UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACTORS AFFECTING COMPLIANCE OF WASTEWATER MANAGEMENT: A STUDY ON WASTE WATER SYSTEM OPERATIONS IN THE CITY OF TSHWANE, GAUTENG

Juliet Ramathabathe Mmotong

Student Number: 1905685

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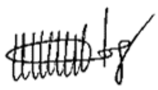
School of Geography, Archaeology and Environmental Studies

Supervisor:

Dr Nzalalemba Serge Kubanza

DECLARATION.

I am declaring this dissertation as my own independent work. I further declare that the work fully acknowledges other works used to draft the report. This dissertation for the degree of Master Science in Environmental Science was not used elsewhere to obtain another qualification.



Juliet Ramathabathe Mmotong

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ABSTRACT

Wastewater Treatment Plants (WWTPs) are likely to collapse, the state of water continues to deteriorate, and rivers remain polluted. Wastewater Operational System are now at the centre of economic value systems expected to drive towards sustainability. Factors affecting compliance with wastewater management in the growing City of Tshwane, Gauteng, were investigated to realise wastewater as a valuable resource where other valuable resources can be harnessed. This dissertation explored professionals' perspectives regarding factors affecting wastewater management compliance in the City of Tshwane (CoT).

The research report explored what professionals perceive as challenges that affect compliance at their workstations and their views on which changes can be introduced. The primary objective of the study is determining the elements responsible for challenges to a complying facility; challenges with the current governing wastewater legislation toward realising efforts for a new paradigm shift. Among others, the findings revealed a shortage of staff, a lack of consumables for effluent monitoring, and maintenance irregularities contributing to the shortfalls in achieving complying wastewater. As pollution of the water resource has become a national challenge where treatment plants must continue doing the intended work, the need to explore new technologies that can assist in treatment efficiencies in the City of Tshwane is discussed. Although there was dissatisfaction with the Green Drop incentive programme, with correct consistencies and proper championing, it was found to instil a positive attitude in professionals.

Keywords: City of Tshwane; Green Drop programme; wastewater; wastewater management

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DEFINITION OF KEY TERMS

WASTEWATER -can be a combination of raw sewage and effluent from treatment plants derived from dissolved or suspended matter from domestic, industrial and storm water

WASTEWATER MANAGEMENT is defined as the collection, treatment, and discharge of effluent with little to no impact on the receiving environment

COMPLIANCE can be defined as conformance to norms and standards

WASTEWATER OPERATION SYSTEMS- includes an array of technologies at different stages of primary, secondary, tertiary, and advanced treatment that are capable of household and commercial sewage treatment

OPERATIONS- Refer to wastewater sections involved in the actual operations of wastewater treatment plants

OPERATIONS MANAGEMENT- Refer to section of treatment plant involved in the management of wastewater treatment plants

MONITORING- Process and section assigned to monitor (and analyse) the operational and effluent compliance of wastewater against set standards

EFFLUENT- Treated wastewater discharged from treatment plants into receiving water bodies

EFFLUENT COMPLIANCE- the state of compliance and non- compliance of treated wastewater against effluent standard limits

GREEN DROP PROGRAMME – An incentive based programme launched by the Department of Water and Sanitation to monitor operations of Wastewater Treatment Plants across the country

CENTRALIZED SYSTEMS- typically involves large collection pipes for collection and treatment of wastewater

DECENTRALIZED SYSTEMS- smaller systems that treat wastewater near point of sourc

CHAPTER 1

Introduction

1.1 Overview

This dissertation is focused on a study that sought to explore professionals' perspectives regarding factors affecting wastewater management compliance in the City of Tshwane (CoT), Gauteng, South Africa. The research report explored what professionals perceive as challenges that affect compliance at their workstations and their views on which changes can be introduced. Wastewater Treatment Plants (WWTPs) are likely to collapse, the state of water continues to deteriorate, and rivers remain polluted. There is ground-breaking legislation that can achieve extensive desirable outcomes; however, there is less platform (unless through scholarly research) to professionals involved in day-to-day operations to express views that can guide legislation to better implementation.

The prominence of sustainability narratives leads to operations being viewed sustainably. Change, whether or not intended, is unavoidable. On the other hand, resilience narratives have positioned well in the research space. Among others, bouncing back, recovery and individual traits have all been used to describe resilience (Liu, Reed & Girard, 2017). At the centre of this narrative is an economic value system, including wastewater operational systems. To contribute to this line of research, this study sought to explore the views of professionals with the courage that wastewater treatment plants can be viewed as valuable resources, especially as wastewater management now forms part of the circular economy. WWTPs located in the CoT were used in this study to understand these perceptions in the context of wastewater management and its compliance.

1.2 Introduction

There are several ongoing discussions held regarding the use of current natural resources, including water, with idea that do not undermine current need and will not deprive future generations on their needs. The witnesses to unplanned population growth in most cities worldwide have shown that natural water bodies receive a significant volume of treated and untreated wastewater (Foster, 2017). Many arguments have pointed out that untreated wastewater eventually leads to disorder and chaos if not managed through compliance (Hao et al., 2022). In some developing countries, a large percentage of the population lacks access to clean safe water, exposing them to water-related diseases (Dungeri, van der Merwe & Momba, 2010). While some of the problems can be circumvented, the reality remains that water plays a fundamental role in life and socio-economic development (Dungeri et al., 2010). This cements the magnitude and impact wastewater compliance has on the entire water course as its quality determines its usability. It is in this context that institutions and global policies must prioritise existing and future wastewater infrastructure systems, together with guidelines that support operational compliances (Ruiters & Matji, 2015).

For sub-Saharan African (SSA) countries, clean water is a major need, particularly because of its significance on local economies (Onu et al., 2023) Apart from the above, wastewater management is a challenge that requires attention. Population expansion has led to poorly treated wastewater paving the way for water pollution in various regions. As an example, SSA suffers from waterborne diseases emanating from raw wastewater reaching the environment, insufficient management of effective wastewater treatment, and reduced water quality (Onu et al., 2023). Treatment plants from paint industries compromise the quality of the water bodies. In Nigeria, it was revealed through a non-compliance analysis illustrating the high pollution levels introduced to the environment (Aniyikaiye et al., 2019). In Rwanda, one treatment plant was non-compliant and closed operation as an order from the Ministry for deliberately discharging untreated effluent.

South Africa is no exception when deliberating on wastewater compliance problems. The country's wastewater infrastructure failures contribute to the contamination of water, theft, and vandalism that have taken precedence, the misuse of wastewater treatment infrastructure, poor performance and insufficient wastewater treatment, which are the factors leading to wastewater management (Ntombela et al., 2016). According to the National Water Resource Strategy (NWRS), the management of wastewater is placed at the bottom of the water value chain under regional water institutions (Pillay, 2017). Compliance issues still feature as factors that threaten the goals of sustainability. Its water legislation remains ground-breaking; however, lacks implementation and enforcement, especially with regard to non-compliance.

1.3 Brief Overview of South Africa's Water Resource Challenge

South Africa is regarded as a water-scarce country. The country currently faces challenges of growing water demands due to an increasing population. Incorrect design of process operations contributes to the water challenges due to lack of efficient management. (Pillay, 2017). In their study, Coulibaly et al., (2016) predicted that soon secondary cities in developing countries will be faced with major population growth where they will compete for access to potable water and sanitation services (Coulibaly et al., 2016). The country further has an emerging challenge in the form of governance, which is aggravated by the uneven distribution of water. This gives rise to incidents of conflict over water use in water-scarce areas. Nsubuga, Namutebi and Nsubuga-Ssenfuna (2014) highlight that the migration of people in search of water and vegetation creates a transfer of diseases from one area to another. The unstable seasonal rainfall has significantly affected economic activities that depend heavily on rainfall (Nsubuga et al., 2014). South Africa is also prone to water conflicts. On the other hand, demand is by far greater than anticipated. Therefore, Pillay (2017) insists that these challenges inspire the need to understand institutional frameworks and, therefore, contributing challenges cannot be underestimated (Chepyegon & Kamiya, 2018). The challenges around water resources are further exacerbated by invasive non-native plant species. The attempts to manage them in cities are often controversial due to the diverging views of the stakeholders involved (Gaerlner et al., 2016).

Climate change has a significant impact on water resource management. There is consensus that the increase in atmospheric pressures will result in climate imbalances and will cause sea levels to rise, as well as increase the frequency of extreme climatic conditions such as storms (Kusangaya et al., 2014). These studies, and several others, show that climate change will have an impact on the availability of water. In another study conducted by Vollmer et al., (2018), it is suggested that water insecurity has caused a degradation of freshwater ecosystems and several services that are derived from them. It is also suggested that the management of freshwater systems needs to consider how humans benefit from the use of water, and maintaining the freshwater ecosystems and structures that govern them. They conceptualised freshwater resources as part of an integrated socio-ecological system in which a set of corresponding indicators to monitor freshwater was developed. In conclusion, the socio-ecological framework presented, and associated indicators, take into account the relationship between governance, stakeholder engagement and the ecosystem services they provide. The paper also highlighted that local pressures are high whereas the integrated management was weak in the area explored (Vollmer et al., 2018).

Therefore, in consideration of the above, solutions to wastewater problems depend on many factors such as processes through which water is managed, the treatment of water and the recovery of wastewater through which the final product is returned to rivers, competence and capabilities of the institutions (private and government) that manage them, regulation mechanisms, and the heed to compliances by institutions or water service authorities that govern water and wastewater services.

1.4 Rationale

Insufficient wastewater treatment is often referred to as the main cause of pollution in South Africa. According to Dungeri et al., (2010), the majority of WWTPs are not efficient in removing unwanted pathogens from the effluent (Dungeri et al., 2010). Considering the notion that compliant wastewater effluent remains a key influence on the spread of wastewater-borne diseases, current practices have threatened to prove otherwise. An existing regulatory mechanism facilitates enforcement and compliance of wastewater; however, non-compliance challenges persist (Ntombela et al., 2016). Furthermore, effluent standards are presently used to regulate the quality of discharge effluent (DWA, 2022), leaving a gap to explore the challenges in the wastewater arena through the lens of professionals on the ground. Several studies have looked into assessing microbial indicators in wastewater and some have been focused on evaluating the effectiveness of policies regulating wastewater operations; however, fewer studies have provided a platform for professionals to express their views and knowledge regarding the challenges faced in wastewater sectors, leaving an ample margin for engagement.

1.5 Problem Statement

According to reports released in 2008 by the Department of Water and Sanitation (DWS) on the performance of WWTPs, 96% were not functioning according to operational procedures (Foster, 2017). The non-compliant effluent that is released into rivers and lakes causes serious pollution and water contamination (Foster, 2017). Pollution of these rivers can be attributed to the non-functioning infrastructure, incorrect operations, and lack of available disinfectants. It is important to recollect that overall water quality in South Africa is declining, the demand for water availability is rising, and pollution has become a dangerous challenge to water resources (Adom & Mulala, 2021). Several policies for water management have been reformed to bring about access to water; however, the implementation to enforce pollution remedies and penalties has become unsuccessful as many were thought to be fragmented, unclear and silent on addressing water quality decline challenges (Adom & Mulala, 2021).

Failure of functioning treatment plants to produce a complying effluent of high-quality standards is a grave concern, especially as pollution depletes water bodies (Dungeri et al., 2010). The role of WWTPs in the transmission of diseases and depletion of water resources tends to be forgotten as many studies have primarily focused more on water quality issues and water provision initiatives (Dungeri et al., 2010). The prominent role of treating wastewater is to remove pathogens to comply with standards, assuring the protection of water resources and the reduction of costs relating to further treatment. For many of these facilities, various ways exist to monitor compliance wih effluent standards, yet other treatment facilities are unable to monitor them. In light of challenges to wastewater management, this study proposes to investigate factors that contribute to non-compliance and whether existing policy gives provision to adopt wastewater management alternatives. The study explores the following set of questions:

i. What factors affect compliance with wastewater management in the CoT?
ii. Which existing policy documents govern wastewater management in the CoT?
iii. What can be done to enforce compliance with wastewater management in the CoT?

1.6 Aims and specific objectives

The main overriding aim is to investigate the factors affecting compliance with wastewater management in the CoT, taking into account the perceptions of selected professionals involved in day-to-day operations. The following aims are employed to investigate the research questions:

i. To examine factors affecting compliance with wastewater management in the CoT;
ii. To review existing policy documents governing wastewater management in the CoT; and
iii. To determine ways in which compliance with wastewater management can be improved in the CoT.

CHAPTER 2
Conceptual Framework and Literature Review

2. Overview

The study was introduced in the previous chapter. This chapter outlines the literature review conducted.

The concepts of compliance, wastewater, and wastewater management, as well as their definitions in the current stance in the field of research, are introduced in the first section. factors affecting compliance with wastewater management in developing countries and how developing countries are on track with wastewater management are also presented. It is further extended to factors affecting compliance from an SSA point of view and, lastly, a detailed review is provided on the application of wastewater management in South Africa. As wastewater systems were designed with public health at the centre of protection, the effects of untreated/poorly wastewater on the general public are discussed briefly. The chapter concludes with the significance of the literature review conducted.

2.1 Theoretical Framework

Resilience Theory in Wastewater Management- There is a growing interest to incorporate the concept of resilience into wastewater management (Juan-Garcier et al., 2017). Initially, resilience was introduced to understand how systems can withstand disturbances and still retain and return to its original function (Holing, 1973), later, they referred resilience as the ability to bounce back to its equilibrium state upon perturbations (Holing, 1996). Following the above said, a system has a threshold that can be exceeded, which may be reversible or not irreversible (Gooch, Butler, Cullen-Unsworth, Rigano & Manning, 2012).

The contexts in which resilience can be explored and defined are diverse. It can be defined as the ability of communities to withstand shocks and perturbations (Saunders & Becker, 2015), and the ability of communities to display resistance (Douxchamps, Debevec, Giordano, & Barron, 2017). Naturally, an organisation cannot, or would not, be sustainable without the presence of resilience, as it is susceptible to continuous changes or may be derailed from providing a certain service.

