PERCEPTIONS AND INVESTIGATION OF POOR QUALITY WATER SUPPLIED TO THE RESIDENT OF THE CITY OF BLOEMFONTEIN

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DECLARATIONS

I, Palesa Moja, student number __________, herby declare that this research project submitted to the Central University of Technology, Free State for the Master Health Sciences in Environmental Health, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification

______________________ 1 May 2026

Signature of student Date

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ABSTRACT

The Mangaung Metropolitan Municipality (MMM) still experiences challenges in addressing water shortages, a problem that has affected socioeconomic development, the agriculture sector, and the municipal population. The systematic water interruptions to the city have fuelled the perception of the residents regarding poor water quality supplied to the city. The purpose of the study was to examine the existing water infrastructure and quality supplied by the Vaal Central Water and the Mangaung Metropolitan Municipality to residents of Bloemfontein, and to assess community perceptions of the supplied water quality. The study used a mixed-methods approach with two stages. The first stage included a quantitative approach with the use of a questionnaire (n=115) to collect data on the community perception of supplied water quality. Graphical representation and data analysis were conducted using Microsoft Excel. The second stage involved the collection of water samples from two sources (Vaal Central Water and MMM water works) for water quality laboratory testing. A spectrophotometer, inductively coupled plasma mass spectrometry, inductively coupled plasma optical emission spectroscopy, as well as a heterotrophic plate count and the IDEXX Colilert, were used to analyze the microbial and physicochemical parameters. The study shows a correlation between the colour of water samples and respondents' perceptions of colour and turbidity. Results indicate elevated levels of zinc, colour, and microbial contaminants exceeding SANS 241 standards, correlating with negative public perceptions of organoleptic properties; the majority of residents do not trust the quality of the tap water, and 79.1% of respondents believed authorities did not adequately communicate concerning water quality issues. The study concludes that respondents hold a negative impression of their water, which was driven by a lack of trust in the Municipality and negative organoleptic properties; although Bloemfontein's municipal water infrastructure largely delivers water that complies with SANS standards, shortcomings in maintenance, efficiency, and public awareness drive community dissatisfaction and water insecurity, emphasizing the importance of better communication and enhanced water quality management.

Keywords: Water supply; water quality; resident perception; water management; water infrastructure

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Background of the problem

For many years, the city of Bloemfontein has experienced water interruptions and water scarcity. Residents have recently experienced an increase in interruptions and the discoloration of water caused by the non-maintenance of burst pipes (Green Overall, 2018). Dr Vos, a water quality specialist, contended that the earthy taste and smell in raw water are caused by the algae, which produce organic compounds (Green Overall, 2018). Although the Municipality has developed public education and public awareness programmes to educate the general public through National Water Conservation and Water Demand Management (SALGA,2011), residents are still concerned about the deteriorating water quality and water interruptions (Express News, 2019).

Water is supplied to the Bloemfontein residences by Bloem Central Water and the Mangaung Metropolitan Municipality (MMM). The Department of Water and Sanitation (DWS) has reported that water shortages in South Africa are due to climate change and drought effects (DWS, 2016). In view of water interruptions caused by non-paid transactions and lack of expertise and resources, the contact gap between MMM and Bloem Central Water has deteriorated (Kusakana et al., 2019). Despite several large reservoirs and dams being built over the past years, water quality and supply are still a serious challenge in the city (Botes, 2016). Therefore, the study focuses on exploring the existing water structure and infrastructure of Bloemfontein, the community perception of the supplied water quality, and the water quality in localities within Bloemfontein.

1.2 Problem statement

One of the main challenges faced by South Africa is the declining water supply, which adds pressure to water resource management. The MMM is still experiencing challenges in addressing water shortages despite the National Water Affairs Resource Strategy, which provides policies and goals set to improve the water resource planning and management (Hedden & Cilliers, 2014). This problem has negatively affected socio-economic development, the agricultural sector and the municipal population. Motse reported high volumes of *E. coli* and coliform bacteria found in the Bloemfontein public water, while Dr Vos claimed that algae caused the bad odour and taste of the water (Express News, 2019).

Furthermore, owing to the maintenance of frequent burst pipes, residents have seen a surge in brown water flowing through their taps. Often, residents have been left without water for days. Residents of Bloemfontein have gone as far as to report Mangaung Metro Municipality to the SAHRC for defying the right to access adequate water and food (Ofm News, 2019). In 2018, most of the dams providing water to residents of Bloemfontein experienced a drop in water levels (Green Overall, 2018). The Bloemfontein residence raised questions about low water quality in the same year.

Despite efforts made by MMM along with Bloem Central Water to make Bloemfontein water quality better, the MMM's Blue Drop score decreased by 10.36% from 2010 (95.05%) to 2011 (84.69%) owing to the insufficient information received from MMM and Bloem Central Water on retaining the Blue Drop status (DWS, 2015).Owing to low reimbursement from the Municipalities and drought, Bloem Central Water has had financial difficulties during 2016 and 2017. Given the additional water plants at Maselspoort since the beginning of the 20th century, and the addition of many major dams and reservoirs over time, the city's water shortage has not been adequately addressed, in particular since the extreme droughts of 2016 (Botes, 2016). Communication between the MMM and Bloem Central Water has also had a negative effect on water supply, as Bloem Central Water and MMM were in court twice over water rights and supply issues to Bloemfontein in 2019 alone. These problems are perceived by the residents of Bloemfontein to affect the quality of water supplied to the city.

1.3 Research question

What is the link between measured water quality parameters (microbial, trace metals, and physicochemical) and the perceptions of residents regarding the quality of water supplied to the residents of Bloemfontein by Bloem Central Water and the Metropolitan Mangaung Municipality?

Sub-questions:

1. To what extent do residents' perceptions of tap water quality correlate with measured water quality across various localities in Bloemfontein?
2. What are the variations in chemical, physical, and microbial water quality components at the point of use across urban locations in Bloemfontein, and how do they align with the documented distribution system?

1.4 Research hypothesis

Research Hypothesis (H_1):

Deficiencies in the existing water structure and infrastructure are significantly correlated with the presence of contaminated and poor water quality supplied to specific localities within Bloemfontein, as perceived by the community.

Null Hypothesis (H_0):

There is no significant correlation between the existing water structure and infrastructure and the contaminated or poor water quality supplied to the residents of Bloemfontein

1.5 Research aim and objectives

The study aims to investigate the source of contaminated and poor water quality supplied by Bloem Central Water and the Metropolitan Mangaung Municipality to the residents of Bloemfontein, while determining the community perceptions regarding the quality of water supplied to the Bloemfontein residents.

The objectives of the study are as follows:

1. To get the community's perceptions of the supplied water quality;
2. To investigate the water quality in localities within Bloemfontein.

1.6 Significance of the study

The significance of this study lies in addressing research gaps related to water quality perceptions, public awareness, and the maintenance of existing water infrastructure.

Sustainable water infrastructure can be ensured by employing resource efficiency, lifecycle system resilience, as well as minimizing water loss and energy use. This includes the prioritization of equitable access in rural locations and capacity for community-led monitoring and minor repairs. Even though the water at the treatment plants meets the South African water standards, dilapidation in distribution can affect public confidence. Research shows that negative perceptions drive risk behaviour in communities, such as the boiling of water (energy loss) and buying bottled water (financial loss and waste) (Doria et al., 2009).

Low levels of trust reduce the willingness to pay for tariffs, thereby depleting municipal revenue required for maintenance, which leads to infrastructure decay. By researchers' mapping perceptions against infrastructure conditions, they can identify areas with high levels of distrust and enable targeted upgrades or repairs that encourage tariff compliance and improve trust. The study provides valuable insights that can assist stakeholders and the government in improving service delivery, addressing water infrastructure challenges, and ultimately ensuring safer water access and healthier communities.

1.7 Scope and limitations of the study

This study had a few limitations that affected how far it could reach and the amount of data that could be collected. One of the main challenges was limited resources and funding, which made it difficult to cover all areas of Bloemfontein, including the rural parts. The available funds were not enough to use more platforms for distributing the questionnaire or to collect water samples from every district. Additionally, the study was limited to examining drinking tap water and did not cover other sources of drinking water, such as bottled water, groundwater, or boreholes. This affected how much data was collected, and the overall coverage of the study was limited. In future research, these challenges could be improved by securing more funding and support to reach a wider population.

1.8 Structure of the dissertation

This dissertation consists of seven chapters outlined as follows:

Chapter 1: This chapter covers the introduction and the background of the study, important issues related to the problem statement, aims and objectives, research questions, research hypotheses, significance, scope, and limitations of the study.

Chapter 2: This chapter presents a review of the literature related to the research, with an overview of the challenges facing water resources and societal perceptions.

Chapter 3: It describes the area in which the study was conducted, the geographical area of the location, climate, water sources, water shortage challenges, and the environmental and socioeconomic background of the study area.

Chapter 4: This chapter outlines the methods used to obtain the necessary data, including the research design, laboratory water testing procedures, and survey data collection and analysis.

Chapter 5: It outlines the results which were achieved by conducting both non-target screening and quantitative analysis of emerging contaminants.

Chapter 6: This Chapter gives a discussion of the results.

Chapter 7: This chapter provides conclusions on the results of the study and offers recommendations for future studies.

CHAPTER 2 LITERATURE REVIEW

This chapter reviews literature on theories and models related to water quality.

2.1 Introduction

Globally, more than a billion people cannot easily obtain accessible clean water for drinking or domestic use. Water scarcity challenges have been increased by the cost of developing new sources of water, land degradation in irrigated areas, depletion of groundwater, water pollution, and degradation of the ecosystem (Hanjra & Qureshi, 2010). Ensuring that communities have access to safe drinking water requires an understanding of the different components that influence water quality. The three core dimensions of water quality assessments are physicochemical parameters, microbial contamination, and trace metal concentration (WHO, 2022).

