), pp. 254-262.

Appendix 1: Letter of consent from Umgeni Water to conduct the Study

Appendix 2: Questionnaire

Appendix 2: Draft Covering Letter

I am currently registered for MBA Dissertation at University of KwaZulu Natal (UKZN) conducting a research regarding " Wastewater Sludge Management Options For Umgeni Water," for MBA Dissertation under the guidance of a Research Supervisor from UKZN. I am conducting a survey using questionnaires on the topic and require information to complete research methodology and dissertation under the topic chosen.

Enclosed is the questionnaire which will gather data pertaining to this research and will give further insight into wastewater sludge management options available for Umgeni Water. Completion of this questionnaire will take about 15 minutes of your time.

Participation in this research is completely voluntary. All information through your participation in this research will be for study purposes and for improvement when recommendations are implemented. You will not be identified in the dissertation or any research work.

I will appreciate it if you could complete the questionnaire attached, nevertheless please note that you are not obliged.

Thank you in advance for your co-operation in my research.

Yours sincerely

Sikhumbuzo Eric Nene

Survey: Title Wastewater Sludge Management Options For Umgeni Water

SECTION A: Demographic Information

Please tick with an X or (√) in the box with the appropriate response. Mark one box only

1. **How long have you been working for your company ?**

	Results	
0-1 year		
1-5 years		
5-10 years		
10-15 years		
15 or more years		

2. **What is your age?**

Below 20 years	
20-29 years	
30-39 years	
40-49 years	
50-59 years	
60 years and over	

3. **What is your highest qualification?**

Below matric	
Matric	
Certificate	
Diploma	
Undergraduate Degree	
Post graduate Certificate	
Honours / BTech	
Masters	
PhD	

SECTION B: Wastewater Sludge Knowledge

This section measures your knowledge towards wastewater sludge understanding.

Please put a cross (X) or (√) in the appropriate box to rate your level of agreement or disagreement. Mark one box only.

No	Item	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree
1	There is a need for developing strategic approach towards global impact on the environment.					
2	Wastewater treatment plant (WWW) forms part of an ecological system					
3	Sludge is a by-product from wastewater treatment and its disposal is one of the most challenging environmental problems in waste water treating processes.					
4	Different wastewater treatment process will result in different sludge produced.					
5	Sludge management and disposal is governed by Legislation					

SECTION C: Sources of Sludge

This section measures the understanding of sources of sewage inflows that results in sludge

Please put a cross (X) or (√) in the appropriate box to rate your level of agreement or disagreement. Mark one box only.

No	Item	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree
1	For your Treatment Plant do you know the origin for the influent you are receiving					
2	The influent received is purely domestic.					
3	The influent received is industrial					
4	There is a split between domestic and industrial in the influent					
5	Knowing the source of influent can enhance sludge treatment and disposal					
6	Company strategy provides greater value and productivity with regards to sludge management.					

SECTION D: Sludge Treatment Process

Sludge is treated by various processes that can be used in various combinations.

D 1: Please put a cross (X) or (√) in the appropriate box to indicate Preliminary Operations sludge treatment for your Treatment Plant.

No	Item	Sludge Grinding	Sludge Bending	Sludge Storage	Sludge Degritting
1	Darvil WWW				
2	Howick WWW				
3	Mpofana WWW				
4	Richmond WWW				
5	Cool-Air WWW				
6	Lynnfield WWW				
7	Ixopo WWW				
8	Appelsboch				

D 2: Please put a cross (X) or (√) in the appropriate box to indicate Thickening sludge treatment for your Treatment Plant.

No	Item	Rotary Drum Thickening	Gravity Thickening	Floatation Thickening	Centrifugation
1	Darvil WWW				
2	Howick WWW				
3	Mpofana WWW				
4	Richmond WWW				
5	Cool-Air WWW				
6	Lynnfield WWW				
7	Ixopo WWW				
8	Appelsboch WWW				

D 3: Please put a cross (X) or (√) in the appropriate box to indicate Stabilization for treated sludge for your Treatment Plant.

No	Item	Heat Treatment	Lime stabilization	Anaerobic Digestion	Aerobic Digestion
1	Darvil WWW				
2	Howick WWW				
3	Mpofana WWW				
4	Richmond WWW				
5	Cool-Air WWW				
6	Lynnfield WWW				
7	Ixopo WWW				
8	Appelsboch WWW				

D 4: Please put a cross (X) or (√) in the appropriate box to indicate Conditioning for sludge treatment for your Treatment Plant.

No	Item	Chemical Conditioning	Heat Treatment	Elutriation
1	Darvil WWW			
2	Howick WWW			
3	Mpofana WWW			
4	Richmond WWW			
5	Cool-Air WWW			
6	Lynnfield WWW			
7	Ixopo WWW			
8	Appelsboch WWW			

D 5: Please put a cross (X) or (√) in the appropriate box to indicate Disinfection for treated sludge for your Treatment Plant.

No	Item	Long Term Storage	Pasteurization
1	Darvil WWW		
2	Howick WWW		
3	Mpofana WWW		
4	Richmond WWW		
5	Cool-Air WWW		
6	Lynnfield WWW		
7	Ixopo WWW		
8	Appelsboch WWW		

D 6: Please put a cross (X) or (√) in the appropriate box to indicate Dewatering sludge treatment for your Treatment Plant.

No	Item	Drying Bed	Lagoon	Centrifuge	Belt Presses
1	Darvil WWW				
2	Howick WWW				
3	Mpofana WWW				
4	Richmond WWW				
5	Cool-Air WWW				
6	Lynnfield WWW				
7	Ixopo WWW				
8	Appelsboch WWW				

D 7: Please put a cross (X) or (√) in the appropriate box to indicate Sludge Disposal Method for your Treatment Plant.

No	Item	Landfill	Land Application	Reclamation	Reuse
1	Darvil WWW				
2	Howick WWW				
3	Mpofana WWW				
4	Richmond WWW				
5	Cool-Air WWW				
6	Lynnfield WWW				
7	Ixopo WWW				
8	Appelsboch WWW				

Wastewater Sludge Management Options For Umgeni Water

By

Sikhumbuzo Eric Nene

Research Proposal submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School Business and Leadership

2016

Appendix 3: Ethical Clearance Letter

Appendix 4: Turnitin Report