The impact of consensus on the definition of resilience and elements of assessment has however, hindered the application of resilience in wastewater management (Juan-Garcier et al., 2017). The author stated that no framework of resilience is completed and is inclusive of stressors encountered by the system and the metrics of measurement directly for wastewater practitioners. An area where Nkhata and Breen (2016), expressed that developing metrics and assessments suited for the local contexts are helpful in decision making and defending (Nkhata & Breen, 2016).

The Compliance Framework consists of the instrumental model and legitimate- based motivation models rooted at different motivations (Oyanedel. Gelcich & Milner-Gulland, 2020). The instrumental or deterred model of compliance assumes that actors are prone to weigh the potential costs and benefits of non-compliance. The model states that actors will engage in certain non-compliance behaviours when the benefits outweigh costs. This implies that individuals may attempt to maximise utilising resources due to budget constraints (Oyanedel et al., 2020). The legitimate-based motivation is rooted in the acceptance of decision making where the outcomes motivates actors to comply with regulations. The said model provide basis into measuring and conceptualising legitimacy through procedural legitimacy inclusive of collective decision making, legitimacy of authority detailing how leaders are perceived and outcome of legitimacy which considers the fair and appropriate rules (Oyanedel et al., 2020)

The System Theory involves interrogating systems in any form of its existence be it of nature, society and scientific domain (Mele, Pels & Polese, 2010). The theory allows us to apply a global vision to understand its functioning. Understanding the system from a holistic approach allows prospects to understand the phenomena under study comprehensively (Mele et al., 2010)

2.2 Conceptual Framework

2.2.1 Compliance

Compliance can be defined as conformance to norms and standards (Perlman, Reddick & Demir, 2023) and an approach to evaluate conformity based on directly observable practices (Boos et al., 2022). The broader acceptable definition of compliance means a change in practices at the request of another group (Breckler, Olson & Wiggins, 2006). Furthermore, compliance is a behavioural display of trust and reactance (Brehm, 1966). Boos et al., (2022) recommend that to maximise achievable compliance efforts, designers should prioritise the probability of perceptions and the probability of comprehension to prevent negative effects. Compliance with wastewater can, therefore, be defined as the behavioural actions conducted by personnel to conform with standards, as set out by governing legislation.

Achieving compliance reflects an organisation's commitment to excellence. Internal policies, regular audits and capacity building among staff are some of the aspects that assist organisations in building strong compliance records. Achieving compliance puts an organisation at a better platform to be able to secure funding or contracts and can act as a key performance indicator (Jalundhwala & Londhe, 2023). In this study, compliance with wastewater management regulations is a prime focus. Adherence to prescribed standards, laws and policies is highlighted and accurate reporting is maintained. Non-compliance with wastewater treatment plants can pollute the ecosystem and put public health at risk (Mzantsi, 2021). This makes compliance important for environmental management. Wastewater compliance requirements vary from place to place. In South Africa, wastewater treatment must comply with a plant-specific wastewater treatment licence that stipulates the acceptable discharge limit (Coothen, 2022). This licence is usually based on the general discharge permits and limits as stipulated by DWS.

2.2.2 Wastewater

Wastewater comprises raw sewage and treats effluent from treatment plants derived from dissolved or suspended matter from domestic, industrial and storm water (Agoro et al., 2018). Wastewater effluent discharge can be a contributor to water pollution (Agoro et al., 2018) and, therefore, its treatment effort must be efficient. Moreover, poorly treated wastewater poses significant environmental irritation and pollution owing to its chemical and microbiological constituencies (Bohdziewicz & Sroka, 2006). The Office of Water United States for Environmental Protection declared wastewater systems as being considerate of and catering to the treatment of household and commercial sewage (Chirisa et al., 2017). Chhipi-Shrestha, Hewage and Sadiq (2017) further expatiate that the treatment of wastewater includes an array of technologies at different stages of primary, secondary, tertiary, and advanced treatment (Chhipi-Shrestha et al., 2017). A typical wastewater treatment process is explained in Table 2.1.

Table 2.1 A typical wastewater treatment plant

Stages	Process Description
Wastewater collection	Wastewater is typically collected from industries, businesses, homes and sometimes storm waters and transported to a treatment plant (Kumari et al., 2023)
Pre-treatment	This process removes unwanted objects that can harm the treatment plant like rags, plastics and other large items. Processes like screening and grit removal are some of the pretreatment stages of wastewater treatment (Ahmed et al., 2021)
Primary treatment	This process can be by primary clarification or sedimentation where solids in the water settle at the bottom and water floats at the top. This process normally assists in reducing the organic load of wastewater (Rezai & Allahkarami, 2021)
Secondary treatment	Common methods used for secondary treatment include trickling filters where wastewater is sprayed over a bed of media for biofilms of microorganisms to break down organic matter. Biological Nutrient Removal removes eutrophication causing nutrients in wastewater to prevent eutrophication of receiving water bodies whereas the activated sludge process involves aerobic microorganisms breaking down organic pollutants in aeration tanks, with air continuously supplied to sustain microbial activity (Darra et al., 2023).
Advanced treatment	The remaining nutrients, chemicals or bacteria from the secondary treatment are treated by processes like filtration, disinfection, or nutrient removal.
Sludge treatment	The sludge is treated to stabilize it and reduce its water content. Processes like digestion, thickening and dewatering are used, sometimes even disposal by incineration or landfill (Di laconi et al., 2020).
Recycle and reuse	This process includes using treated wastewater for other functions like agricultural irrigation, industrial processes and sometimes drinking water if the water is treated using advanced technology (Chauhan & Kumar, 2020)

Finally discharge or disposal	This stage is when water meeting the discharge limit is disposed into the environment like rivers to ensure that the water does not harm the receiving environment or public health (Ahmed et al., 2021).

2.2.3 Wastewater Management

Pollution emanating from wastewater effluent as an ongoing challenge has institutions considering wastewater management initiatives. Effluent wastewater management involves the collection, treatment, and discharge of effluent with little to no impact on the receiving environment (Larsen, 2015). In succinct wastewater management is the collection, treatment, and reuse of wastewater. These definitions are evidenced through a variety of strategies or initiatives. As an example, Minimal Discharge Liquid (MDL) and Zero Discharge Liquid (ZDL) are possible strategies for wastewater management as they allow the elimination of wastewater discharge while recovering extra freshwater (Sionkowski, 2023). Although rainwater ingress can pose a challenge to wastewater management in the sewer system and even overwhelm the capacity of treatment plants (Sionkowski, 2023), devices that can detect and monitor rainwater ingress have proven to be essential in their utilisation.

The success of wastewater management is dependent on the strategies that promote and consider the conservative use of available resources and the protection of public health (Karri et al., 2024). Among the strategies are efficient wastewater treatment, wastewater reuse and recycling, energy efficiency at treatment plants, nutrient recovery from possible banks, and improving aeration efficiency in treatment plants to aid in minimising greenhouse gas emissions (Larsen, 2015).

Wastewater management involves competent wastewater system operations that are crucial to protecting the environment and the people living in it. They aid in compliance with regulations, prevention of pollution, and promotion of sustainable water resource management. Wastewater systems assist with resource recovery and the promotion of a circular economy while supporting urbanisation and economic growth. Effective wastewater treatment systems dilute the microbial load of water, eliminate contaminants from sewage, assist in harnessing potential nutrients from sewage, and ensure that the water released to the rivers is safe for the ecosystem (Ngo et al., 2024) (see Figure 2.3).

Protection of Public health	• Waterborne diseases like Cholera, dysentery, typhoid are removed before water is released to the environment .
Protection of the environment	• Effective operations ensures that wastewater is treated free from nutrients and safe to protectect the ecosystem.
Compliance with Regulations & preventing Pollution	• A complying effluent entails that regulations are adhered to while preventing pollution.
Resource Recovery	• Advanced wastewater treatment systems are able to recover energy, nutrients and water thereby reducing the environmental impact
Economic Growth	• Poorly operated wastewater systems are costly to maintain, repaire and use. efficient operations reduce operational costs and extend lifespan of the infrastructure.
Sustainable Water Resources Management	• Effective wastewater systems contributes to sustainable water resource management by enabling water recycling and reuse.

Figure 2.1: Importance of effective wastewater system operations, (Ahmed et al., 2021; Kumari et al., 2023).

2.3 Factors Affecting Compliance of Wastewater Management in Developing Countries

It was predicted that 55% of the population around the world live in cities, and an estimated 70% rise would rise (United Nations, 2018). The population growth has worsened the situation uncovering poor management of water resources (Zubaidi et al., 2020). Many nations are over-burdened with a plethora of wastewater challenges, and now managing wastewater efficiently is becoming the prime focus. To achieve and introduce alternative initiatives, a parading shift from the centralised system of operation due to various irregularities and non-compliances must be adopted (Chirisa et al., 2017).

The general public acceptance of water reuse is still low in many areas. This could be because knowledge is not easily available to them. The success of this new technologies and application methods are dependent on public acceptance. It is therefore crucial that the general public is made aware and informed on how the new changes are able to preserve water. It was revealed that both gender have a problem with reusing wastewater (Buyyukkamaci & Alkan, 2013). Their concerns were mostly centred on the health impacts of the wastewater being reused (Buyyukkamaci & Alkan, 2013). Acceptance must be encouraged on the reuse of greywater and mixed wastewater. As the likelihood of households accepting grey and mixed wastewater is influenced by gender, it highlights the difficulties that one could encounter concerning public acceptance (Mu'azu & Blaisi, 2020). Considering the aforementioned, public acceptance of wastewater reuse and its value to the country's economy provides a higher chance of planned projects being successful and accepted.

Unlike developed countries, developing countries are facing challenges regarding maintaining centralised wastewater treatment systems. Agarwal, Darbar and Saha (2022) describe wastewater management as the process of collecting wastewater in a central place, treating it, and reusing it for activities such as agriculture, industry and domestic use, or simply disposing of it. These processes are important to protect the general environment from wastewater and highlight the significance of complying effluent. Treatment of wastewater can be physical, where solids are removed without the use of chemicals (Ahmed et al., 2021), for instance, the processes of screening, sedimentation, aeration and filtration. Another process is chemical treatment where different chemicals, such as chlorine, are introduced into the water to eliminate bacteria (Ghazal et al., 2022). Another common treatment is biological where microorganisms are introduced into wastewater to decompose organic matter using an aerobic or anaerobic system (Etsuyankpa et al., 2024).

In developing countries, most of the sewerage systems have been built as separate systems and are not well maintained (Beard et al., 2022). For some, the systems are pressured by the growing population or the extension of infrastructure because of urban settlements. Owing to this, the separate systems result in cross-connecting sewage and surface run-off pipes. The results of such occurrences are sewage and surface run-off water being released back into the water cycle before it can be treated. When there are ineffective sewerage systems, it is difficult to correctly quantify the amount of wastewater that is released into the rivers (Bentes et al., 2022). Old and decaying infrastructure increases the severity of the problem, because during pipes break, water infiltrates into the sewage pipes and then exfiltration into the groundwater, causing the contamination of drinking water supplies.

The process of treating wastewater can be divided into eight stages, namely collection, pre-treatment, primary treatment, secondary treatment, advanced treatment, sludge treatment, recycling and reuse, and discharge or disposal (Agarwal et al., 2022).

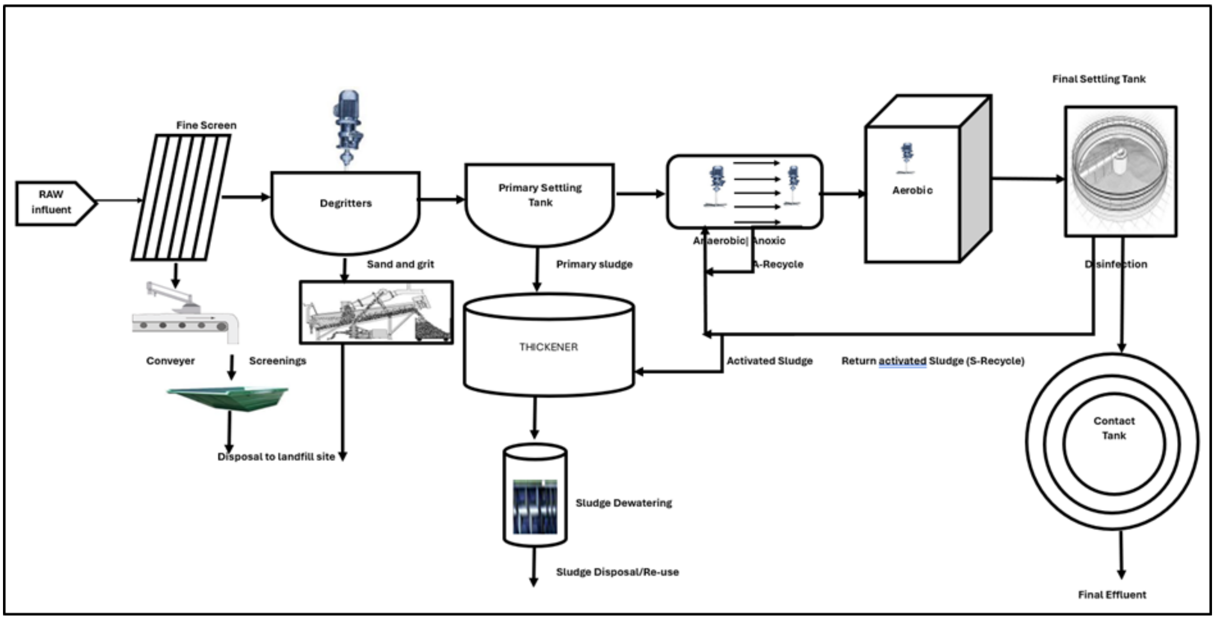

Figure 2.2: Typical wastewater treatment plant flow diagram, (Majumder et al., 2019)

Treating wastewater improves the quality of the water to lower harmful levels and to acceptable limits for intended reuse or reduces the environmental impacts of wastewater (Agarwal et al., 2022). Treated wastewater can further provide a sizeable source of clean water for the supplement of river flows, specifically where there is less water available in quantity t. Untreated wastewater has threatened the health of aquatic ecosystems and their species. Wastewater has been identified as a reliable and economical source of freshwater, specifically for agricultural purposes (Khan et al., 2021). However, wastewater remains an “untapped” and “undervalued” resource. Treated wastewater can be used for groundwater restoration, assisting in conserving the sustainability of freshwater withdrawal from groundwater into the future (Scanlon et al., 2023) much of which remains unexplored. Additionally, wastewater treatment can further improve river health, water quality and ecosystem health.