2.2 Water quality

2.2.1 Water Quality Parameters

The physicochemical properties of water are characterized by pH, temperature, turbidity, dissolved oxygen, nitrates, phosphates, electrical conductivity, and hardness. These are important because they indicate the overall water quality, influence microbial survival, and also affect the chemical reactions and solubility of metals (Luvhimbi, Tshitangano, Mabunda, Olaniyi, 2020;WHO, 2022).

Physicochemical parameters give guidance to water treatment processes and compliance with regulatory standards (WHO, 2022). A study conducted in Uganda concluded that surface water and springs in the study area had unsafe drinking water, and the physicochemical parameters of the water were favourable for waterborne diseases such as cholera to propagate (Bwire, Sack, Kagirita, et al., 2020). Luvhimbi et al. (2020) assessed the physicochemical and bacteriological quality and human health risk from source to households, noting how intermittent municipal water supply, transportation, and storage practices increase risks to water contamination. Similarly, Agoro et al. (2018) tested three municipal sewage treatment plants in the Eastern Cape of South Africa and concluded that the sewage plants were a source of pollution since some of the physicochemical components did not meet the recommended limits of the SANS standards (e.g., turbidity, ammonium, nitrate, and nitrite, etc).

For the study, the following parameters were tested:

2.2.1.1. pH

The measure of alkalinity or acidity in a solution is pH (Rudzivo & Silent, 2020). The pH scale is from 0 to 14, and according to the South African National Standards (SANS:241), a pH range of 5 to 9.7 is acceptable in water (Sigudu, Mundackal, Makhubedu, Mahlako, 2024; SABS, 2015). The pH of water is important because as an indicator of metal solubility and affects chemical reactions in water. If it falls outside the range 6.5-9.5, it can corrode pipes and cause heavy metal toxicity (Fondriest Environmental, Inc., 2013). The specific pH ranges can also affect microbial survival, can promote the growth of pathogens like *E.coli* or create hostile environments for good bacteria. The pH levels of water treatment processes are monitored to identify risks in water sources (Sigudu, et al., 2024).

2.2.1.2 Turbidity

Turbidity, the cloudiness or haziness of a fluid caused by suspended particles, is commonly regarded as a fundamental marker of water quality in aquatic ecosystems and water supply systems. In drinking-water and wastewater treatment contexts, high turbidity complicates treatment processes: suspended particles can protect pathogens from disinfection, block filters, and increase operational costs. Recent breakthroughs highlighted the significance of new monitoring approaches, such as continuous river turbidity monitoring based on image processing, which enhances temporal and geographical resolution over traditional sampling (Sahoo & Anandhi, 2023). Turbidity is still a vital indication for assessments of water security, ecological assessment, and the sustainable management of freshwater resources owing to its vulnerability to both natural and man-made disturbances (such as erosion, urban runoff, and changes in land use) (Sahoo & Anandhi, 2023).

2.2.1.3 Temperature

Temperature is a crucial indicator in measuring water quality and aquatic ecosystem health. Temperature variations have a significant impact on dissolved oxygen concentrations, aquatic species' metabolic rates, the timing of biological processes (such as spawning and growth), and the solubility and reaction rates of chemical constituents (Larance et al., 2025). For instance, recent research in the Athabasca River utilizing time-series data from 1960 to 2023 showed that variations in water temperature had a major impact on dissolved oxygen patterns, which are essential for maintaining aquatic biodiversity.

2.2.1.4 Electrical conductivity

The ability of water to conduct an electric current is known as electrical conductivity (EC). It is widely applied in water-quality examinations as a quick, comprehensive indication of salinity and dissolved ion content. Conductivity increases when salts, minerals and other charged species (e.g., Na^+, Ca^{2+}, Cl^-, SO_4^{2-}) are dissolved in water, because these ions accelerate the passage of electrical charge (Kumar et al., 2023). Example in the 1980s the Jukskie river in the Gauteng Province was characterized to have low pH values and high concentrations of sodium, fluoride and nitrate which was potentially caused by industry along the Modderfontein Spruit (Huizenga et al., 2005). The water in Limpopo (Mvudi river) and the North West Province showed elevated concentrations of chloride in certain seasons (Edokpayi et al., 2015). Huizenga noted that surface water chemistry in South Africa is dominated by chloride salinisation and sulphate contamination (Huizenga, 2011).

2.2.1.5 Total hardness

The concentration of dissolved polyvalent cations, principally calcium (Ca^{2+}) and magnesium (Mg^{2+}), represented as equivalent calcium carbonate ($CaCO_3$), is known as total hardness (TH), and it is an important indication in water-quality investigations and water-use evaluations (Shmeis & Reham, 2018).

2.2.1.6 Microbial parameters

The microbial properties of water are assessed for disease-causing organisms (WHO, 2022; Sigudu, Mundackal, Makhubedu,2024). They indicate direct impact on human health, while assessments of these properties in water assist in tracing human contamination pathways and can determine the effectiveness of effective disinfection steps.

2.2.1.7 Trace metals

Trace metals assessed in water for toxicity provide indications of long-term health risks. Persistent and non-degradable metals in water also originate in various contamination sources such as mining, landfills, and agricultural inputs (Oke, Mugudamani, Gumede, Senbore, Samson, 2023; WHO, 2022). Therefore, the core dimensions provide a holistic evaluation of water quality by offering early detection of pollution, high risk in raw water, and treated water. To inform the appropriate water treatment strategies and ensure compliance with SANS standards, and to protect public health by the prevention of exposure to waterborne and chronic diseases (Mackintosh & Jack, 2008; WHO, 2022).

A study conducted by Olowoyo, Chiliza, Selala, and Macheka (2022) found trace metals with limits above World Health Organization (WHO) standards in drinking water in South Africa, specifically in bottled water. Reports assessed failures and challenges in water treatment works, water management, and water sources (Mackintosh & Jack, 2008).

2.3 Water supply systems in Bloemfontein

The city has two main sources of the water supply, namely Vaal Central Water and the Metropolitan Mangaung Municipality. The southern parts of Bloemfontein receive water from Bloem Central Water, and Mangaung's northern parts receive water from the Municipality, both abstracting water from the Modder River and Welbedacht Dam (Bloem Water, 2020). The national Municipal Benchmarking Initiative (MBI) was established in 2011 to improve water service delivery through comparative and performance benchmarking between municipalities (Hewavisenti, 2020). However, the Water Research Commission in 2012 found that 36.8% of municipal water was lost owing to leakages or losses (Hedden & Cilliers, 2014).

Bloem Central Water is one of 12 water boards that were established in terms of the Water Services Act,1997 (Act No. 108 of 1997), as a National Government Business Enterprise (Department of Water Affairs, 2011; Bloem Water, 2020). Its main activity is to supply water services (bulk potable) to Bloemfontein, Bainsvlei, Botshabelo, Bloemspruit, and Dewetsdorp municipalities. Bloem Central Water is regulated by the Minister in terms of both the Water Services Act, 1997, and the Public Finance Management Act, 1999 (Act No. 1 of 1999). The southern parts of Bloemfontein receive water from Bloem Central Water via the Welbedacht Dam. The Welbedacht dam has lost 95% of storage capacity to high concentrations of silt (114 million cubic meters) over the past 40 years and is augmented by the Knellpoort Dam (137 million cubic meters). The silted dam caused a high level of debris and sediment, which has damaged the pumps. The Tienfontein Pump Station, which supplies 70% of this silted water to Bloemfontein, constantly undergoes repairs. Mangaung's northern parts receive water supplied by the MMM, abstracting water from the Modder River (Bloem Water, 2020) through the Maselspoort water treatment plant. The Maselspoort is about 25 km from the outskirts of Bloemfontein.

2.4 Contamination pathways

Prouty and Zhang (2016) highlighted the need for an alignment in the perceptions of water quality with the actual, measured quality in order to prevent public health outbreaks due to under-treatment. They went further to discuss the importance of related matters that reduce the consumption of water resources, as well as reducing over-treatment, and conserving household expenditures being used to purchase charcoal for boiling water (Prouty & Zhang, 2016).

The contamination of drinking water in South Africa does not only happen at the beginning of treatment stages, but also within the distribution system. The water may meet the SANS standards (South Africa Burea of Standards (SABS), 2015) at the treatment point, although it has been polluted by the time it reaches the consumers. One of the primary pathways is related to inadequately maintained infrastructure, as noted by Botes (2016), MMM continues to face water supply challenges because its aging water and sanitation infrastructure is often repaired rather than replaced.

Over time, pipelines deteriorate to such an extent that entry points for contamination (external pollutants) develop in the distribution system. Pressure fluctuations in the water supply also cause contaminated pathways. Hedden & Cilliers (2014) found that the gap between demand and supply of water increases and that the solutions proposed by the Department of Water Affairs and Sanitation will not close the gap without additional, aggressive measures. In Bloemfontein, where water supply pipes can have low to negative pressure, contaminated groundwater or sewage can be drawn into the water distribution system, thereby compromising the quality of the water (Hedden & Cilliers, 2014; Ashbolt, 2004).

Environmental factors also contribute to contamination of water pathways for instance in Bloemfontein some areas have been reported to have pollutants from industrial effluent, urban runoff and domestic waste water which have affected the quality of water negatively (Edokpayi et al., 2020).

In addition, biofilm formation inside the pipeline, where microorganisms resistant to disinfectants such as chlorine attach themselves to pipe surfaces. Changes in the flow to remove them can result in contamination at the point of use (Ashbolt, 2004).

2.5 Health implications

Water contamination causes serious harm to human health, both immediately and over the course of a lifetime. When water is polluted with pathogens (bacteria, viruses, protozoa), it becomes a significant vehicle for water-borne diseases. For example, widespread gastrointestinal infections that cause diarrhoea, dehydration, and even more serious illnesses are caused by microbial contamination in drinking water (Ali et al., 2025). Furthermore, recent research indicates that trace-metal contamination of drinking water may exacerbate microbial risks: metals may encourage the formation of biofilms in water distribution systems, which increases the likelihood of pathogen colonization and may even accelerate the growth of bacteria resistant to antibiotics (Li et al., 2025).