2.4 Factors Affecting Compliance of Wastewater Management in Sub-Saharan Africa

In many SSA countries, wastewater management is a fast-growing challenge requiring sustainable solutions. To mitigate this, policies and initiatives for the protection of public health must be willing to embrace discussions around wastewater management. Governments of SSA countries must invest in wastewater management projects (Onu et al., 2023). The industrial expansion has led to gradual metal pollutants enlarging the challenges of industrial cities in the SSA region as metals such as Cr and Zn from factoring effluents exceeded effluent guidelines (Zinabu et al., 2018). Owing to wastewater association with diarrhoea outbreaks, wastewater interventions must start at the household level (Ali & Gujiba, 2023). The impacts of these household interventions (although scarce) on public health were evidenced through the reduction of diarrhoeal morbidity (Ali & Gujiba, 2023).

Despite threats of wastewater to public health and ecosystem services, nutrients and organic matter can be harnessed into useful resources, for example, harnessing CO2 from treatment plants aids in the reduction of greenhouse gas emissions (Larsen, 2015). Larsen (2015) further asserts that C02-neutral treatment plants are achievable while recovering energy sources such as COD, nutrients, and energy (Larsen, 2015). Arthur (2022) conducted a study in Ghana, evaluating an anaerobic sludge blanket reactor coupled with trickling filters on its performance and methane production. Data were collected for 35 weeks and the results showed that efficient technology can be used for sustainable wastewater management (Arthur, 2022). Countries within the region generally use centralised systems (Foster, 2017). Several cases of non-complying effluent can be attributed to the type of system utilised; hence, alternatives must be considered alongside current operating practices. The incorporation of decentralised alternatives is a suitable option for wastewater management in SSA countries, with acceptance and public awareness being some of the criteria to articulate discussions with actions that occur in reality (Chirisa et al., 2017).

Some SSA countries lack adequate wastewater collection and treatment facilities; and rely on on-site systems for their sanitation (Chandana & Rao, 2022). Many people still use unimproved facilities such as pit latrines despite the adoption of septic systems. In selected towns of Ethiopia, 17% of households were found without toilet facilities, while 5% practised open defecation. A total of 20% have flush toilets, 42% use vacuum tracks for emptying and 37%

dump waste outside their premises (Adugna, 2023). In Zambia, 40% of the population has access to sanitation, of which the majority are people in urban areas (Nyambe, Agestika & Yamauchi, 2020).

Sound wastewater management requires an effective collection system. Some countries do not have a reliable off-site centralised treatment facility and some of those who have a collection system, have poor maintenance. Poor planning of the collection networks, old and decaying networks, poor installation of systems, systems that do not have resistance to storms and other related issues, ineffective maintenance and operation, and a minimal solid regulatory framework are some of the main reasons for not having good wastewater management.

In rural areas, pit latrines are used without the need to empty them, since the waste will gradually percolate the soil and, once full, they can be filled with soil and abandoned. (Mafuku, Musakwa & Chirisa, 2023). However, the risk of polluting groundwater remains high. In SSA areas at least 2,4 billion people use on-site systems that generate faecal sludge that does not get treated (Chandana & Rao, 2022). Some common issues with on-site systems include the containment systems not being adequately constructed, which makes emptying challenging; illegally dumping wastewater into water resources and landfill sites, and a lack of sludge treatment facilities (Chandana & Rao, 2022).

Improving inexpensive wastewater management provides opportunities for both pollution decrease and clean water supply growth, while concurrently promoting sustainable development and supporting the evolution to a circular economy (Jones et al., 2021). It is reported that the majority of populations have no proper way of disposing of greywater and blackwater (Akter, 2022), which is one of the pressing issues that has dragged wastewater management and the protection of public health. Poorly treated domestic wastewater has high pathogen concentrations, posing a health challenge as communicable diseases can be spread easily. Early contact with untreated wastewater and consuming contaminated drinking water can cause disease and death. Approximately 1,45 million people die annually due to diarrhoea and at least 50% of these deaths are due to poor sanitation (WHO, 2024).

2.5 Factors Affecting Compliance of Wastewater Management in South Africa

The Gauteng province alone is faced with numerous challenges. As an example, there are challenges in meeting the demand of water, worn-out infrastructure, budget issues, and to an extent inadequate solid waste management. The situation is worse because of rapid population growth (Zubaidi et al., 2020). Sound management of its municipal wastewater system is essential to sustain the city and its compliance (Zubaidi et al., 2020). Wastewater management currently falls short of responsive and adaptive strategies many of which are able to create jobs and grow the economy (Ward & Mutombi, 2018).

Challenges to achieving a suitable and progressive management of wastewater continue to scourge in the Gauteng province. This finding was reported by the Gauteng City-Region Observatory. (i) Pursuing demand or supply measures in an interconnected manner – this is because Gauteng's per capita water use is high and must be reduced (ii) Effective Institutions – there are no sufficient wastewater institutions governing the operations of wastewater (CGRO, 2019). Further to this, municipalities are not prioritising efforts to introduce treatment and reuse measures but rely on supply from Rand Water alone. (iii) Stormwater management and subsequent risk of flooding fall under the responsibility of municipalities. The relevant department has to account for reduced flooding risks and the efficiency of wastewater treatment plants that accommodate the treatment of stormwater, (iv) Water Quality- cities are a major polluter of water resources, much of which is due to inefficient treatment of wastewater (CGRO, 2019). In short, municipalities in South Africa carry the mandate to manage wastewater treatment infrastructure challenges and compliance.

2.5.1Technical Challenges

Wastewater treatment systems can face challenges such as nutrient removal, emerging contaminants like micro plastics and pharmaceuticals, high energy consumption, and the costs of advanced treatment technologies (Ahmed et al., 2021). In many wastewater treatment facilities, the most prominent risk is often surpassing their design capacity, having dysfunctional processes, inefficient disinfection equipment and consumables, lack of flow monitoring devices, and non-compliance in the treatment of sewage and sludge (Zhang et al., 2024). When treated effluent does not meet the necessary discharge standards, particularly on bacteriological parameters, there is a potential health risk for downstream users of water, and it may weaken the receiving ecosystems.

In South Africa, it is estimated that over R8 billion is needed to clean up the wastewater crisis and achieve compliance (Daily Maverick, 2022). The 2022 Green Drop Report reported that 39% of South Africa's WWIP were in a critical state, 24% in poor condition, 22% on average and only 11% good (DWS, 2022). The report painted a critical state of water pollution released into rivers. The poor quality of water disposed has a ripple effect on water quality in lakes, rivers, wetlands and groundwater. The majority of SA's rivers and wetlands ecosystems are at risk of pollution. This can cause further natural disasters as these systems play a crucial role in supporting ecosystem services such as drought mitigation, flood control, and nature-based water treatment.

2.5.2 Aging Infrastructure

Infrastructure can present a significant challenge when limited or when it is ageing. Many wastewater treatment facilities are affected by one or many of the following challenges that affect the performance, efficiency, and reliability of wastewater treatment systems. Ageing infrastructure poses more than technical issues, it also impacts finance and environmental challenges. Several wastewater systems were erected about 30 years ago when the population in the urban areas was smaller than today's population, and when many communities used pit hole toilets (King et al., 2018). A major noticeable problem is that wastewater systems were not upgraded to adapt to the increase in population. Hence, population increase has affected the design capacity of these systems.

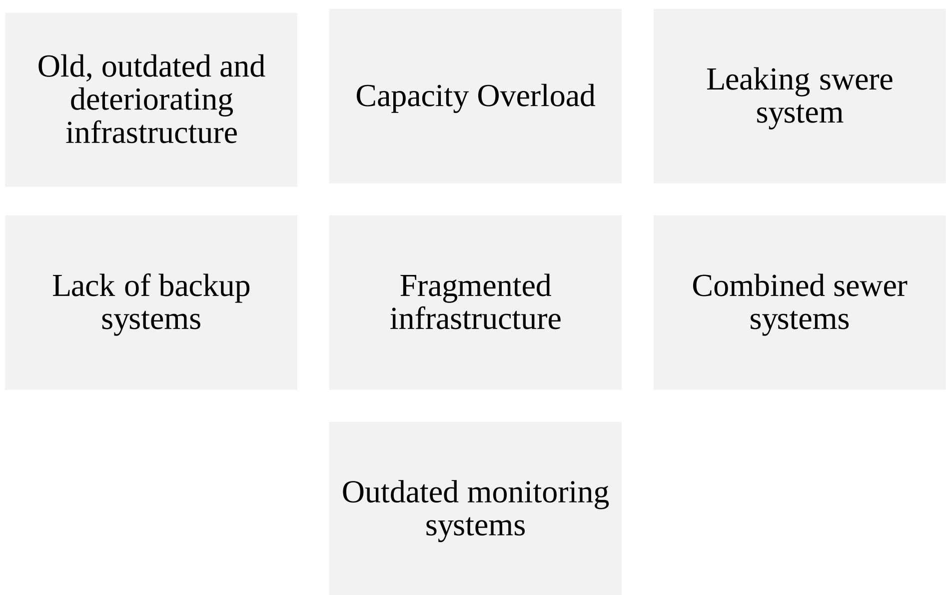

Figure 2.3: Typical wastewater treatment plant challenges (King et al.,2018)

Many WWTPs in South Africa were constructed over 30 years ago with many having exceeded their intended lifespan (Montwedi et al., 2021). Over time, pipes and pumps wear and tear, causing leaks and potential breakdowns with many not having backup systems. The ageing pipelines may crack and leak, contaminating the surrounding environment. Owing to urbanisation and population growth, many wastewater treatment plants are operating over their capacity, overwhelming the systems, especially during heavy rains. Many of the wastewater treatments, such as tricking filters, do not have the technology to treat emerging contaminants.

2.5.3 Financial challenges and compliance

The cost of wastewater management can vary based on the type of system, scale and specific requirements needed for that system to function. Infrastructure, operation and maintenance, regulatory compliance and monitoring energy costs, and upgrade and rehabilitation costs are some of the costs associated with wastewater management systems (Corominas et al., 2020). Research shows that South African municipalities' budgets make provision for wastewater management maintenance; however, these funds are most often inadequate (Motsoeneng, 2022; Bikam & Chakwizira, 2021). In SA, resource-related factors include ageing infrastructure, a lack of maintenance, the outsourcing of repairs, the theft of equipment, budget, and a lack of resources.

2.5.5 Skill Gap and Workforce Shortage

The skills gap and lack of capacity have been identified by Montwedi et al., (2021) as one of many challenges wastewater treatment plants face. Wastewater treatment can involve a basic unskilled workforce to complex specialised technicians who are knowledgeable with skills and management experience. Factors such as technical skills deficiency, a lack of digital training opportunities, an ageing workforce, as well as budget and resource constraints contribute to widening the skills gap within the wastewater sector. Montwedi et al., (2021) and Edokpayi et al., (2020) identified process control, monitoring, chemical treatment knowledge, maintenance, repair, data analysis, interpretation, understanding regulatory compliance, emergency preparedness, and green technology awareness as the top technical skills gaps in the South African wastewater sector. These gaps contribute to the wastewater's inability to maintain and improve wastewater management systems.

The shortage of workforce also affects compliance with set regulations, such as Regulation 17 of the Water Services Act, 1997 (Act No. 108 of 1997). Under-resourced teams may find it difficult to manage higher workloads, which may lead to mistakes, errors in processes or oversight of important processes. A lack of skilled workers is also a major safety risk in operations such as wastewater treatment. It increases the risk of accidents and injuries; and could bring legal liabilities for wastewater treatment (Rezai & Allahkarami, 2021). Skills gaps and a lack of capacity lead to organisations outsourcing the function of compliance monitoring to contractors, which often leads to inconsistencies in compliance practices.

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2.6 Public health risks from poor Wastewater effluent

Domestic wastewater comprises blackwater (excreta, faecal sludge, and urine) and greywater (kitchen and bathing wastewater). Almost half of the world's population does not have a proper way of disposing of both greywater and blackwater (Akter, 2022). Poorly treated domestic wastewater can have high pathogen concentrations, posing a health challenge, as communicable diseases can be easily spread. Exposure to untreated wastewater or contaminated drinking water will cause disease and can result in death. Approximately 1.45 million people die annually because of diarrhoea and at least 50% of these cases are caused due to poor sanitation (WHO, 2024).

The water crisis is an alarming matter facing SSA, with approximately 400 million people without a safe water supply that is causing infections from waterborne pathogens (Brookings Institution, 2021). These diseases generally originate from the raw wastewater that enters the environment and leads to an epidemic of waterborne diseases (Yang et al., 2020). Water scarcity is not the only dilemma that the people in this region face, there is also a growing need for adequate management of the constrained water resources and the importance of effective wastewater management. When wastewater is appropriately treated, the value that can be derived from it is quite huge, apart from environmental safety and enhanced public health, there would be an assured source of water for agriculture and industry, nutrients for agriculture, soil conditioners and energy (Arena et al., 2020). The increased availability of treated wastewater for irrigation will increase productivity and crop yields (Arena et al., 2020).

2.7 Conclusion and Gaps in Literature

From a global perspective, literature has postulated that cities will be overpopulated in the years coming. As many are already overburdened with wastewater challenges, a paradigm shift toward a change of perceptions in water reuse is facilitated. Unlike Africa, developed countries are financially and technologically well-muscled; hence, the current focus is aligned with educating people to view wastewater as a valuable resource. For SSA countries, South Africa included similarities in structure and operations of institutions were observed; however, South Africa is ahead in technology used to treat wastewater. Accountability to wastewater management is weak, perhaps due to the fact that wastewater is not generating revenue, highlighting a gap that must be investigated as there are possibilities for revenue generation. The impact of pollution on water resources, failing infrastructure, and non-complying effluents have not propelled municipalities to adopt alternatives that can save costs and produce other valuable resources.

The drivers behind wastewater management are a combination of economic, geographic, hydrological, social and environmental factors globally. The continuous failure to address wastewater as a social and environmental disruptor hinders progress toward the 2030 Agenda for Sustainable Development. A paradigm shift in wastewater management is essential, from observing wastewater as only an environmental problem associated with pollution control and regulations, to identifying the economic opportunities of wastewater, which can provide a means of financing management and treatment. In many SSA countries, wastewater management is a fast-growing challenge requiring sustainable solutions. To mitigate this, policies and initiatives for the protection of public health must be willing to embrace discussions around wastewater management.

CHAPTER 3
Methodological Considerations

3.1 Introduction

The preceding chapter dealt with literature relevant to this study. The research methods and study area where it was conducted are outlined in this chapter.

A research project relies heavily on the selection of appropriate research methods and techniques. An outline of the research methods and tools that guided the study and the approach that was used are proffered in this chapter. Techniques that were used during data collection and how the data are presented; are outlined. Additionally, research involves various steps in an orderly manner to achieve the desired outcome. In this study, factors affecting compliance with wastewater management are investigated. The focus is directed to sources of data tools utilised, a description of the study area, and data analysis. The first section is dedicated to describing the study area and research methodology, while the data sources and its analysis are outlined in the second section.

3.2 Research Methodology: Qualitative Approach

A qualitative study can be described as seeking to depict a situation where the information is gathered through a scale of variables, descriptions of situations, or different perspectives of people toward a phenomenon (Choy, 2014). The method is aimed at describing how the social world is experienced and viewed by people who live in it. According to Du Plooy-Cilliers et al., (2014), qualitative research is concerned with the richness of subjective experiences and the meanings attached to them. Moreover, with qualitative research, the researcher seeks to gather rich in-depth experiences in a specific context.

The choice of the qualitative method over the quantitative method relates to the suitability of a method for the kind of study being explored. The choice, therefore, correlates with the research questions that needed answers. The qualitative method seeks to build new theories and draw from existing theories, which have their own strengths and weaknesses. The strengths include raising more questions through open-ended questions and understanding the depth of experiences and behaviours of those under study. A weakness is that the process can be time-consuming.

3.3 Description of Study Location

South Africa is positioned in the southern part of Africa. It stretches for more than 2, 500 km from the desert border on the west to the Indian Ocean on the east. South Africa has nine provinces that vary in size (Figure 3.1). The smallest is the Gauteng province, which is highly urbanised with a high number of work opportunities. The largest province is the arid and empty Northern Cape, which comprises almost a third of South Africa. The country also shares long borders with Namibia and Botswana. This research study is positioned at the CTMM located in the Gauteng province.

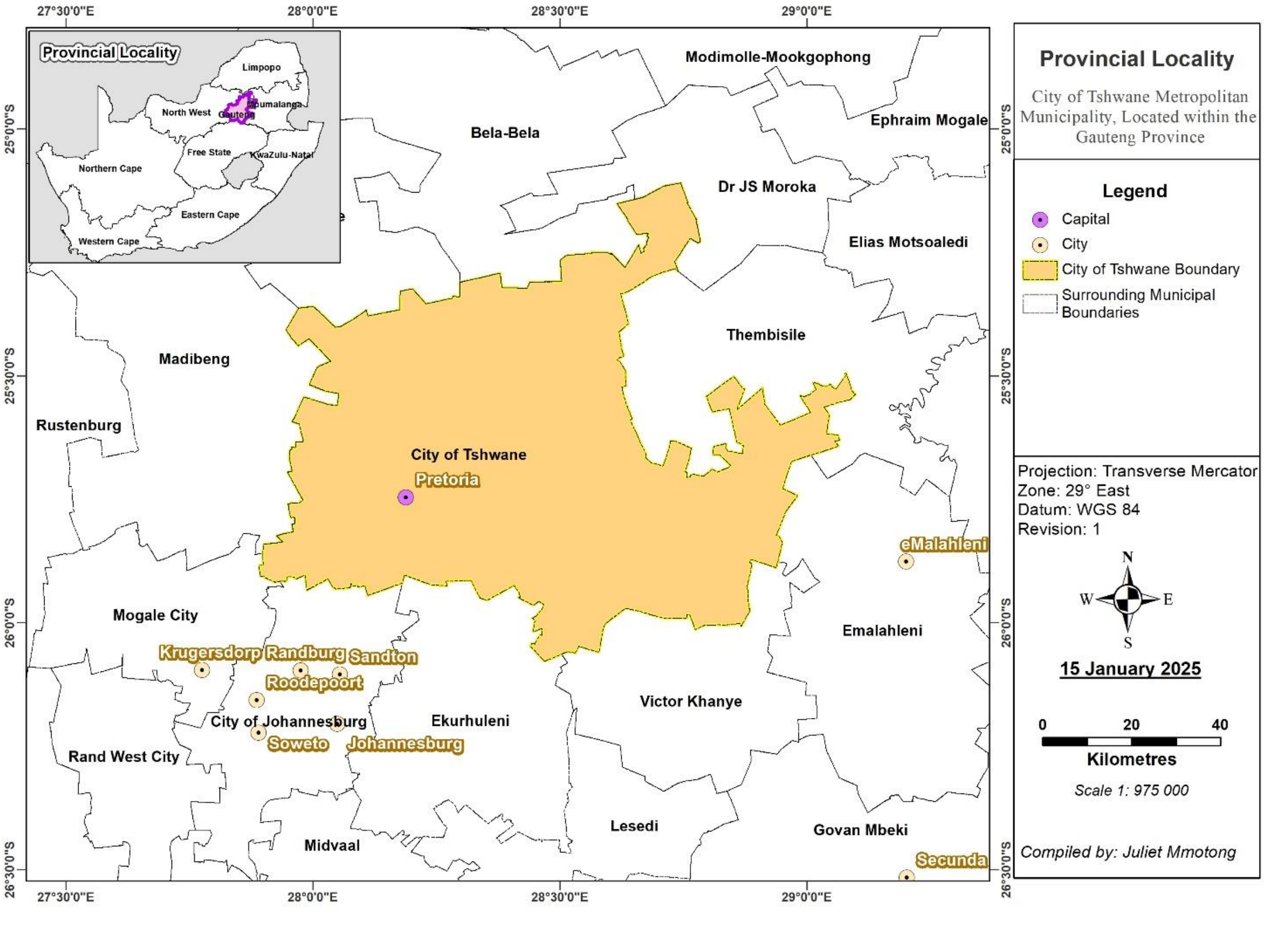

Figure 3.1 City of Tshwane Metropolitan Locality

The CTMM borders seven municipal regions and 107 wards (Figure 3.1). The CTMM is situated in the Gauteng province of South Africa, making the city a huge attraction for rural migration. Population count comprises black-African, coloured, Indian, and white races where, in 2019, the total population peaked above 2 million (Hamann & Horn, 2015). Growth in the

CoT can be attributed to the high populations, migration, declining birth rates, and declining household size (Roux & Geyer, 2017). The Pretoria CoT is one of the capital cities of the Republic of South Africa, and is a host to industries and recreational activities. Sustaining these activities depends on the correct efficient use of complying water status. Agriculture, businesses, and livelihoods require good surface water quality while at the same time experiencing challenges in protecting water resources in the vicinity (City of Tshwane, 2020).

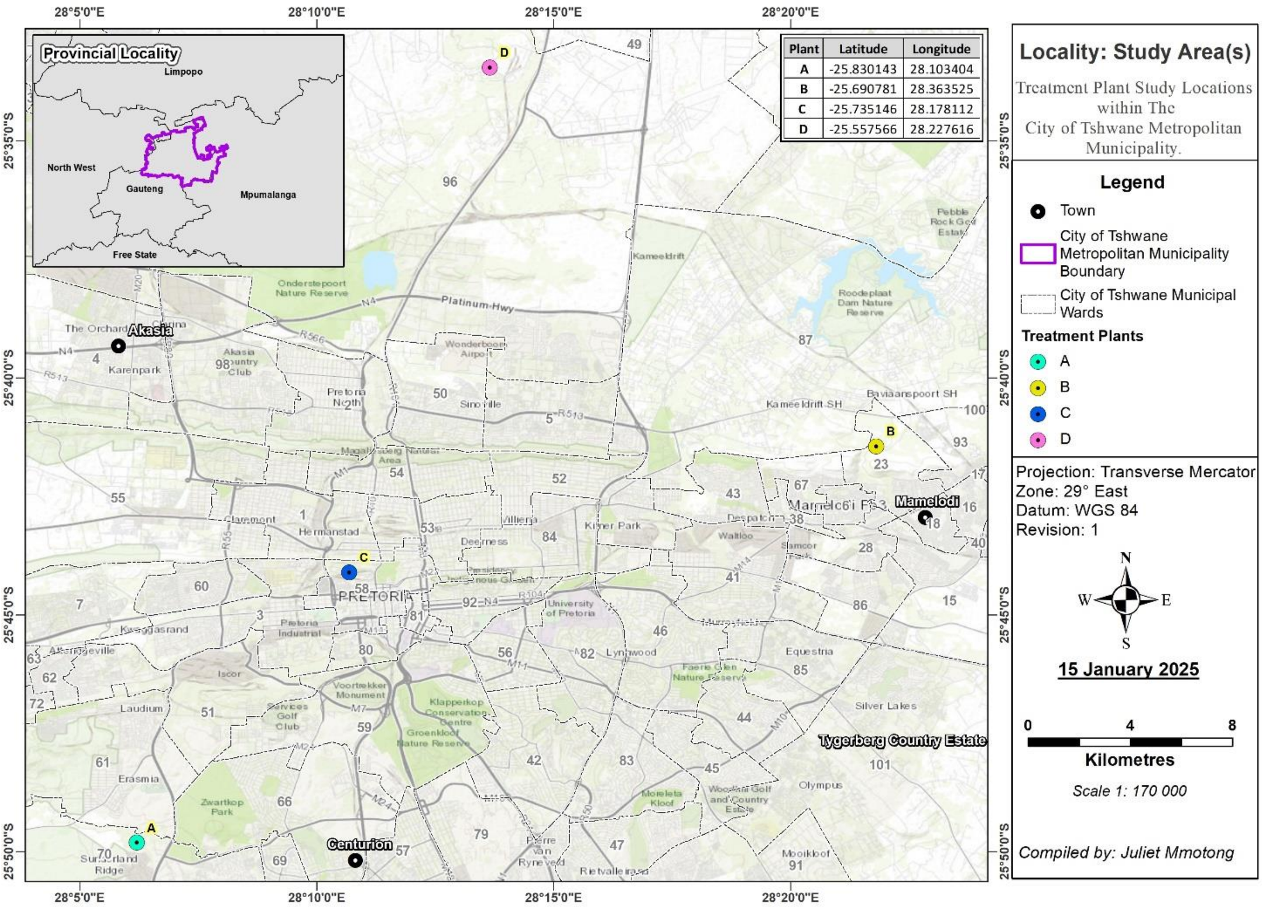

Figure 3.2 Study locations within the City of Tshwane

Professionals from four different treatment plants were interviewed. The locations were situated far from each other in sensitive areas (Figure 3.2). The Hennops River, Hartbeesboort Dam (rivers from CoT drain into the Dam) and Roodeplaat Dam are the first points of reference to depict CoT's water status. The Hennops River situated between Pretoria and Johannesburg has been in the news regarding water pollution and fish deaths (Sadiki, 2020). Applied management approaches are yet to be reported to have been effective (Sadiki, 2020). The Roodeplaat Dam is positioned 24 km north-east of Pretoria Central, whereas the Hartbeesboort Dam can be found toward the North-West province (Batayi et al., 2020). Three water purification plants treat water withdrawn from the Roodeplaat Dam for human consumption, highlighting a difficult position requiring an injection of funds to purchase chemicals and support the operation altogether.

The pollution and declining water quality are caused by nearby settlements of Tembisa, Ivory Park and Rabie Ridge, located upstream of the Hennops River (Latcheman, 2023). The areas do not have enough sanitation facilities, poor solid waste management and poor stormwater drainage system. As a result, the river is polluted by a variety of constituencies (Latcheman, 2023). People living in the mentioned locations do not have proper sanitation services, subsequently triggering the build-up and overflow of raw solid waste into the river (Latcheman, 2023). The rising population in these informal settlement places will increase pressure on the WWTPs that service the area.

3.4 Research Design

The research design elaborates on what were the main sources of data in the study. During this research project, interviews were conducted with professionals in the wastewater space, existing literature on Green Drop Certification was reviewed, and plants' technical reports analysed. The main source of the study was interviews with professionals from different work sections.

3.4.1 Research Design Strategy

Mapping out how to conduct the research was first aided by designing a research strategy (Table 3.1) as a guiding tool. The table below provides insight into the sources of information utilised against the research question, and where the outcomes were produced.

Table 3.2 Research Design Strategy

Research Questions	Source of Information	Envisioned Outcomes
I. What factors affect compliance with wastewater management in the City of Tshwane?	• Interviews with professionals	Tabled perspectives from operations, management and monitoring on COT's wastewater management.
II. Which existing policy documents govern	• Desktop documents review on Green Drop Literature	Review through the Green Drop programme and against

wastewater management in the CoT?	• Interviews with Management Professionals	CoT performance on wastewater management
III. What can be done to enforce compliance with wastewater management in CoT?	• Interviews with professionals	Tabled perspectives on views regarding enforcing and improving compliance with Wastewater Management in CoT'.

3.4.2 Target Population

The population that participated in this study are selected professionals stationed at different CoT wastewater treatment works. The CoT region is host to a number of WWTPs owned by the municipality. A target of 45 professionals ranging from the Operation, Management, and Monitoring sections was met. These included the following professionals:

- General workers;
- Process controllers;
- Assistant process controllers;
- Managers; and
- Monitoring technicians.

3.4.3 Selection of Population Participants

The population was selected using a snowball sampling technique (Mouton, 2001). To further satisfy the research objectives, interviewees were asked to nominate people who they know have a passion for wastewater treatment and management. The interviewees were also asked to select people within the organisation with qualifications closely related to the matter under study who wished to participate.