2.6 Drinking water quality globally

Water and sanitation together are vital for reducing the global disease burden and for improving people's health, education, and economic productivity (Hanjra & Qureshi, 2010; UNESCO, 2020). The World Health Organization (WHO, 2022) created guidelines on drinking water quality to support the acquisition and application of risk management strategies, including the promotion of protecting people's health and safeguarding systems to ensure countries adhere to standards of safe drinking water. In the year 2022, 73% of the global population had access to safe, accessible drinking water, and 1.7 billion people used contaminated water with faeces as a source of drinking water. These strategies are supposed to assist in controlling the limits of hazardous substances in safe and accessible drinking water (WHO, 2022).

2.7 Drinking water quality nationally

South Africa is widely regarded as a water-scarce country, and this is largely due to its geographical location and climate. The lack of water supply, infrastructure failures, the decrease in quality, and environmental changes are the reasons for its scarcity. In South Africa, beyond the regulations of water quality, are the National Water Act (Act of 36 of 1998) (The Southern African Legal Information Institute, 1998), Water Services Act (Act of No. 108 of 1997) (South African Government, 1997), the National Environmental Management Act (South African Government, 1998), the Municipal Systems Act (Act of No. 32 of 2000) (South African Government, 2000), and the National Health Act (Act no 61 of 2003) (South African Government, 2003). They are legislative frameworks that were established to ensure the protection of water quality, access to drinking water for all people in the country, and sufficient water services and infrastructure, including protection against the deterioration of water resources and pollution. The Department of Water and Sanitation is required by legislation to ensure the protection and adherence to regulations that support the use, production, maintenance, and efficient delivery of water supply and sanitation (DWS, 2020). The Free State Province is bounded by the provinces of Eastern Cape, Gauteng, Northern Cape, North-West, KwaZulu-Natal, and Lesotho.

2.8 Drinking water locally

Bloemfontein is the capital city of the Free State province of South Africa and was established in 1846 (University of the Free State, 2012). In 2016, the population of the greater Mangaung was at an average of 787,929 according to the Community Survey. It lies on a plateau at an elevation of 1,392 meters and is famous for being the judicial capital of South Africa. It was made part of the Mangaung Local Municipality in the year 2000 (Britannica Editors, 2019). Currently, the water supply and quality have deteriorated because of the aging water and sanitation infrastructure, which the city fails to replace (Botes, 2016).

The MMM was promoted from Category B to Category A in 2011. Category A municipalities are defined by their high population concentrations, multiple business districts, complex and diverse economies, and broad development (NCOP Finance, 2018; Government Communications, 2019). The MMM is one of the smallest metropolitan areas in South Africa. It acquires around 70 % of the water it supplies to the residents from the Bloem Central Water. The MMM uses the following methods for managing its water and sanitation systems in operation. This includes routine IDP preparation and IDP analysis, a collection of regulatory criteria, tariff policy, tariff setting, drinking water quality, water demand management initiatives, and ability for regulation (Department of Water and Forestry, 2002). Water demand management initiatives and other interventions (Department of Water and Forestry, 2002).

The water and sanitation department (DWS) of the MMM has faced the challenge of water scarcity owing to climate change and the consequences of drought in South Africa. To alleviate this problem, the MMM initiated the Water Demand and Conservation programme together with the Department of Water and Sanitation. The programme involved building the following reservoirs: the 45-mega-liter Langridge reservoir, an eight-mega-liter reservoir in Botshabelo, and, in particular, the 35-mega-liter Naval Hill reservoir (Mangaung Metropolitan Municipality, 2013). An estimated 199 million rand was invested in projects to provide basic water services and bulk water to the MMM (Mangaung Metropolitan Municipality, 2013).

2.9 Perceptions in water quality

Public perception in urban settings demonstrates high levels of confidence, though driven by subjective personal trust and sensory lived experiences, it often diverges from objective data-driven measurements (Nelson et al., 2024; Sarah Slabbert Associates, 2011), however, subjective perception may not be a true reflection of microbial and physicochemical status of water which can only be determined by scientific analysis of water. This divergence points out the limitation on reliance of experiential judgement in assessing water safety (Artell et al., 2013). It is noted that in urban cities around South

Africa, approximately 80% of the residents perceive water to be safe to drink, which is consistent with international findings (Sarah Slabbert Associates, 2011). The greatest influences on perceptions are from the organoleptic properties of water (taste, smell, and appearance), and the single strongest factor is direct personal experience (e.g., nobody getting sick) that shapes risk perception. Currently, the awareness of the “Blue Drop status” has a limited influence on consumer perception, showing a significant challenge in communication (Sarah Slabbert Associates, 2011).

There is a need for improved governance and communication underlying challenges in public perception in South Africa (Sershen, Rodda, Stenström, Schmidt, Dent, et al., 2016). According to Sarah Slabbert Associates (2011), the MMM has the least consumer confidence in the safety of tap water than the eThekwini Metro. A lack of knowledge concerning water treatment processes, especially among lower socio-economic (LSM) groups, shows a clear need for educational awareness campaigns. Governance obstacles occur when misconceptions hinder the implementation of crucial infrastructure upgrades (Nelson et al., 2024). Research indicates that there are scarce studies on the perceptions of drinking water in South Africa, including gaps in understanding how various factors interact (Sarah Slabbert Associates, 2011).

2.10 Social and Environmental Issues in Bloemfontein

Bloemfontein has experienced significant social issues, development backlogs, and historical spatial inequality. Disadvantaged communities, primarily situated in the south-eastern quadrant of Mangaung, are separated from the city and western suburban areas by railway and road infrastructure. This fragmentation has resulted in distant urban dependency for areas such as Thaba Nchu, which are more than 50km away. They rely on Bloemfontein’s economic hub for employment, accessed through limited public transport. The MMM struggles with a historical housing backlog, the consistent existence of informal settlements, and an urgent need for the eradication of the bucket system and Ventilated Improved Pit latrine (VIP) toilets in Botshabelo, Thaba Nchu, and Bloemfontein (Mangaung Metropolitan Municipality, 2023).

Given that South Africa is a water-scarce country, the MMM area is burdened with environmental issues such as drought and climate change, which threaten water supply (Coetzee, Oke, Kusakana, 2019). Additionally, the environment has been affected by illegal community dumping and weakened waste management, which have led to pollution and damage to wastewater treatment works (Mangaung Metropolitan Municipality, 2023).

2.11 Water supply and demand in Bloemfontein

Based on the report "Identification of Bulk Engineering Infrastructure in Support of Housing Development in Mangaung" created for the MMM, the low population growth scenario estimates that Bloemfontein's population will grow by 1% annually until 2030 while the high population growth scenario based on the IDP report a growth rate of 3.2% annually for the MMM (Department of Water and Sanitation, 2012). These scenarios were used to estimate the bulk water requirements in the coming years (Department of Water and Sanitation, 2012).

The bulk water system infrastructure consists of four storage dams, three water treatment plants, and numerous pipelines. A network of pipelines connects the dams, treatment plants, and reservoirs. The study examines the key pipelines of the water that was tested, specifically the Welbedacht-Bloemfontein pipeline and the Bloemfontein-Maselspoort pipeline (Bloem Water, 2018).

2.12 Water Challenges in Bloemfontein

2.12.1 Vaal Central Water and Mangaung Metropolitan Municipality

The relationship between Vaal Central Water and the MMM is burdened with financial instability and conflicting roles, threatening water service delivery. Vaal Central Water is a bulk water service provider (WSP) and is categorized as a Schedule 3B National Government Business Enterprise established to operate the Caledon/Bloemfontein

Government Water Scheme. It supplies water to over 1.2 million people, while the MMM, which functions as both the Water Services Authority (WSA) and the Water Service Provider (WSP), purchases 70% of its bulk water from Vaal Central Water.

Since the MMM is Vaal Central Water's major client, accounting for 95% of its income, non-payment by municipalities, and specifically by the MMM, has posed the greatest financial loss to Vaal Central Water, which caused severe strain on its operations and threatens its status. It also challenged the implementation of drought tariffs approved by the Minister, and later failed to make payment plans resulting from mediation. The MMM had a pending claim of approximately R313 million against Vaal Central Water related to raw water billing from 2010.

There is no clear separation between the WSA and WSP roles within the MMM. The water service functions have no set funding, meaning that the revenue is pooled into the municipal account, resulting in the Water Services Division having to compete for budget allocation along with other departments. This reinforces the delayed maintenance of critical water infrastructure and low capital investment. Collaboration between Vaal Central Water and the MMM occurs when the MMM undertakes projects on behalf of the Department of Water and Sanitation and assists when the MMM's own maintenance of boreholes in areas such as Wepener is inadequate.

2.12.2. Infrastructure

Bloemfontein's bulk water infrastructure is characterized by old resources, maintenance backlogs, and quantity constraints, all of which have directly impacted a reliable supply and are exacerbated by the city's expanding population. Theoretically, the water supply gap for the MMM is 60 megalitres. The infrastructure reveals symptoms of deterioration and dilapidation. There is confirmation that Vaal Central Water's 106-kilometer main pipeline, which is more than 47 years old, often bursts, causing needless delays in water deliveries. The system's degradation and ruptured water pipes are the main causes of raw water losses. Only three of the Tienfontein Pump Station's six pumps can operate simultaneously owing to electrical restrictions (Notified Maximum Demand), which restrict output (Mangaung Metropolitan Municipality, 2023).