Another strategy that was adopted was that after having been introduced to the senior manager, they then suggested professionals who were willing to participate in the interviews. The professionals were then approached at their workstation at the researcher's cost.

To grasp the setting and the involvement in the issue, the interviewer began approaching people in high positions who already had qualifications or vast experience in wastewater treatment and management. This process commenced once the municipality had provided a go-ahead for the interviews to be conducted. The selected professional assisted in answering the questions related to wastewater management strategies. Interviewees at this level were also asked to nominate people with an interest in the subject matter.

Before any of the selection and interviews took place, the researcher was granted permission by the municipality to allow for the interviews to take place. The communication was undertaken to eliminate confusion and misunderstandings. Everyone (including people in positions of authority) was notified that interviews would be recorded, providing a platform for professionals to freely decline or give their consent.

3.5 Data Collection Methods

Qualitative research methods were used to investigate factors affecting non-compliance with wastewater questionnaires and key informant interviews are some of the tools that were used to collect data. Content analysis was then used to analyse the data, during which emerging themes were grouped and discussed. The data collection tools selected (Table 3.2) assisted in establishing and capturing the rich thoughts and experiences held by the interviewees. Similarly, data analysis entails mapping out the underlying quality of experiences. Therefore, data analysis was done through the analysis of content of a qualitative nature (Mouton, 2001). The qualitative approach assisted in laying out the research findings in a richer context.

Table 1.2 Data Collection Methods

Method	Role of researcher	Data collection technique	Target Station
Interviews	Interviewer	Interviews with professionals through a set of questionnaires	All work stations of a treatment plant
Document Review	Document reviews	Municipal Technical report review	Operation Works
			Internet/ Desktop

		Green Drop Reports Desktop Review	

3.5.1 Interview Questionnaires

A total of 45 interviewees were initially sought; however, two professionals withdrew during the data collection stage. The interviews were conducted from mid-December 2024 until January 2025 using an informal snowball sampling technique, which is an informal sampling method where interviews stop when the saturation point has been reached. Questionnaires were used to obtain details of operations and management from professionals on-site, in management, and in monitoring with a view to exploring their perspectives on operation and management styles. The areas that were specifically targeted are around challenges and possible changes that could be introduced to operations. Although the same questions were asked, simpler jargon was used for those who were not able to understand. Moreover, the responses were different as these professionals are positioned at different work stations. Questions were, therefore, tailored in line with the level of understanding and position of work.

Questionnaires were administered to assistant process controllers and general workers to gather their views on challenges faced by the on-the-ground day-to-day operations. Similar questionnaires were administered to senior process controllers and managers on technical management, legislative requirements, challenges hindering compliance, and what changes could improve compliance. Finally, questions were asked relating to monitoring services in terms of their views on how they assist wastewater management in the CoT and their views on the quality of wastewater discharged.

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3.5.2 Desktop Study on Green Drop Literature

A relevant desktop study on legislation, particularly the incentive-based mechanism Green Drop Certification programme, was conducted. The literature was used, in conjunction with the responses from professionals responsible for Green Drop management. The 2013 and 2022 CoT Green Drop reports, among other Green Drop literature, was consulted to identify challenges and constraints.

3.6 Data Analysis

Data was analysed through the content analysis method (Erlingsson & Brysiewicz, 2017) of the interviewer transcripts. Variations in responses were reported as per the qualitative method. Reporting of themes was undertaken, including statements that may have contradicted each other. This method allowed for identifying themes and patterns emerging from the conversations. In consideration of the literature explored and reports read, the workable wastewater management narrows down to competent policies, legislation, and guidelines that are designed to guide treatment plants to be considerate of public health at large.

3.6.1 Procedure

The interview recordings were written verbatim by the researcher. To ensure the accuracy of the expressions provided, interview audios were replayed while re-reading the transcribed interviews. After the transcribing, coding began. The procedure was adopted, as follows:

- Audiotaped personal interviews;
- Verbatim transcription;
- Familiarisation with the content of each interview by reading and re-reading transcripts;
- Condensation of text;
- Comparison and grouping of similar statements; and
- Categorisation of similar statements under themes.

Where the recording was not done as per the preference of interviews, the researcher transcribed on a hard book. Coding units are used to identify patterns and keywords within a text (Singer & Couper, 2017). The patterns or keywords are then grouped into categories. In this study, transcripts were read and re-read to identify potential indicators categorised in relation to a working wastewater management facility. The categories accommodated all the data collected. For the purpose intended in this study, emerging themes were sought and grouped for the purpose of not developing a framework, but to provide a platform of exploration for a new paradigm shift and policy reconfiguration.

3.7 Ethics Consideration

Ethics clearance was obtained from the University of Witwatersrand ethics protocol number GAES-2024-112 Research Ethics Committee, with the nature of this study being declared minimal risk. The participants were notified in writing to obtain their consent prior to the commencement of the interviews. A thorough explanation of the study, consent to record or not, as well as the right to refuse to participate, were some of the ethical issues explained before the consent forms were signed.

The study was explained to professionals in their local language where necessary. The researcher's information was also provided to the participants for further clarity. The participants were fully informed that their participation was voluntary and that they could withdraw at any time. They were further informed and assured of their anonymity and that any information provided would remain confidential. The language that is dominant in the CoT is English and Setswana/Sepedi, which the researcher is conversant with and, therefore, no interpreter was hired.

3.8 Validity and Reliability

Reliability was determined through the triangulation of data sources. The triangulation involved using different methods of data collection within the study in order to ensure that the data collected is accurate (Pillay, 2017). This study ensured that triangulation was established by comparing the data collected from data collection methods and techniques, such as interviews with the professionals' informal discussions, and field notes.

A peer review was incorporated by the researcher to establish the reliability of the study. A peer review involves review of the data and the research process by someone conversant with the research under exploration (Creswell & Miller, 2010). Chapters of this research report were examined by colleagues and scholars who are adept in research methodology, and by other colleagues who are knowledgeable in qualitative methods. This procedure provided support and challenged the researcher as they asked difficult questions about methods and interpretations that had been employed during the period of the study.

3.9 Study Limitations

Limitations to the study were mainly encountered during the data collection stage. Two professionals indicated that they were no longer comfortable with being interviewed and withdrew from the study. Other professionals expressed their wish to not reveal their age and qualifications. The major limitation was locating professionals for interviews as they worked different shift patterns across all four locations, of which the furthest was 64 km apart. As a result, telephonic interviews were arranged for those who were physically present at treatment plants.

CHAPTER 4
Results

4.1 Introduction

The research methods and study area in question were presented in the preceding chapter. The research results are provided in this chapter. The study explored professionals' perspectives on factors that affect wastewater compliance. The study was focused on how professionals perceive the factors that are affecting on-ground operations, the management of these operations, and lastly, the monitoring of these operations. It was designed to improve the understanding of challenges that hinder smooth operations and the adoption of possible sustainable wastewater management practices and current challenges regarding management practices.

The chapter is divided into three sections. The first provides a brief socio-description of the professionals who were interviewed. The second section presents the factors affecting compliance, as perceived by professionals. The third section presents the perceptions of an ideal wastewater management facility, where tertiary knowledge is illustrated to have shaped the perceptions of respondents. A brief perception is provided on policy and legislation that govern wastewater management in the CoT, and its review under the last section of the discussion chapter.

4.2 Socio Description of professionals who participated in the study

Following the strategy laid out in Chapter 3, face-to-face and telephonic interviews were conducted with professionals from three targeted work stations within Operations. A total of 43 interviews were conducted with varying levels of qualifications. All professionals within Operation Management and Operations Monitoring had different qualifications, ranging from matric to tertiary qualifications. Data were collected from 12 female respondents and 31 males from all four locations. The socio-demographic characteristics comprised characteristics such as age, gender, position, years of employment and qualifications. Years of employment ranged from 5 to 40 years for those interviewed; however, this section did not play any role in the perceptions as the most exposed to education had high perspectives of wastewater management practices.

Figure 4.1 represents the number of representations from the respective target stations. The interviewed target stations included the Operations, Operations Management, and Monitoring sections.

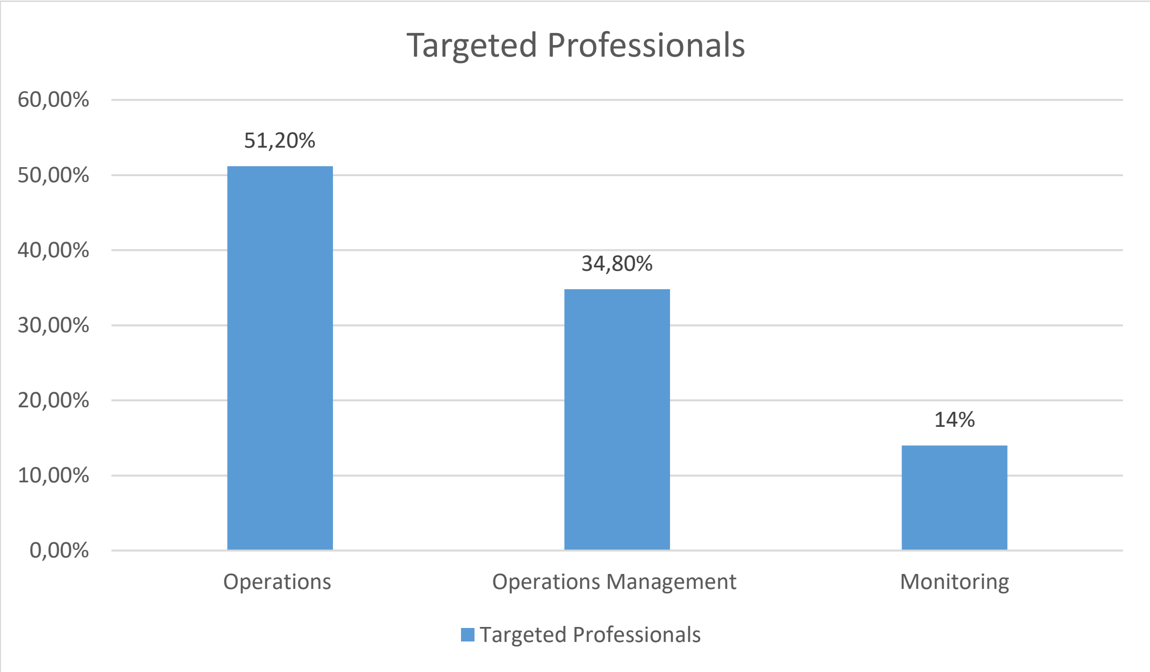

Figure 4.1 Representation from different sections

Figure 4.2 illustrates the gender of the professionals. A total of 29,91% (12) of the respondents were female, while 72,09% (31) were males. Although the study tried to ensure that there was female representation, it can be observed that the treatment plants are male-dominated employees over females. Nonetheless, the purpose was to ensure that there was representation of both genders.

4.2

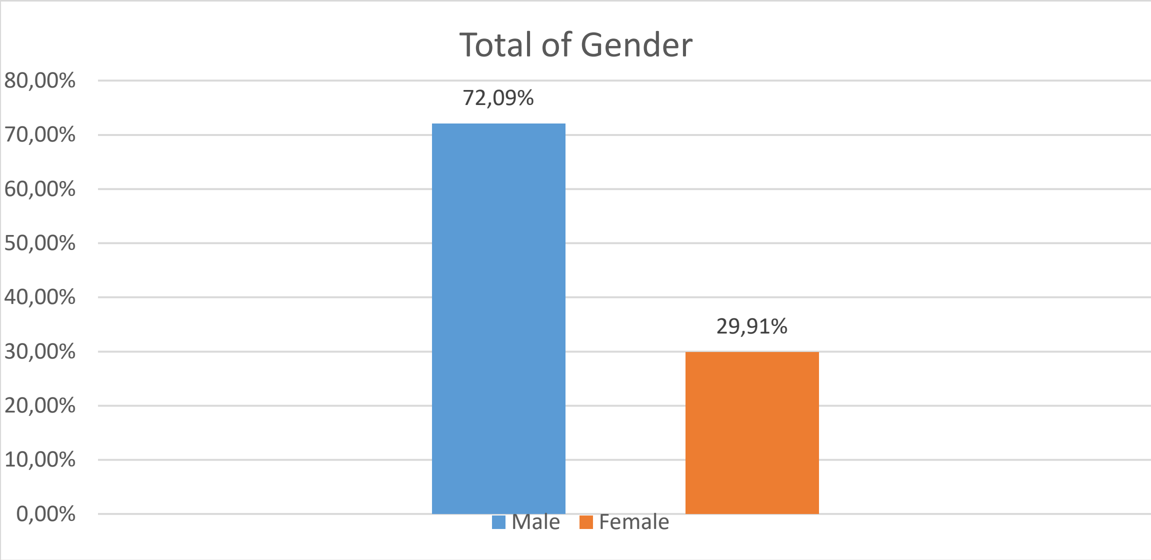

Figure 4.2 Gender Representations

Figure 4.3 below illustrates the age of the respondents from all locations combined. Operations professionals did not reveal their age; only professionals in Operations Management, and Monitoring revealed their age.

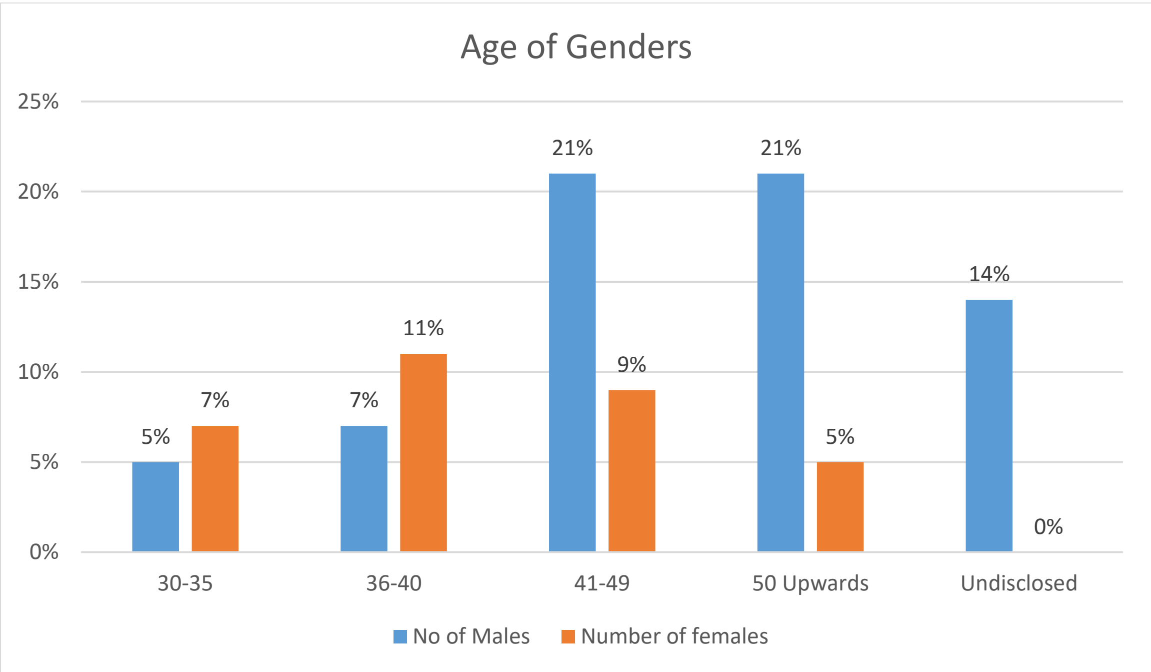

Figure 4.3 Age representations of professionals

Figure 4.4 below represents a number of professional representations from different treatment plants. The names of the treatment plants are not mentioned therefore will be coded as Location

A, B, C, and D. This was done to protect professionals' identity and the possibility of being traced where they are stationed.

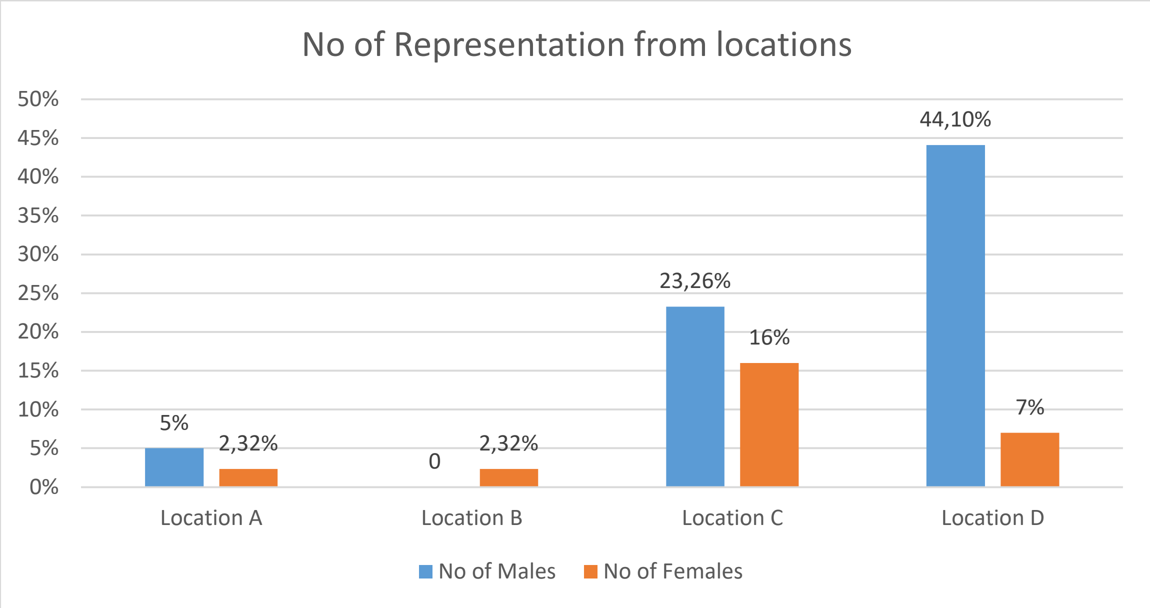

Figure 4.4 Total number of representations from different locations

Figure 4.5 below presents the respondents' level of education (qualifications). This was most crucial as perceptions of these professionals were not only valued based on years of experience but also the level of their education. Some respondents had Matric and below qualifications whilst others had tertiary qualifications. It can also be argued that the level of education had the most influence on professionals' perspectives.

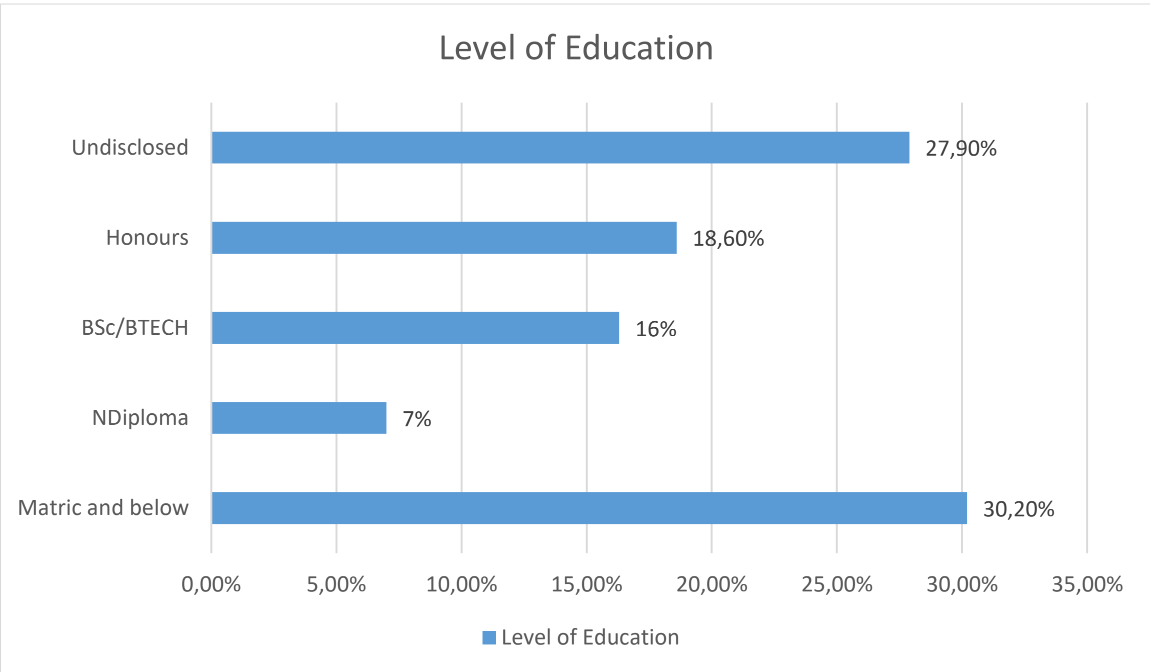

Figure 4.5 Professionals level of education

4.3 Perspectives on Factors affecting compliance of wastewater management in the COT

The study sought to explore and understand what professionals perceive as factors affecting compliance with wastewater management. The study revealed types of challenges, including a shortage of staff and a lack of budget ring-fenced solely for wastewater operations. Non-complying effluent was associated with ageing infrastructure, and deficits and inefficiencies of process operations (Table 4.1).

The perspectives from the different target sections were then tabled. These sections provided their perspectives in detail on what hinders complying effluent. The sections are divided into Operations (ground forces), Operations Management and (Operations) Monitoring.

Table 2.1 Perspectives on factors affecting compliance at the City of Tshwane

Operations	Operations Management	Monitoring
Lack of working tools	Lack of Budget	Lack of consumables & calibration instruments
Broken process equipment	Lack of Maintenance	Budget allocation
Lack of PPE	Relying on contractors	
Blockages of Working Equipment	Ageing infrastructure	
Frequent pump failures	Operational Capacity	
Shortage of personnel	Wastewater Effluent Compliance	

4.3.1 Operations

The Operations section comprises ground professionals who are hands-on with the daily activities of process treatment. The study revealed that workers are limited in doing their work due to a lack of working tools. The working tools are in the form of screens to trap the large particles and rakes to remove the screenings from the screens. Others mentioned that the process equipment was not operational at the time of data collection. They mentioned that the aerators were not working and would take time for the contractor to fix them. One participant expressed the following:

‘*The rotating bridges are currently not operational, and the aerators are also not operational and take time to be fixed. Therefore, when we clean, we face hard challenges as the dirt comes back.’*

It also appeared that some process units were blocked, especially on the primary settling tanks, which form part of the crucial primary stages of the treatment process. This stage sets the precedence for further secondary settling of aerated wastewater. Two professionals reiterated the following in this regard:

‘When these PSTs are blocked like now, the scum stays on top which becomes hard to clean later.’

‘The desludge lines are currently blocked, so I am not desludging now.’

When these challenges are further ignored or not timeously addressed, it puts pressure on the workers to rotate and try to remedy the situation with limited personnel. Many workers on the ground are on pension and were never replaced, with the treatment plants now facing a shortage of staff. Some of the professionals expressed the following:

‘We are only 2 at this station, although we are managing, we are not enough, in fact, the whole plant needs more workers.’

‘There is a serious shortage of people here, sometimes we do the work of those who aren’t here. That’s how bad we are short of staff.’

‘We do not have enough employees on the ground. When others are going on pension those positions are not filled.’

The workers expressed a lack of personal protective equipment to conduct their daily duties. Additionally, there is a challenge of frequent pump failures, which result in wastewater overflowing. They then have to wait for a contractor to be appointed to fix the problem. Another health-threatening scenario is the inhalation of methane gas.

‘We have frequent pump failures here; they stop working until they come and fix them. The water will not move to the next process unit until the pumps are fixed.’

4.3.2 Operations Management

Lack Over time, the lack of a budget has proven to be a hindrance to achieving required goals and keeping operations under check. The professionals in management expressed how they are allocated low budgets in their section and are expected to cater for almost all breakdowns. Others expressed the need for a budget to refurbish the dilapidated process units.

> *'We do not have a budget to refurbish or upgrade the treatment plant. It will only maintain but will not sustain the lifespan of the current infrastructure.'*
>
> *'The budget is not ring-fenced, the money that is within the department does not always come here.'*
>
> *'Most of the time we are told there is no budget, hence maybe lack of maintenance.'*
>
> *'With all municipalities failing in wastewater treatment, everything leads to a lack of funds. The municipality must allocate more funds for the specific use of the treatment of wastewater.'*

It has been proven that proper maintenance is a prerequisite for a functioning treatment plant. The study revealed that the lack of maintenance and its team have proven to be a setback in keeping the continuous operations of the treatment plants. The professionals stressed the need for a maintenance team and how the lack thereof has greatly cost their processes.

> *'The over- reliance of tenders is causing us big time. We do not have a maintenance team so we rely on contractors to come to fix breakdowns.'*
>
> *'We need proper maintenance; they take time to fix things, so processes get affected when there are mechanical breakdowns.'*
>
> *'We need enough funds for maintenance, and refurbishing the old plants.'*
>
> *'We need our own maintenance team in case of emergencies. We rely on contractors and their processes take time.'*

Ageing infrastructure was described as major obstacle to wastewater management. The professionals expressed how the treatment plants had been constructed a long time ago and now the infrastructure is showing signs of collapsing. Some were quoted saying the following:

'We are having a challenge with the ageing infrastructure here. Instead of improving we still have to go back to correct other things that have aged.'

'The plants were constructed somewhere around 1913, a serious challenge of aged infrastructure, therefore, the budget won't be enough. It will sometimes look like it's caused by lack of maintenance but it is actually aged infrastructure.'

'There is a total need to refurbish the treatment from the inlet until the outlet works.'

For a wastewater treatment plant to release a complying effluent, alongside working equipment and efficient processes, it needs to operate within the design capacity. There has been population expansion and housing developments that have put the treatment plants under pressure to treat the load of incoming wastewater.

'We are currently facing a challenge with the capacity of the treatment plant. People are growing in numbers; nearby villages are also growing whereas the treatment plant remains the same. Now the plant is operating above capacity.'

'The capacity of the treatment plant must be increased. The flow is way above design capacity. We are now operating above capacity with 80 ML.'

Effluent wastewater compliance carries points in the Green Drop Evaluation Key Performances. The study revealed that some of the treatment plants are struggling to meet effluent-compliant standards. This means that a level of pollution is added to the receiving water bodies. Some plants are not analysing all the parameters, particularly because of a lack of consumables that are described under the monitoring sections.

'*We are compliant but not analysing all of them. We are currently compliant with ph, ammonia, nitrates and nitrates, orthophosphates, Chemical Oxygen Demand and Conductivity. Suspended solids on 90 % and faecal coliform is complying with 90%'*

'If there is no load shedding and breakdowns, we comply between 70 % to 80% in effluent water quality.'

'We are currently not complying with a lot of parameters except for physical parameters only. Microbiological and chemical we are not complying due to the ongoing refurbishment on the plant.'

4.3.3 Operations Monitoring

The monitoring sections assist the treatment plants with the testing of analytical results. Their function is to receive samples, analyse and provide results for treatment plants to do corrective measures. This section has its own challenges, as well as the lack of consumables and calibration instruments. The professionals expressed the challenge that comes with not submitting results timeously, which has to do with a lack of consumables at that time, as follows:

'We have a challenge with lab consumables and calibration of instruments. We had a contractor that took too long to be awarded, by the time it was awarded the prices were affected by the COVID-19 pandemic and had sky rocketed therefore, CoT could not adjust the prices which made the companies not honour those contracts.'

'We struggle to get consumables here, so sometimes the work moves slowly.'

'The lack of consumables is a nightmare here; we are told the budget is finished.'

Budget is always the engine of any section as it enables the purchase of needed equipment and technology. Even the Monitoring section expressed that a lack of budget is causing serious delays in honouring work goals and set targets. The professionals voiced out the following:

'There is no budget here. The technology is outdated. Most of the sample constituency is difficult to analyse by the type of technology we use.'

'Every month we need to participate in proficiency testing for various parameters. We must pay for these tests, when we have low budget allocation, we fall short off. Resulting in us requesting good citizens to assist us in paying for the proficiency testing.'