The Groothoek Dam dried out owing to drought (it has been non-operational since July 2015). When it was recommissioned, its capacity was reduced from 18 Mℓ/day to 2 Mℓ/day to ensure the sustainability of the resource. Since its construction in the early 1900s, the Maselspoort Water Treatment Works (WTW) has faced significant challenges in operations and bottlenecks that have limited its capacity to meet the current demands of Bloemfontein. The reason is that deferred maintenance and expansion of infrastructure are major consequences of the municipality's failure to secure set funding for water revenue. Illegal encroachment of settlements within servitudes along the pipeline that belongs to Vaal Central Water has also posed challenges for construction and service delivery.

2.12.3 Siltation

The Department of Water and Sanitation (DWS) commissioned studies by the Council for Scientific and Industrial Research (CSIR) and Water Research Commission (WRC) to investigate sustainable ways to address the siltation problem. The delay in finalizing these investigations impacts planning for future water demands. The Welbedacht Dam has seen substantial siltation, averaging 2500 Nephelometric Turbidity Units (NTU), especially during the summer season, owing to silt, which constitutes a major environmental and operational danger to the Caledon system, demanding significant financial interventions. The yield of the existing Caledon system has been considerably diminished as a result of the dam losing 95.3% of its storage capacity. Siltation has also impacted the Tienfontein Pump Station. Vaal Central Water launched designs for a bi-directional pipeline connecting Knellpoort and Welbedacht Dams (estimated R384 million) in an effort to decrease. The pipeline is supposed to provide the Welbedacht WTW with an appropriate supply of raw water and to permit extended scouring of the dam during floods in order to restore the minimum storage capacity (Villiers, 2008).

2.12.4 Water Losses

Non-revenue water (NRW) remains excessively high within the MMM, threatening the financial and resource sustainability of the water supply chain. Significant quantities of treated water are being lost in the reticulation system. Mangaung's reported Non-Revenue Water (NRW) losses are critically high: estimates include 34.8 %, rising to 41% in the 2015/16 financial year, and subsequently assessed through the 2024 Municipal Strategic Self-Assessment (MuSSA) as 50% or more. Material water distribution losses incurred by the MMM amounted to R454.2 million in the 2022/23 financial year. The reason is that the bulk water losses are primarily due to burst water pipes, leaks, and unmetered water sites, while a widespread problem of aging infrastructure exacerbates these losses. The target for the Water Conservation and Water Demand Management (WC/WDM) programme was not achieved owing to delayed procurement and contractual matters.

2.12.5 Population growth

A continuously growing population, coupled with economic expansion, places increasing pressure on the already constrained water supply systems, necessitating urgent augmentation projects. Vaal Central Water currently supplies water to a population in excess of 1.2 million. The population of the MMM was projected to grow from 833,138 in 2015 to 1,045,301 by 2036. The ongoing growth of the Mangaung Metro area drives increased water demand, visible in the increased abstraction rates at pump stations such as Novo. The current water demand exceeds the yield of the Caledon and Modder River supply systems (DWS, 2015). A fast-growing population, combined with consumption habits, puts stress on global water resource limits. The MMM recognizes the need to increase water supply to allow for a growing population and a growing economy. The

Mangaung Gariep Water Augmentation Project (MGWAP) is required to obtain a reliable, efficient, and sustainable long-term water source (Bloem Water, 2019).

2.12.6 Economic profile of the city of Bloemfontein

In recent years, Bloemfontein has been developing economically, which has led to an increase in population and centralization of economic services (Department of Water and Sanitation, 2012). Bloemfontein is one of the urban centres of the MMM. According to Mugudamani (2024), government services contribute 42%, trade 22%, finance 18%, transport 15%, agriculture 2%, and mining 1%.

2.12.7 Bloemfontein Residents Communication

Communication gaps and the lack of a comprehensive public awareness programme related to water quality and operational risks contribute to community dissatisfaction. Poor water quality and shortages have caused residents to raise concerns, resulting in a negative image of the MMM and the Department of Water and Sanitation (DWS). Communities expect high-quality services and anticipate being informed at the correct time about challenges that may affect their expectations (Coetzee et al., 2016).

A primary problem is the failure to clearly specify the functions of the WSA and WSP, contributing to communication failure. According to a 2024 self-assessment, a comprehensive customer awareness programme (which should inform customers of water system operations impacting supply, water quality, and incident reporting) is not in place. The function of government communication at the local level (MMM) is deemed critical for ensuring communication and mitigating reputational damage during a crisis. MMM officials are expected to engage communities for input during the planning (IDP) process, while the municipality implements social awareness and public education programmes on water use efficiency, disseminating information through means such as pamphlets. Vaal Central Water actively engages in public awareness campaigns, including War on Leaks campaigns, to promote water conservation and river health. DWS regulatory efforts globally emphasize that educational and outreach efforts should be developed to increase public awareness of water quality, helping mitigate discrepancies between perceived and measured water quality (Bloem Water, 2018; Bloem Water 2019)

Vaal Central Water claims that the bulk water treatment has good compliance levels of treated water. They constantly report that the water treated by their facilities meets the required standards of SANS 241:2015, achieving 99% compliance in 2018 and 2019, as indicated in the financial year report of 2018/2019 (Bloem Water, 2019). Environmental health practitioners under the MMM are also tasked with quality assurance by testing water samples from the Brandkop and Maselspoort reservoirs, including residential households, and have reported a good compliance status of SANS 241 (Bloem Water, 2018).

The city obtained Blue Drop status in 2009 and 2010 for drinking water quality because of the good performance (Mangaung Metropolitan Municipality, 2023). Unfortunately, the standard fell from 95% to 84.5% in 2011. The drop was caused by a deteriorating water network that distributes water from the Welbedacht dam to the residents of Bloemfontein (Ratikane, 2013). The status continued to drop in the year 2012 at 84.45%. Additionally, the water supply system is faced with operational challenges related to aging infrastructure, resulting in water loss. Management failures have been acknowledged, including a lack of chemical compliance monitoring systems and inadequate maintenance on boreholes in smaller towns such as Dewetsdorp (Ratikane, 2013). In addition to all the issues are consistent challenges with raw water and localized contamination, such as the Welbedacht Dam, comprising high siltation and turbidity, along with high algae content in the Knellpoort Dam, and traces of faecal coliforms in the Rustfontein Dam (Bloem Water, 2018). Moreover, research has highlighted a "dearth of data on selected emerging contaminants (ECs)" such as pharmaceuticals, in dams and wastewater effluent around

Bloemfontein (Oke et al., 2023). This shows an urgent need for continuous monitoring in the area.

2.13 Summary

The literature reviewed shows that the decreasing water quality and water shortage is a critical global challenge pressed by urbanization, environmental breakdown , and climate change (Hanjra & Qureshi,2010; WHO, 2022). In South Africa, these pressures are made worse by urban municipalities, governance challenges, and infrastructure dilapidation.

A consistent trend across the literature is that water quality assessment, consisting of physicochemical, microbial, and trace metal parameters, is multidimensional. These parameters determine water safety collectively and interrelatedly (Luvimbi et al., 2020; WHO, 2022).

There are still certain gaps notwithstanding these findings. In Bloemfontein, there aren't many integrated, localized studies evaluating physicochemical, microbiological, and trace metal elements in the same system. Additionally, the Mangaung distribution network's contamination paths under sporadic supply situations have not been thoroughly investigated. There is currently a dearth of information about new pollutants at the local level. In addition, there aren't many studies that look at the connection between public opinion and real water quality in this setting.

Sustainable Development Goals (SDGs): SDG 6 (Clean Water and Sanitation), which aims to ensure the availability and sustainable management of water for everyone, is directly affected by this research. The study contributes to the global goal of supplying safe and reasonably priced drinking water by examining the discrepancy between treatment plant compliance and point-of-use quality. By offering localized data that could enhance water resource planning and management in the Mangaung Metropolitan Municipality, it also advances the goals of the National Water Affairs Resource Strategy.

A major scientific contribution of this study is its mixed-methods approach, which provides a rare correlative analysis between objective technical data (physicochemical, microbial, and trace metal parameters) and subjective human perception. This helps scientists and policymakers understand how taste, smell, and sight serve as the public's primary warning signs. The study addresses a major "dearth of data" on new pollutants in the Bloemfontein area. By identifying contaminants like zinc and feacal coliforms at the point of consumption, the study underscores the need to expand monitoring over and above treatment facilities to the entire distribution network and provides a foundation for correlating resident mistrust to specific infrastructural conditions.

CHAPTER 3: DESCRIPTION OF THE STUDY AREA

3.1 Introduction

The purpose of this chapter was to describe the study area used for the study, which is the city of Bloemfontein. Furthermore, the climate, water source, geology, soil, and topography, the socio-economic status, water supply, demand of water challenges, and communication between residents and municipality are discussed. The city of Bloemfontein is known as the City of Roses, is well-known as the judicial capital of the Free State, and forms part of the MMM. The Mangaung Metropolitan is located within the Free State province in South Africa (Britannica Editors, 2020).

3.2 Location of the study area

The city of Bloemfontein is situated on a plateau at an elevation of approximately 1,392 m, with GPS coordinates of 29.1208°S, 26.2376°E (Britannica Editors, 2020) as shown in Figure 3.1. Bloemfontein is a semi-arid region with a critical water management system owing to its scarce water resources and sporadic droughts. It is characterized by its predominantly grassy vegetation (Britannica Editors, 2020). The geology of Bloemfontein comprises exposed sheets of rock, sills, and dolerite dykes (Figure 3.2). Subterranean clay soils are found at the bottomlands of wetlands and streams, while dolerite sheets of rock are overlayed with a shallow layer of red and dry sands over grassy vegetation (7 Dams Conservancy, 2025). Diverse species and plants adapted to semi-arid conditions are found in nearby areas (Mshelia & Belle, 2024).