4.3.4 Effluent compliance

Most of the treatment plants are faced with challenges regarding effluent compliance. The challenges can be attributed to the fact that some work stations have been put on hold owing to the refurbishment of the treatment plant, delays in the fixing of process equipment that aids in adequate processing, and parameters not analysed due to a shortage of consumables.

‘We are compliant but not all of them, we are complying on Ph, ammonia, nitrate-nitrite, orthophosphates, COD, Conductivity, suspended solids at 90% and faecal coli at 90%.’

‘We are complying with some parameters except Ammonia due to maintenance, they are repairing the pump at the reactors whereas aerators are also down.’

‘No we are not compliant, we only comply with physical parameters. Microbiological and chemical parameters are not compliant because there is an ongoing refurbishment project.’

4.4 Documents that govern wastewater management in the City of Tshwane

DWS Green Drop, alongside the discharge licence, is used as the guiding tool to streamline correct operations in the CoT. The professionals expressed how the programme has assisted the plants in improving operations and expressed their dissatisfaction with the programme. For the most part, the programmes have assisted them in keeping track of performance and monitoring effluent compliances. The shortfall of the programmes was found to have been in the monitoring of the feedback by the DWS.

‘We find the programme very useful. We have operationalised the programme and we have learned that it is not just a programme where you prepare and get over with. But for us, we have operationalised it, even if the programme is not running, we have set out our standards with those Key Performance Indicators.’

‘Positive criticism from the programme is always a way to strive to do better. With each assessment, you have the urge to correct all that is negative to get a better score.’

‘The programme is helpful just that DWS is slacking a bit, it helps us to comply with their Key Indicators and covers everything from cleaning to compliance.’

When asked if there is anything that could be added or changed in the evaluation criteria, the study demonstrated that the professionals hold different perspectives that could shape the direction of the evaluation criteria and quoted as follows:

‘Yes there are some things that could change with the regulation, there are a lot of things that are required and are not necessarily within our scope, for example, the

water balance, out of whom is it required, there is no standardisation, what is the template thereof or is any draft acceptable?'

'The legislation only guides skilled personnel for the class of works but fails to stipulate on supporting staff that is needed to assist the skilled workers. For skilled workers we comply but they need to recognise the general staff.'

'If DWS put more effort, we won't have a crisis in the water sector as the findings and recommendations would be improved from the previous assessment.'

'More attention and evaluation points must be given to the physical operation and results of the effluent than the administration process.'

The 2022 Green Drop Report for the 2021 analysis presented a decline in the Green Drop scores for the CoT. This can be attributed to the assessment being put on hold and the inability of the municipality to maintain and manage operations for that period.

Table 4.2 City of Tshwane 2022 Green Drop score card

Water Service Institution	**City of Tshwane**	
Water Service Provider	City of Tshwane	
Municipal Green Drop Score		**VROOM Impression (towards restoring functionality):** (Zeekoegat) (Rooiwal) 1. Disinfection 1. Primary settling tanks 2. Belt presses 2. Secondary settling tanks 3. Primary & secondary settling 3. BNR reactor 4. Sludge pumps 4. Disinfection **VROOM Estimate:** R168,000,000
2021 Green Drop Score	60%↓	
2013 Green Drop Score	82%	
2011 Green Drop Score	64%	
2009 Green Drop Score	75	

Source:2022 Green drop report

4.5 Perspectives on what can be done to improve and enforce a complying Wastewater Management facility.

The professionals in this section gave their perspectives on sustainable wastewater solutions that are implemented in their treatment plants, on what composite complying treatment plants are, as well as the lack of their compliance.

'One professional with NQF Level 8 expressed that modern wastewater treatment plant needs to be run in accordance with the public management principle, this means that

the institution is run as if it is private. We need to run it with private sector principles. DWS has to be run as if it is a stand-alone entity like Rand Water and ERWAT. That way reduces a lot of political interference and allows procurement proficiency.

In my opinion, a complying wastewater plant is not just a complying effluent, but about other things such as protecting public health, protecting the environment and, protecting the water bodies. A wastewater treatment plant should cover all of that. It is not sense to have a complying effluent but sludge is disposed incorrectly, or screenings are not disposed well and methane gas is just escaping to the atmosphere.'

Another professional expressed firmly 'that timeous maintenance can foster a complying wastewater facility'.

'Management must give support to operational personnel by escalating the issues in the department so that they can be addressed by top management.'

Wastewater in the CoT is reused as part of sustainability initiatives. Most times the wastewater is being reused for irrigation and sludge is donated to nearby farmers. Several professionals expressed the need for water reuse and other available sustainable wastewater solutions to adopt.

'20% of treated wastewater is used for irrigation at the golf course, Pretoria zoo whereas sludge is taken to an external company that uses it to grow grass.'

'There is a memorandum of understanding between the contractor dealing with sludge on site and the nearby farmers, they come and collect sludge for their own use.'

4.6 Conclusion

This chapter provided an outline of the research results. The socio-characteristics of the professionals were provided, together with an indication of instances where data were not provided. The professionals provided different perspectives on factors damaging the operations of the plants ranging from insufficient maintenance to budget constraints. Regarding a complying wastewater plants they suggested a proper maintenance team and an efficient management team supported by the municipality heads. Green Drop assessment was viewed as an efficient tool that motivates professionals however feedback from DWS remains insufficient and crucial.

CHAPTER 5

Discussions

5.1 Introduction

The preceding chapter provided insights into the research results of the study. The chapter outlined and presented the findings sought through qualitative techniques and the interpretation of results through content analysis. This chapter is aimed at focusing on and presenting a discussion of the results by combining the results with the existing literature findings and then providing concluding remarks.

Factors that affect the compliance of wastewater management from the grouped perspectives of the professionals are discussed in this chapter. The challenges to wastewater operations and effluent compliances are also elaborated on. In the second section, the need to improve wastewater efficiency and management is discussed through a paradigm shift. In the final section, the policy documents that govern wastewater management and the review of the Green Drop programme are expanded on.

5.2 Factors that Affect Compliance of Wastewater Management

Ultimately, the wastewater treatment process is the return of wastewater that is treated into the water bodies with fewer metals and non-metals to ensure the protection of the environment and public health at large. Poor and insufficiently treated wastewater contribute to river pollution (Montwedi et al., 2021). The continuous increase of nitrate and phosphate levels in rivers leads to severe eutrophication, which is defined as enrichment by nutrients such as phosphates and nitrates. Presently, two-thirds of South African dams are affected by surging levels of these harmful nutrients (Turton, 2016). Eutrophication is a major threat to the water security of the country (Montwedi et al., 2021). Through this study, it has been learned that WWTPs are a major cause of the pollution of water bodies. At present, non-compliant effluent is being discharged into water bodies as most of the treatment plants are not compliant with discharge limits.

Worth noting is the combination energy cost and operational costs have placed the sustainability of the operating system under scrutiny and questionable. The impacts of these system has now put financial muscle on heavy pressure. The current state of water resources in the country is not changing in practice. There is a need to realize the potential of wastewater and waste produced from these plants. Although the CoT was acknowledged for being a green champion (DWS, 2022), it was found that less sustainable alternatives have been implemented to increase compliance with wastewater management. This finding corroborates the study conducted by Khuzwayo and Chirwa (2020), who expressed that solutions are known and available; however, challenges are largely concerned with the sources that are equipped to deal with the problems and the implementation of these available solutions (Khuzwayo & Chirwa, 2020).

Wastewater management gaps are revealed through the study, which included, among others, a strong financial muscles and maintenance plans. Therefore, the municipality has to ensure that the shortages are accommodated into budget allocation while involving the relevant stakeholders. Khuzwayo and Chirwa (2020) noted that the major setback in achieving wastewater efficiency was severe skills and training. The CoT has skilled workers at different sections; but does not have enough supporting staff.

The pertinence of financial planning to hire more staff, the purchasing of consumables, and maintenance of the operating system is crucial to attain its efficiency. The results of these financial gaps mean that the entire system is likely to collapse, creating a platform for other risks to emerge. To avoid this catastrophe, the municipality has to allocate a budget that will not run out before the next budget allocation. Alluding to this is World Water Week; when it was stated that providing the finance will assist in diversifying risks and promoting the good work ethics, which is often missed (World Water Week, 2017). Furthermore, the Water Research Commission (2021) boldly reported that inadequate management techniques and delayed maintenance are causing recurring environmental and public health crises (Water Research Commission, 2021).

The problem is perhaps rooted in non-compliance with legislation that is aimed at pollution prevention and the protection of, clearly pointing to poor governance. Good governance involves transparency and accountability of participating stakeholders (Nealer, 2016; Nsubuga et al., 2014). Generally, wastewater is discharged without proper treatment, including in developing countries where wastewater is partially treated. However, in South Africa, a growing concern lies in policy implementation and enforcement. The progressive Green Drop programme is rooted in awarding excellence as it does not carry heavy penalisation. On the other hand, opportunities for reuse, recycling, and cost recovery are of paramount importance and gaining small speed. Wastewater is a potential source of nutrients and energy. To realise these benefits, good governance of wastewater management is needed (World Water Week, 2017).

5.2.1 Challenges within the Wastewater Operational Systems

Challenges with the current operating systems have ripple effect on general public health, which have been the main drivers in the selection and design of wastewater treatment systems. Due to the increasing urbanization and industrial growth, the great challenge facing treatment is to ensure that there is no contamination in rivers and the environment.

For Primary Wastewater Treatment- This is the first stages of preliminary treatment which often prepares the wastewater for secondary and tertiary treatment downstream. The processes are less technical as it involves separation of large particles from the liquid (Tillman, 1992). The study revealed that there are understaffed workers placed at several primary treatment processes. Shortages of working tools and equipment breakdown have become a growing challenge hindering normal operations.

Secondary Wastewater Treatment refers to the removal of biodegradable organic compounds through manipulation of bacterial growth processes. Two types of secondary treatment exist in South Africa in the form of Biological Trickling Filter and the Biological Nutrient Removal (Sperling, 2007). The study has illustrated that facilities are there but are not fully operational, either due to equipment not being installed, out for maintenance, part of the equipment has broken down. Again, the wastewater treatment plants are generally overloaded, indicating that the plant will not be able to remove all unwanted content matter and pathogens.

Tertiary treatment refers to the removal of specific pollutants through sophisticated processes such as Ozone, adsorption and further biological nutrient removal (Sperling, 2007).

5.2.2 Effluent Compliance

The main goal of wastewater treatment is to protect and sustain natural water resources through a complying effluent that considers public health and environmental protection. Physio-chemical treatment includes physical, chemical and biological processes, and sometimes a mixture of these methods to facilitate treatment (Makuwa, 2023). Discharge of effluent-containing chemical substances has the potential to harm the environment. It was revealed that treatment plants are not complying fully, indicating that pollution occurs along the water bodies. This finding is similar to the study conducted by Edokpayi (2016), which revealed that effluents from treatment plants served as the major pollution source of water bodies

5.3 Improving Wastewater Management Efficiency and Compliance

"The Commission therefore recommends that the situation regarding failing WWTWs in South Africa and its consequent pollution of South Africa's water resources be declared a national disaster, in accordance with the DMA" Recommendations from the SAHRC Report (2021).

Recommendations from the SAHRC Report (2021) motivated this section of the report to outline the need to improve wastewater efficiency and compliance through a paradigm shift of acceptable reorganised sustainable technologies.

Current urbanisation and population growth beg planners and industry experts to discuss what is best for compliant and sustainable wastewater systems. With the amount of multiplicity of challenges burdening the country, wastewater management is growing quickly and becoming a significant. Unarguably, expanding populations have exacerbated the management of these systems, of which many are crippled by a plethora of problems that have now shifted discussions to a paradigm shift to decentralised systems (De Gisi, Petta & Wendland, 2014). Important to note, De Gisi et al., (2014) discoursed that the current operating systems consider wastewater as mainly waste, yet there is a huge potential for wastewater to be valuable. A number of innovative solutions can be implemented as separate or together with centralised systems (Brown, Jackson & Khalife, 2010). Recently, the concept of assimilating water and wastewater systems via an isolated collection method has been the centre of discourse in the wastewater agenda, with many other innovative solutions to follow. To enforce compliance in the wastewater arena in South Africa, a paradigm shift is crucial, especially toward simple methods and technologies that can be maintained easily.

Wastewater decentralised systems occur when raw wastewater is treated next to its point of generation or source through simple technologies (Omenka, 2010). Owing to inefficient wastewater treatment technologies, many dams and rivers that supply potable water are polluted with wastewater effluents. Even though rivers are polluted, the country still relies on these polluted sources for raw water supply and abstraction (Archer et al., 2017). Furthermore, Archer et al., (2017b) revealed a recorded number of emerging pollutants detected in water bodies (Archer et al., 2017b). Additionally, this study also revealed that insufficiently treated wastewater effluent is contributing to the overall depletion of water resources. Corroborating this finding is Edokpayi (2016), who also reiterated that poorly treated wastewater was discharged into rivers after a series of evaluations causing a rise in pollution in water bodies. To address these imbalances, an entirely new approach has to be advocated for and introduced.

Another motivation to enforce the paradigm shift is to acknowledge the setbacks and the intensive financial requirement these centralised systems require from the government, while at the same time voicing out the success stories that decentralised systems have brought to especially African countries. De Gisi et al., (2014) castigated the use of centralised systems, expressing that they use high energy and that severe water loss occurs along the pipes (De Gisi et al., 2014). Energy is the most intensively used resource in wastewater treatment, which can account for 10% to 14% of operating costs (Majumder et al., 2019). With increasing housing development and urbanisation, energy consumption is expected to surge owing to expanding demographics and the need to meet effluent standards.

In many parts of the world, centralised systems have contributed to environmental problems and degradation. Simple operations such as urine diversion in Malawi and Mozambique have been successfully implemented as wastewater management solutions (Chirisa et al., 2017). Windhoek has shown considerable progress toward the implementation and management of wastewater systems solutions (Chirisa et al., 2017). A system was trialled in India included Hybrid Treatment Systems (HTSs) that was used to achieve recycling. The system considered combining natural and mechanised approaches to wastewater, resulting in energy savings initiative (Kalbar, 2021). Similarly, a pilot project in Ghana was trialled to illustrate the benefits of organic solid waste as manure. The sludge was dried on sludge drying beds and land, and was later used as compost. The compost was tested and applied to the seed germination capacity and growing of vegetables (Cofie & Kone, 2009).

5.4 Policy Documents Governing Wastewater at the City of Tshwane

South Africa's water is governed by the legislation facilitated by the DWS. Legislation includes the Water Service Act, 1997 (Act No. 108 of 1997). This informs the Water Service Authority to render basic water requirements, as well as the National Water Act, 1998 (Act No. 36 of 1998), which, in turn, informs the nation to protect water resources (Nealer, 2016).

The mentioned legislation addresses the imbalance in the distribution of water resources. The provision of basic water services by water service authorities has since faced numerous challenges, such as dilapidated infrastructure, a shortage of skilled people, poor planning and a growing populace, which has raised the water demand (Nealer, 2016). Since 1994, the Government of South Africa has undertaken massive reforms aimed at addressing the protection of water resources and the provision of basic water needs. The progressive water legislation was and is expected to bring about change. On the other hand, water resource management is a complex arena comprising many actors, anthropogenic states, and environmental disturbances (Liehr et al., 2017). The country continues to be subjected to a water crisis, be it in the form of water mismanagement, a lack of funding for infrastructure upgrades, and/or water quality challenges. Therefore, solutions to water problems depend on the management of current water resources, systems that treat and provide these services, and managing those that are authorised to heed the mandate of water services in the country.

The Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996) stipulates that a governance system that compels "all spheres of government and all organs of State" to cooperate with good trust and faith should occur in all departments (Nealer, 2016). Nsubuga et al., (2014) identify water governance as a range of political, socio-economic and administrative systems that are put together to oversee the management and delivery of water services (Nsubuga et al., 2014). The manner in which allocation regulatory processes embrace water conservation is a focus of governance (Chepyegon & Kamiya, 2018), rather than fragmented institutions that affect governance (Pillay, 2017). These should involve inclusiveness, accountability, participation, transparency, and predictability (Nealer, 2016; Nsubuga et al., 2014), and should include the existence of effective organisational arrangement (internal and external) of which two-way communication is foremost (Nealer, 2016).

Parallel to this, the operation and coordination of cooperative governance rely heavily on a functioning management, whereas water challenges and issues lead to the understanding of change that can be brought about by effective management (Pillay, 2017). Furthermore, the need for water and resources for various uses continues to rise, which is aggravated by climate change.

The uneven distribution of water gives rise to incidents of conflict in water-scarce areas. Moreover, people migrate in search of water and vegetation creates a transfer of diseases from one area to another (Nsubuga et al., 2014). The lack of rainfall has affected the activities that depend on rainfall (Nsubuga et al., 2014). South Africa is also prone to water conflict as demand is by far greater than anticipated supply; hence, Pillay (2017) insists that the challenges that are faced inspire the need to understand institutional frameworks and, therefore, contributing challenges cannot be undermined (Chepyegon & Kamiya, 2018).

5.4.1 The Green Drop Certification Programme

For long South Africa has lagged behind with adequate cooperative governance between stakeholders, particularly in municipalities (Ntombela et al., 2016). This is challenging provided that Water Service Authorities (WSAs) are delegated to provide water and sanitation services to all people. Disposal systems and wastewater treatment are some of the services catered for by legislation. To monitor the compliance of wastewater treatment, the DWS utilises the incentive-based protocol named the Green Drop Certification programme to inform and advise the WSAs on their performance.

In 2008, the DWS, as the custodian of water resources, introduced an incentive-based programme that was aimed at enhancing wastewater management in different municipalities, called the Green Drop programme, through the Green Drop System. This system has transformed wastewater management in South Africa by serving as a benchmark for WWTPs to ensure sustainable and compliant wastewater services. The Green Drop is designed to motivate municipalities to improve their wastewater services and bring high performance. A comprehensive audit is done and wastewater treatments must score 90% or more on set criteria to be awarded a certificate (DWS, 2022). This programme is a comprehensive assessment and reporting system intended to improve the performance of WWTPs. It comprises factors such as the competence of municipal wastewater managers and process controllers to operate and sustain the treatment of sewage.

The Green Drop programme was introduced to assist WSAs/municipalities in improving wastewater treatment due to the rise of pollution in eutrophication that has now encroached on the country's dams (Turton, 2016). Wastewater treatment facilities are by their design and efficiency able to remove organic and inorganic matter before water is released into rivers (Ntombela et al., 2016). Furthermore, the programme was launched to assist in facilitating compliance with regulatory standards (Ntombela et al., 2016). This means that what distinguishes this programme is that it is rooted in motivating municipalities to perform better rather than direct regulation. Since its inception, healthy competition and rewarding good practices have occurred (Ntombela et al., 2016).

Today, the programme seeks to achieve sustainable wastewater solutions in South Africa through a developed set of competencies (Swana et al., 2020). Historically, wastewater management was rooted in solving sanitation problems while avoiding excessive nutrient disposal (Swana et al., 2020). While these, on paper, are clear and straight, current practices signal the need to strengthen enforcement in areas of recurring non-compliance. Over the years, the Green Drop programme raised awareness and the knowledge needed to improve wastewater performance at large (Ntombela et al., 2016) and further provided mitigation measures. Before Green Drop, it was difficult to know the performance of any municipality (Ntombela et al., 2016)

Since April 2005 until date, there have been reports of sewage overflow into rivers. The 2013 Green Drop reported 30,1 % of WWTP in crisis (Ntombela et al., 2016). The programme was then halted in 2012 and reinstated in 2022. The question arises as to what is missing in municipalities that question the value of work that the Green Drop programme is facilitating. The 2022 report detailed an undesirable state of wastewater treatment in the country, representing a national crisis that requires attention. This report shows a disturbing decline since the last report was published. As per the Green Drop Report, SA requires an extra reporting mechanism, similar to the Green/Blue Drop systems, which is focused on the state of water quality after wastewater has been discharged. These reporting systems illustrate progress in the rigour of data collection, validation and responsibility.

Over a third, approximately 334 WWTP (39%) from a total of 955 systems, were categorised as disastrous. In comparison to the 2013 report, there were 248 (29%) critical systems. Moreover, in the 2022 report, only 22 municipalities and one private WWTP reached the Green Drop status. In addition, the risk classification of municipal treatment works declined from medium (65,4%) to high risk (70,1%) between 2013 and 2021 (DWS, 2022). A more pressing issue is that some municipalities are not able to correct these challenges. This was demonstrated in the Municipal Strategic Self-Assessment Report in 2019, which showed the state of water services provision in municipalities, as well as their inability to recover from failing. This is principally due to struggling management, minimal or no capacitated technical staff, and none-revenue collection (DWS, 2022).

The 2022 Green Drop Report indicated that the CoT scored 60% overall, which is a drop from 82% in 2013 (DWS, 2022). The report noted a lack of progressive maintenance strategy, theft, and vandalism, and erratic industrial effluent loads as risks to treatment plants. Nonetheless, acknowledgement of the use of sludge to produce fertiliser was a Green Economy Change Champions award (DWS, 2022).

The shortfall of the programme is the failure to hold municipalities accountable if a score of less than 30% was obtained. The municipalities must respond within 30 days. Failure to do so and the DWS issues a directive. If the directive is also not addressed, the DWS struggles to take further actions against the municipalities.

5.4.2 Wastewater Discharge Licence

Waste discharge licences are compulsory for treatment plants in SA. In cases where a licence has not yet been acquired, general discharge authorisation is then used to guide discharge levels. The implementation of the licence and/or allowable discharge aids in the protection of receiving natural water bodies and improves the standard of discharge (Mzantsi, 2021).

WWTPs that were under study in the CoT operate using the discharge limits from the licence issued. In other treatment plants where a discharge licence does not apply or has not yet been obtained, general authorisation is used as a guideline. Owing to the anonymity that must be adhered to, the discharge licence parameters are not displayed in any section of this report.

5.5 Conclusion

Chapter 5 provided a detailed depiction of the perceptions of the professionals regarding factors that affect compliance with wastewater management in the CoT Metropolitan. This was satisfied by blending the findings with existing literature relevant to the study topic. It also highlighted the insight into challenges within the operational systems, effluent compliance challenges, and insights into the Green Drop Certification programme. It remains pertinent that the importance of technological solidity and simplicity are a pathway to a sustainable wastewater treatment system. In this research report, compliance has been regarded as the ability of a treatment plant to adhere to wastewater effluent standards, as well as adherence to regulation and policy.

Emerging new findings indicate CoT as capable to introduce green innovative approaches to wastewater management. The technical and educational capabilities exist within the municipality to carry and advocate for such development. Given that the current operating infrastructure require large funds for refurbishment and maintenance, it would be sensible to introduce low cost operating operational systems. Achieving the Green drop scores is possible, provided the DWS remain consistent and provide for timeous feedback.

Lastly, the methodology adopted allowed for the study to proceed with ease. Not only was the study able to uncover factors affecting compliance to wastewater management, the study also revealed that there are knowledgeable professionals on the ground who are able to advocate for new developments. The study also revealed that it is imperative for DWS to create Key performance areas in consultation with other professionals stationed at the municipality. Often times those involved in day to day operations and management are more knowledgeable and can provide new appropriate assessment techniques, this was evidenced through this study.

CHAPTER 6

Conclusions and Recommendations

6.1 Introduction

The former chapter delivered the results of the research discussions with reference to existing literature on wastewater management practices and the need for a paradigm shift. The conclusions and recommendations that arose from the study are presented in this concluding chapter. These are based on the wide range of reviewed secondary literature and the collected primary data. Literature was consulted to enhance the understanding of wastewater management and compliance.

The motivation behind the research report was based the fact that research related to the perceptions of professionals on the ground has often been reduced to giving insights into the type of treatment used, providing effluent water quality results, evaluating treatment plants' performance, and gauging whether or not professionals are skilled. This research report provided a platform for professionals involved in groundwork to provide perceptions that are valuable to direct regulation and policy framing. Professionals' perceptions regarding compliance with wastewater management with a focus on the CoT Metropolitan were explored in this study.

6.2 Conclusion

This research report aimed to interrogate factors that are contributing to the lack of compliance with wastewater management in the CoT. The report was not intended to discredit current operating systems, but to promote a discourse of wastewater treatment systems to sustainable wastewater technologies for future use. Factors affecting compliance were explored through perspectives from professionals and reported in this report with the aim of shaping policy and regulation reforms.

"The primary reason for the unacceptable levels of pollution is the failure to manage and maintain existing WWTWs in the City of Tshwane over a prolonged period of time. Failures in management which have resulted in a regression in standards of delivery, include poor

planning and implementation evidenced by the insufficient number of WWTWs to accommodate the growing population in the City of Tshwane" The South African Health Council Report

The above quote from the SAHRC Report is coherent with some of the findings from this report. As the state of water continues to deteriorate, the need for sustainable technologies also continues to intensify. In this context, these conditions are caused by a shortage of maintenance, low budget allocation to maintain current operating systems; and a shortage of supporting staff. Current interventions in the form of simple appropriate technologies with low energy operating costs are pivotal to the protection of water sources. This research report does not offer an exploration of these sustainable technologies; however, is aimed at directing discourse in that direction considering that the CoT has the potential to turn wastewater into a valuable resource.

On a normal day, professionals are hands-on in putting effort into combating the pollution of rivers. However, treatment plants have reached their lifespan wherein maintenance alone cannot salvage the already dire situation. It is also evident that treatment plants are hydraulically overloaded and, therefore, have nutrient removal constraints. On the other hand, the capital or budget for operation is costing the municipality in the long run. In light of this, innovative measures within the very treatment systems need to be considered.

The Green Drop scores on face value provide a negative picture of WWTPs. However, they fare better in operation contexts and professionals work heavily to ensure correct operations; hence, professionals within the interviews have expressed that more points have to be added to the operational aspect of the Green Drop scorecard as failure is often rooted in management. It was revealed that a lack of compliance is not attributed to a lack of skilled workers or technical expertise, but extends to aged infrastructure, treatment plants operating above capacity, corruption, insufficient budget allocation to operations and its monitoring, and a shortage of supporting staff, among others.

6.3 Recommendations

The research results presented in Chapter 4 and the discussions in the preceding chapter revealed gaps and issues that need to be considered and addressed. This study offers the following recommendations that stand to assist the current operational compliances of the CoT:

- This research report commends the efforts that have been made by professionals on the ground to work with the necessary tools, equipment and personnel available. However, it is recommended that capacity be built to increase the understanding of the importance of water management on gender implications. In particular, women have to be hired and present at treatment plants. Therefore, there is a need to increase the number of female employees appointed.
- Considering the context of operations, it became evident that policy and correct governance can play a major role. As an example, methods should be in place to analyse the costs and benefits of maintenance. The cost benefits of using and repairing older infrastructure compared to the cost of new proposed technology infrastructure should also be analysed to guide the municipality.
- A lot of infrastructure is aged and operating above capacity. At the same time, population and development proliferation have placed immersed pressure on these systems. A revised approach to the conceptualisation of wastewater management is encouraged; looking not only as supportive of nearby livelihoods; but also at the potential that they have to contribute to the South African economy.
- Integrated resource recovery is a concept associated with recovering valuable resources from wastewater. Social, economic and environmental benefits can be harnessed from wastewater. Nutrient capture and methane gas harnessing are some of the options available although they have their own challenges.
- Maintenance emerged as the most lacking in all treatment plants explored. All professionals clearly voiced out the need to have proper maintenance in place. The municipality must engage with workers on the ground on options better suited for each treatment plant as challenges differ in severity.
- There is a need for institutional support visibility at treatment plants. Perceptions of the municipality at large from viewing wastewater as a nuisance need to change. Municipalities must also invest in infrastructure upgrades or replacements owing to dilapidated infrastructure currently operating above design capacity.

- The DWS must be consistent in the Green Drop assessment and offer timely responses. Although it is not an enforcement programme, professionals remain committed to assisting WWTPs to adhere to the requirements. At the same time, the DWS must engage with municipalities on changes that are made to the assessment criteria. The requirements must be communicated clearly as to what is required and from whom it is required.

7. References

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