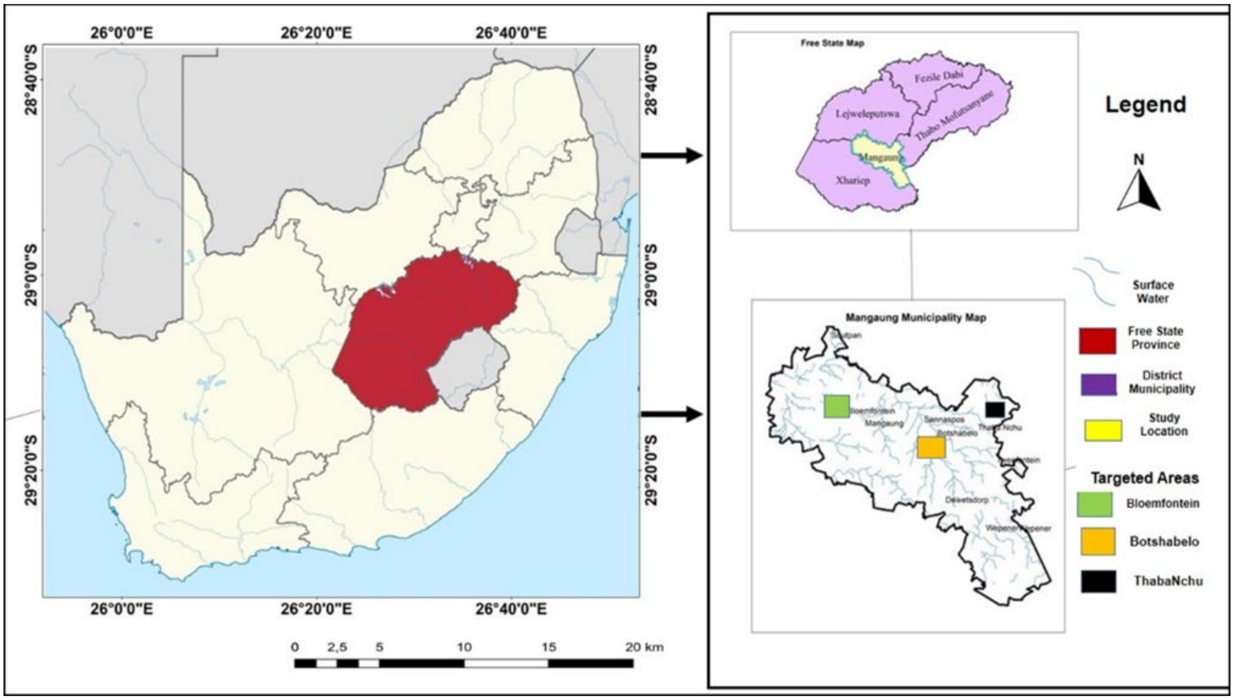

Figure 3.1: The Free State province (Source: Mugudamani, 2024).

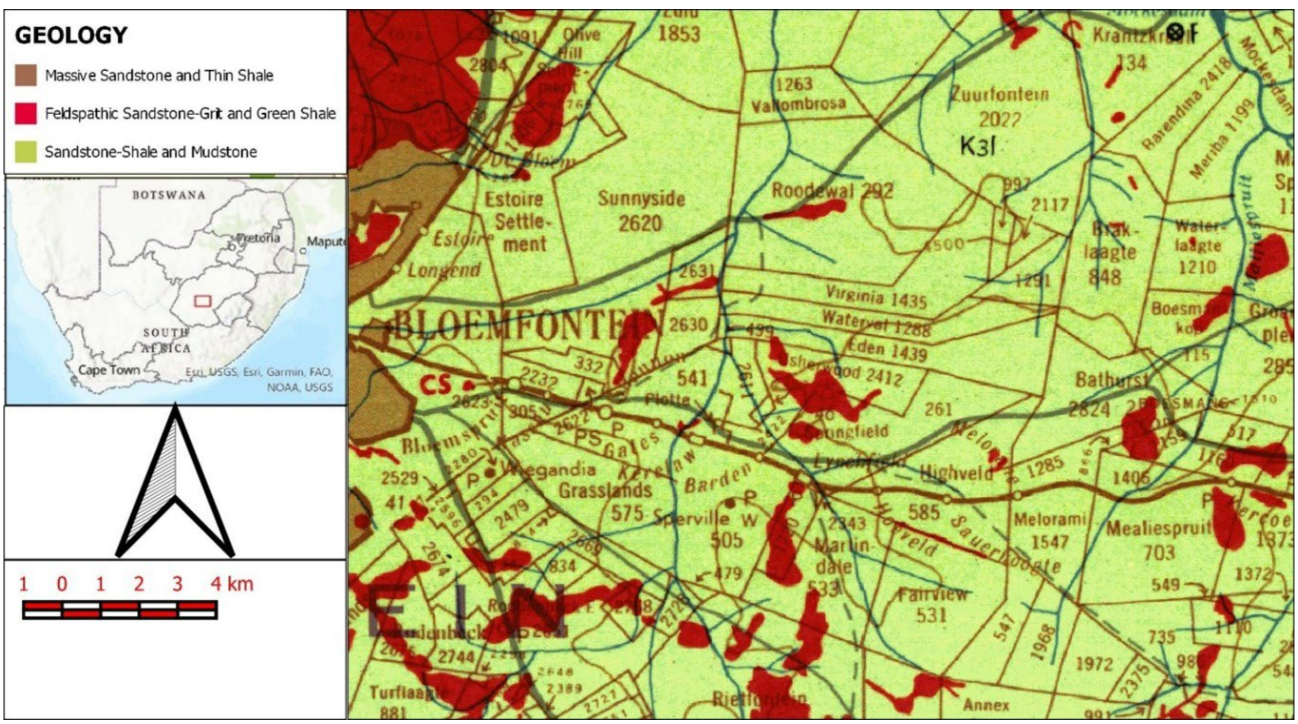

Figure 3.2: Geological map of Bloemfontein (Source: Mugudamani,2024)

3.3 Climate

From June to August, the city is cold with temperatures reaching lows of below freezing point during sundown. Summer temperatures can reach highs of 30 degrees Celsius and above during December and February (Mshelia & Belle, 2024).

Since Bloemfontein is located in the Highveld summer rainfall region, its variation in annual temperature is 14.5 degrees Celsius, with the dampest month being January and the driest month in July (Climate-Data.org, 2019; Mugudamani, 2024). Rainy seasons are experienced between March and October (Mugudamani, 2024) with a precipitation of between 457 to 566 mm (7 Dams Conservancy, 2025).

The predicted decline in rainfall, coupled with climate change and rising global temperatures, poses a challenge for Bloemfontein as it places growing pressure on the demand for fresh drinking water, particularly with the expansion of housing developments (7 Dams Conservancy, 2025).

3.4 Water sources

Bloemfontein's main water supply comes from the Modder River water system, which includes the Rustfontein Dam, Groothoek Dam, the Krugersdrift Dam, the Caledon River, and Groundwater (Figure 3.3). According to the Department of Water and Sanitation, the bulk water infrastructure includes three water treatment plants, four storage dams, and multiple pump stations and pipelines;(i) The Caledon-Modder (also called the Novo Transfer Scheme) provides water to Bloemfontein, Botshabelo, and Thaba Nchu through the Rustfontein Treatment Works; (ii) the Maselspoort Scheme, and (iii) the Caledon-Bloemfontein transfer, which supplies Bloemfontein, Dewetsdorp, and small users from Welbedacht Dam (Department of Water and Sanitation, 2012).

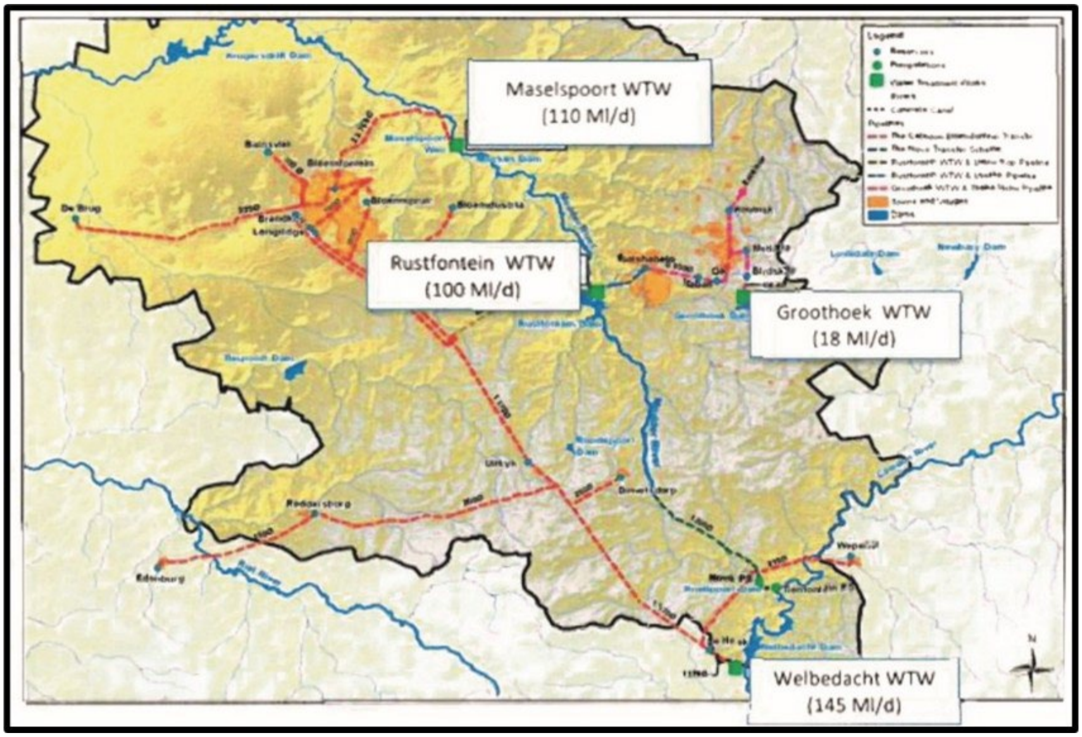

Figure 3.3: Water source infrastructure of Bloemfontein

(Source: Senbore, 2022)

3.5 Population profile of the city of Bloemfontein

According to Statistics South Africa (2011), the capital city of the Free State has a population of 256 185 people. Bloemfontein's demographic is comprised of 56,1% Black African, 29.8 % White, 12.8% Coloured, and 0.8% Indian or Asian people. The majority of the males and females are between 20 and 24 years of age. The most popular languages spoken in the city are Afrikaans and Sesotho at 42.5% and 33.4 %, respectively. There are also additional spoken languages in the city, such as English, isiXhosa, and Setswana (between 7,5% and 5%) (Statistics South Africa, 2011). The highest level of education is matric at 35.1%, and with 2.9% of the population having no schooling. Data shows that 14.9 % of the population's income is mostly between R9 601 and R614 400, while a low percentage of people earn between R1 and R4800, and between R1.2 million and R2.4 million and above. Only 9.5 % do not have any income (Statistics South Africa, 2011).

CHAPTER 4: METHODOLOGY

4.1 Introduction

This chapter outlines the research methodology for investigating the water quality and residents' perceptions thereof in Bloemfontein. The chapter is divided into two sections, whereby it discusses the sampling technique used in water sampling and analysis, questionnaire methodology, and data analysis, respectively.

4.2 Research Design

The research approach used was a mixed method combining qualitative perception analysis and quantitative water quality testing. Quantitative data analysis results compared against community perceptions showed the significance of blending both methods to obtain a broader understanding (Shaw, et al., 2018). Therefore, perception data guides awareness strategies, technical fixes, communication, and accounts for lived practices, while objective measurements offer scientific evidence (Nelson et al., 2024; United States Environmental Protection Agency (EPA), 2021).

4.3 Target population and sampling

4.3.1 Resident participants

The target group consisted of residents within the city of Bloemfontein, since the survey was to determine the community perceptions of the water quality. Additionally, the survey was restricted to urban areas. The residents of Bloemfontein were chosen because they make use of the services of the MMM.

4.3.2 Sampling method

A non-probability sampling method was employed to select participants**.**

- Convenient sampling was the chosen method.
- The questionnaire was distributed via various social and online platforms, such as email, WhatsApp, and Google.
- The gatekeeper letter was used to distribute the survey to staff and students from the Central University of Technology, Free State.

- The questionnaire was targeted at households. Since Bloemfontein has a population approximated size of 567,000, at a confidence level of 95 % and a margin of error of 3%, a sample size of 1066 was deemed appropriate.
    - The sample size collected was calculated using equation (1):

$$Sample\ size = \frac{\frac{z^2 p(1-p)}{e^2}}{1 + \left(\frac{z^2(1-p)}{e^2 N}\right)}$$

$N = population\ size$

$e = Margin\ of\ error\ (percentage\ in\ deciaml\ form)$

$z = z - score$

- A total of 115 participants responded to the online survey.

4.4 Water Sampling Technique

Municipal drinking water representative samples were collected from the northern and southern ends of Bloemfontein city (Figures 4.1, 4.3, & 4.5). Two locations were used to collect water samples, namely P1(29°09'15.1"S 26°10'24.5"E) and P2(29°06'46.6"S 26°13'25.8"E), in Bloemfontein. The study found that a lack of funds and resources was the primary barrier to collecting water samples from every district or the entire Bloemfontein region, including rural areas. The two locations (P01 and P02) were specifically chosen to provide representative samples from the northern and southern edges of the city. The Welbedacht-Bloemfontein pipeline, which feeds the southern portions, and the Bloemfontein-Maselspoort pipeline, which provides the northern portions, are the two primary water treatment systems, which is why these specific infrastructural locations were selected. The choice also allowed for the comparison of different urban environments, with P01 representing a residential suburb (Pellissier) and P02 representing the heavily crowded commercial Central Business District (CBD).

The samples were collected according to the SANS 5667-5 techniques (ISO, 2006). Sterile plastic bottles of 750 millilitres were used to collect the water sample from an outside tap. The bottles were labelled P_{01} and P_{02} (Figures 4.2 & 4.4), with the date of collection and time, and a form which was signed with the collector's details at the lab. The taps at both sites were inspected and were clean, functional, and free from leaks. The spout of the tap was cleaned with a tissue, and the tap was opened and allowed to run for five minutes to ensure that the water coming from the tap was representative of the main supply and not stagnant water in the pipeline. The flow was then reduced to a steady flow to collect water in the bottle, leaving a small air gap. The researcher avoided any splashing or contamination inside the bottle cap. The bottle was closed tightly and put inside a cooler box with ice to keep it cool (Figure 4.6). The bottles were then transported to the University of the Free State laboratory within 30 minutes of collection.

The first sampling site, P_{01}, is located in a residential area, while the second site, P_{02}, is situated in the Bloemfontein CBD. Both were selected because their water pipelines are supplied directly from treatment water plants; i.e., the Welbedacht-Bloemfontein pipeline and the Bloemfontein-Maselspoort pipeline, respectively.

P_{01} is located in the Pellissier suburb, exclusively residential, with no industrial discharges or informal settlements. It is 7.5 km south-west of the Bloemfontein central business district, and is a medium-density residential neighbourhood with coordinates (29°09'15.1"S 26°10'24.5"E). The location is characterised by single- and double-storey households constructed predominantly between 1975 and 2005, with an average stand size of 850 m². Pellissier features local amenities such as churches, schools, a shopping centre, garages, and the Windmill Casino complex, which lends a semi-rural feel within urban bounds (Chas Everitt International Property Group, 2025). The reticulation system comprises uPVC and galvanised steel service lines (Ø 20–50 mm) installed in 1982, and fed directly from the Maselspoort Water Treatment Works via a 500 mm diameter asbestos-cement trunk main. Peak domestic water demand occurs between 06:00 and

08:00 as well as between 17:00 and 20:00, resulting in water ages of between four to eight hours in the peripheral pipes (Vaal Central Water, 2024).

P_{02} is situated in the Bloemfontein CBD in Zastron Street, within a high-density commercial area. The location comprises office blocks, retail outlets, and lodges and hotels. Water is supplied through cast-iron mains (Ø 150–300 mm) laid in 1958 and renovated in 2014, connected to the same Maselspoort treatment outlet via a parallel trunk main. The hydraulic regime is dominated by commercial demand, with diurnal peaks at 12:00 to 14:00 and water residence times of between two to four hours in the local network (IDP and OPM, 2024).

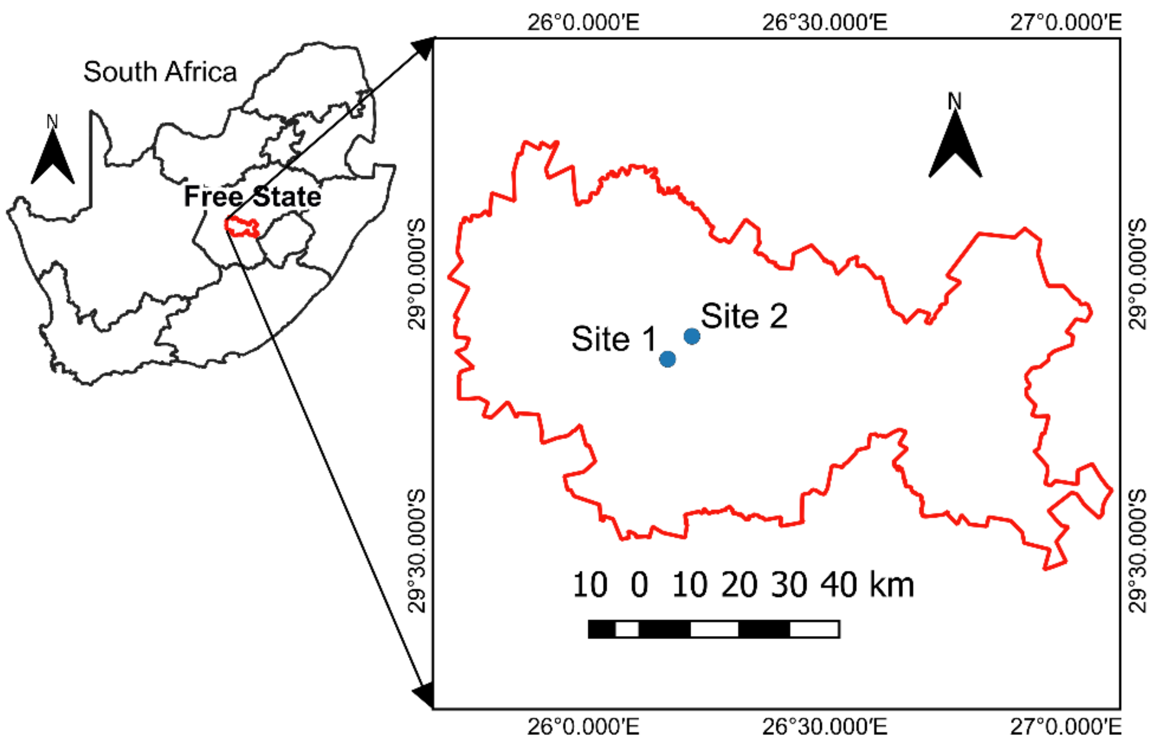

Figure 4.1: Location of sampling sites P01 (residential area) and P02 (CBD) within Bloemfontein, showing pipeline routes from Maselspoort Water Treatment Works (Source: By Author).

Figure 4.2: Sample P_{01}

Figure 4.3: Image representing the tap from Site 1 of sample P_{01}

Figure 4.4: Sample P_{02}

Figure 4.5: Image representing the tap from Site 2 of sample P_{02}

4.4.1 Water quality data

The water samples collected from the study sites were tested for physical, microbiological, and chemical components at the Institute of Groundwater Studies at the University of the Free State in Bloemfontein, and the measured components of the physical, microbiological, and chemical components of the samples were then tabulated in an Excel spreadsheet to detail the results. It was presented as min, max, mean, and standard deviation. The following methods were used to test the water samples:

4.4.1.1 Turbidity

The spectrophotometer is an instrument used to measure the intensity of light when it passes through a sample (HunterLab, 2022). This instrument was used to measure colour and turbidity measured in nephelometric turbidity units (NTUs), *4.4.1.2 Electrical Conductivity and pH*

An Eco pH meter is a scientific device used to measure the alkalinity and acidity of a liquid by detecting the concentration of hydrogen ions in a liquid. It measures the difference in electrical potential between a pH electrode and a reference electrode; this difference is measured in millivolts (mV). The device's primary unit of measure is pH units (Encyclopedia Britannica, 2026).

4.4.1.3 Macro and Micro cations

ICP-MS (inductively coupled plasma mass spectroscopy) is an instrument that uses argon plasma to convert a sample into ions, then measured using a mass spectrometer- MS (Weinrich, 2007; Agilent Technologies Incorporated, 2026). ICP-OES (inductively coupled plasma optical emission spectroscopy) is a technique that was used to measure macro and micro actions. It is used to determine the elemental composition of a sample by using the fact that atoms and ions absorb energy to move electrons from the ground to an excited state (Agilent Technologies Incorporated, 2026).

4.4.1.4 Anions

A discreet analyzer is an automated chemical analyzer. It performs tests on specific chemicals kept in discrete cuvettes, different from a continuous flow analyzer that uses a peristaltic pump for a continuous stream of reagents. The analyzer was used to conduct specific chemical tests by measuring anions (Astoria-Pacific, 2011).

4.4.1.5 Microbial parameters

HPC (heterotrophic plate count, grown on standard plate count agar at 36°C) is a microbiological testing method that was used to determine the total count of aerobic heterotrophic bacteria in water. It involves placing a sample of water on a solid growth medium to feed bacteria to grow and form colonies (Sure-BioChem Laboratories, 2026). IDEXX Colilert is a method was used for detecting and quantifying the total coliforms and *E.coli* in a water sample. The method involves a reagent powder added to a 100 mL sample, incubated at 36°C for 24 hours to determine the Most Probable Number (MPN) of bacteria p/100mL (Amp Tech Instruments, 2012).

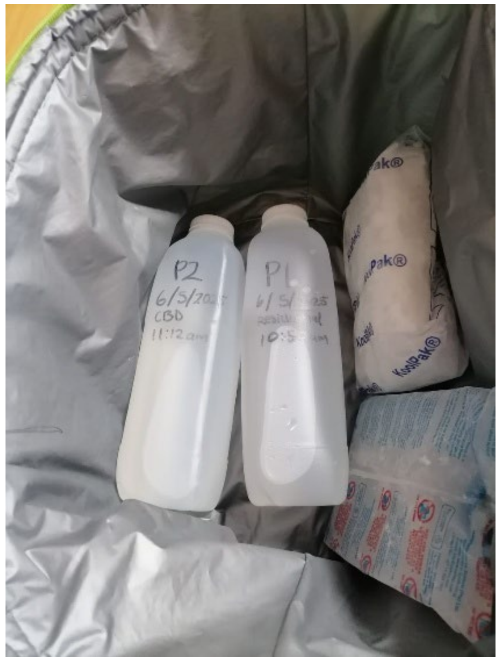

Figure 4.6: Samples delivered to the Institute of Groundwater Studies at the University of the Free State in Bloemfontein

4.5 Survey data collection

4.5.1 Survey on residents' perception

The survey questions were designed to collect information on the community's knowledge about their sources of water, the quality of the water, and the frequency of interruptions. The questionnaire was divided into two sections, namely: i) Knowledge perception, which focused on asking questions about the sources of water and use, and ii) The perception of water quality. Section A of the questionnaire was composed of closed-ended questions (SP Group LLC, 2022), while Section B included mostly closed-ended questions and one open-ended question (see Appendix A).

4.5.2 Survey data

Although the sample is relatively small, the feedback provided valuable insights into the perceptions of water quality among participants who are residents of Bloemfontein.

4.5.3 Validity and reliability

Reliability is the degree to which an experiment or measurement technique produces consistent results when replicated, and validity is the degree to which a measuring device measures what it is supposed to measure (Carmines & Zeller, 1979).

4.6 Survey validity

The study employed a mixed-method approach combining quantitative water testing and qualitative perception analysis, a mixed method approach as defined by Shaw, Hiles, West, Holland, and Gwyther (2018, p. 227):

"Mixed methods is defined as research in which the inquirer or investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of study."

This approach was inherently comprehensive in objective scientific evidence with community-based lived experiences.

4.7 Ethical consideration

4.7.1 Letter of Consent

A letter of consent was given to all participants, ensuring voluntary participation and autonomy. The letter guarantees that participation in the survey was voluntary, and participants confirmed that they were free to withdraw at any time without penalty. The participants were made aware of their protection of rights and confidentiality and that the consent form is signed to protect their rights. In addition, they have the option to indicate whether they wish to remain anonymous as far as possible. The letter explicitly informs participants that "There will be no risks or discomforts in participating in the research," and no person will be negatively impacted if they choose not to participate. The letter also informed the participant that the results of the study would be processed into a research report, journal publications, and/or conference proceedings (see Appendix B).

4.7.2 HREC approval

An application for ethical clearance was submitted through the CUT Clarivate Converis platform. The process for ethical clearance submission is as follows (Matlawe, 2023):

1. The researcher creates a profile on the Converis Clarivate platform and fills in an HSSREC application, which requires information on the study, data management, and research participants chosen, including funding and expenses.
2. A request is then sent to the supervisor and or co-supervisor for review and to add recommendations or comments, and finally to approve the submitted details.
3. After the supervisor's approval, the application is sent to the Faculty Research Committee (FRC) for review and or recommendations. If approved, then it will be submitted to the Research Ethics Committee (REC) for review and approval.
4. The researcher will have to reapply if changes or additions are required after being recommended by the REC or FRC. The final process will be the REC sending an HREC approval letter to the researcher for once the study has been approved (see Appendix C).

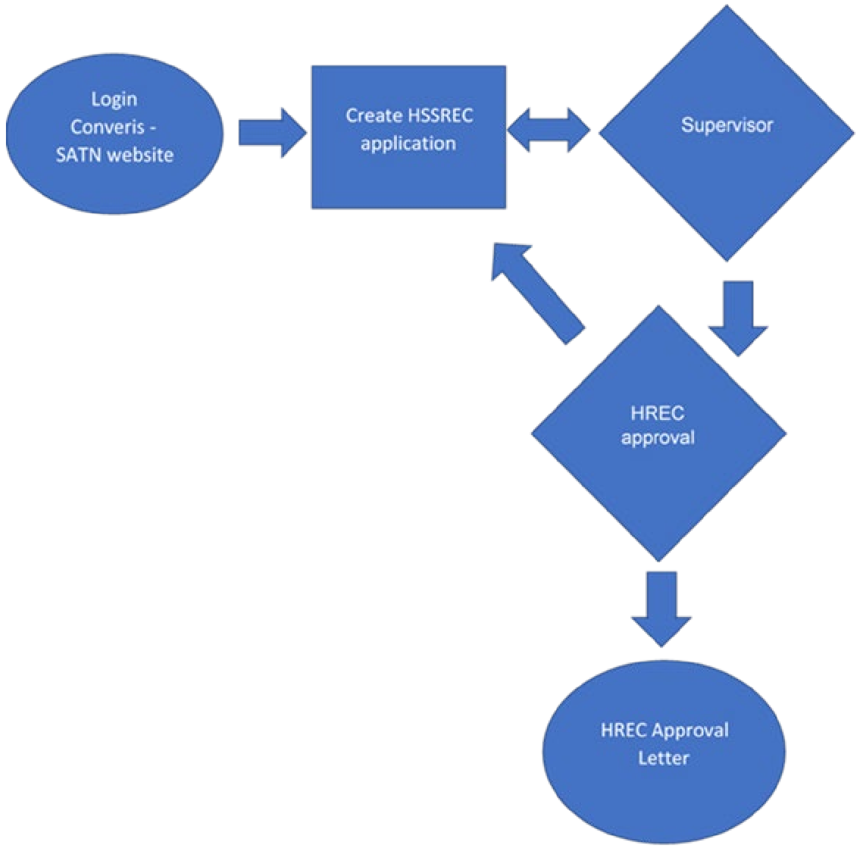

Figure 4.7: The process for ethical clearance approval via the Clarivate Converis platform (Image: by Author)

The research also submitted a request with an HSREC approval letter to the Central University of Technology gatekeeper for the survey to be distributed to staff and students of the University, and a gatekeeper letter of approval was received (see Appendix D). The data collected were handled according to the Research Data Management plan and stored under the CUT storage procedures.

4.8 Chapter summary

In summary, ethical compliance is a core requirement for the formal HREC approval received from the Central University of Technology. Data collection and data management procedures were outlined, detailing the collection, handling, and storage of data.

CHAPTER 5: RESULTS

5.1 Introduction

This chapter presents the study's outcomes. The results were organized according to the research objectives. The results were divided into two parts: i) Water quality test results, and ii) Questionnaire results. The water quality test results focused on physicochemical parameters, heavy metal concentrations, and microbiological parameters. The questionnaire focuses on community perceptions, behaviors, and knowledge.

5.2 Quantitative Water Quality Results

This section reports on the results from the water quality tests conducted on samples collected from the sampling sites P_{01} and P_{02}. The results are presented in both summary and detailed table formats.

5.2.1 Physicochemical parameters and microbial parameters in drinking water

5.2.1.1 Physicochemical parameters

Table 5.1: Measurements of the physicochemical parameters in P_{01} and P_{02}

Concentration						
Contaminants	Unit	Min	Max	Mean	STD	SANS
Physiochemical parameters						
Turbidity	NTU	0.42	1.43	0.93	0.71	≤ 5
Colour	mg/L as Pt-Co	7.00	21.00*	14.00	9.90	≤ 15
pH	pH units	7.67	8.44	8.06	0.54	≥ 5 to ≤ 9.7
EC	mS/m	18.48	19.73	19.11	0.88	≤ 170

Ca	mg/L	26.10	27.00	26.55	0.64	≤ 150
Mg	mg/L	5.86	8.00	6.93	1.51	≤ 70
Na	mg/L	9.21	9.70	9.46	0.35	≤ 200
K	mg/L	3.71	5.62	4.67	1.35	≤ 50
Alkalinity	mg/L	84.21	89.58	86.90	3.80	-
F	mg/L	0.24	0.29	0.27	0.04	≤ 1.5
Cl	mg/L	9.50	14.46	11.98	3.51	≤ 300
N	mg/L	0.31	0.33	0.32	0.01	≤ 1.5
SO4	mg/L	6.52	11.79	9.16	3.73	≤ 250
CaCO2	mg/L	91.55	98.11	94.83	4.64	-
TDS	mg/L	160.36	168.18	164.27	5.53	≤ 1200

Note: Values exceeding standard limits are highlighted in red*.

5.2.1.2 Microbial parameters

According to Table 5.2, the results of the faecal coliforms and the E. coli are greater than the limits detected, though smaller than 1 MPN/100ml, which indicates contamination.

Table 5.2: Measurements of microbial parameters in P_{01} and P_{02}

Concentration				
Contaminants	Unit	min	max	SANS
Microbial parameters				
Total coliforms	MPN/100ml	<1	<1	≤ 10
Faecal coliform	MPN/100ml	<1*	<1*	No detection
E. coli	MPN/100ml	<1*	<1*	No detection

Note: Values exceeding standard limits are highlighted in red*.

5.2.2 Trace metal concentration in drinking water

Table 5.3: Measurements of trace metal parameters in P_{01} and P_{02}

Concentration						
Contaminants		**min**	**max**	**mean**	**STD**	**SANS**
Trace Elements						
Al	mg/L	0.026	0.102	0.064	0.053	≤ 0.3
Sb	mg/L	<0.001	<0.001	-	-	≤ 0.02
As	mg/L	<0.010	<0.010	-	-	≤ 0.01
Ba	mg/L	0.042	0.042	0.055	0.017	≤ 0.7
Boron	mg/L	<0.040	<0.040	-	-	≤ 2.4

Concentration						
Contaminants		**min**	**max**	**mean**	**STD**	**SANS**
Trace Elements						
Cd	mg/L	<0.001	<0.001	-	-	≤ 0.003
Cr	mg/L	<0.010	<0.010	-	-	≤ 0.05
Cu	mg/L	0.013	0.013	0.02	0.01	≤ 2
Fe	mg/L	<0.011	<0.011	-	-	≤ 2
Mn	mg/L	<0.005	<0.005	-	-	≤ 400
Ni	mg/L	<0.001	<0.001	-	-	≤ 70
Pb	mg/L	<0.001	0.001	-	-	≤ 10
Se	mg/L	0.018	0.018	0.02	0.01	≤ 40
U	mg/L	<0.001	<0.001	-	-	≤ 30
Zn	mg/L	0.007*	0.007*	0.01	0.00	≤ 0.005

Note: Values exceeding standard limits are highlighted in red*.

5.3.1 Water Usage

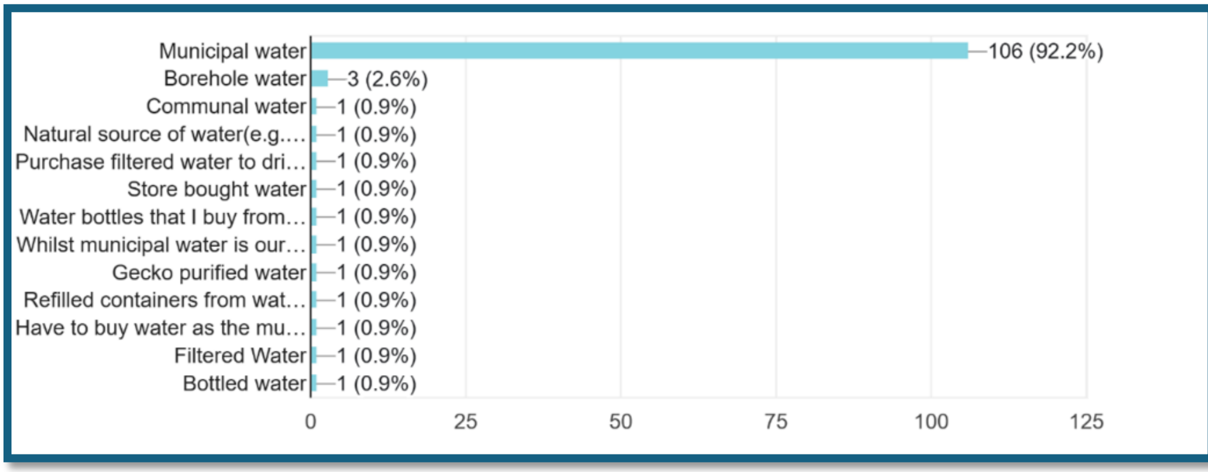

Figure 5.1: Respondent's main source of household drinking water and water for food preparation

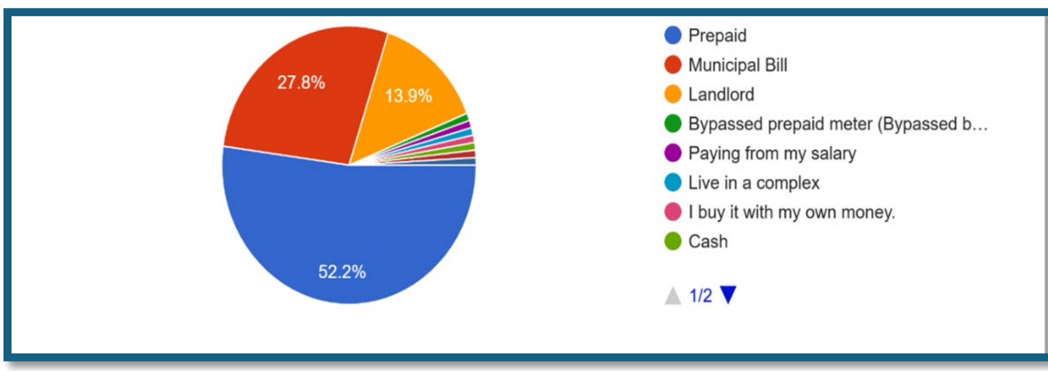

Figure 5.2: The mode of payment that respondents use to pay for water

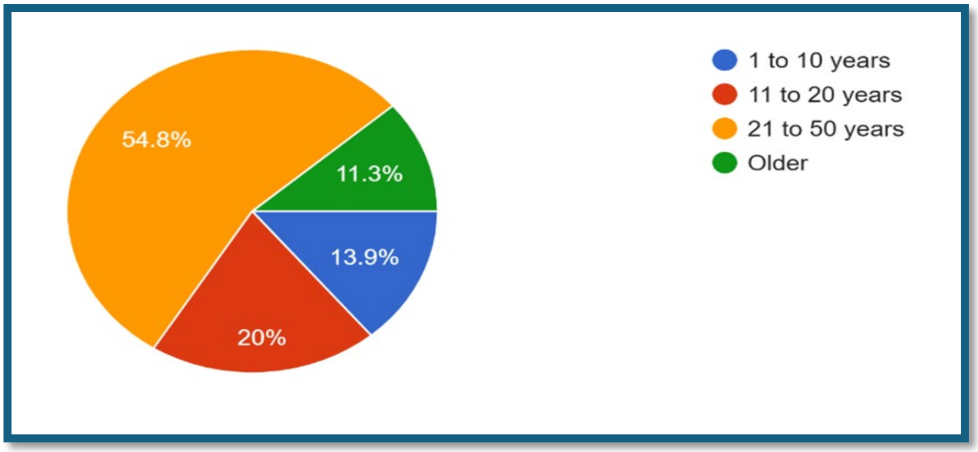

Figure 5.3: The percentage of the respondents' approximate age of their houses

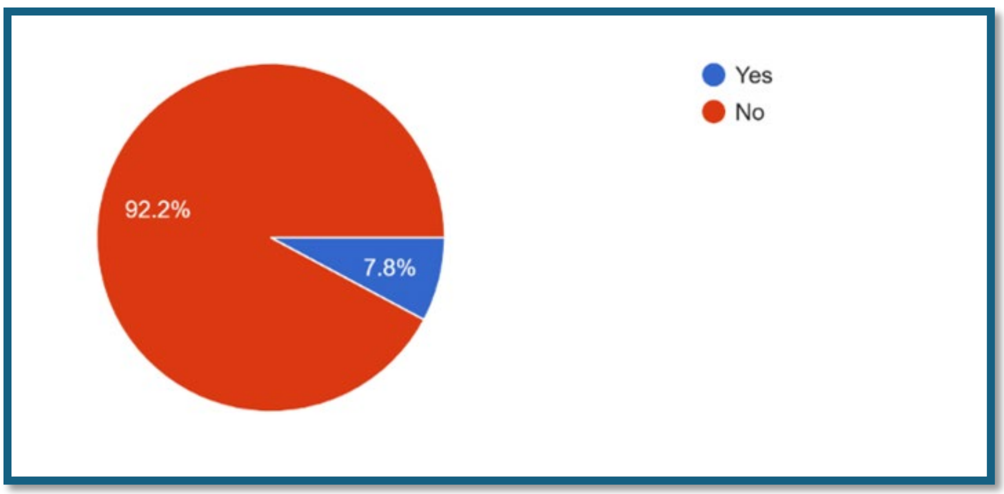

Figure 5.4: The percentage of respondents who have tested their household water

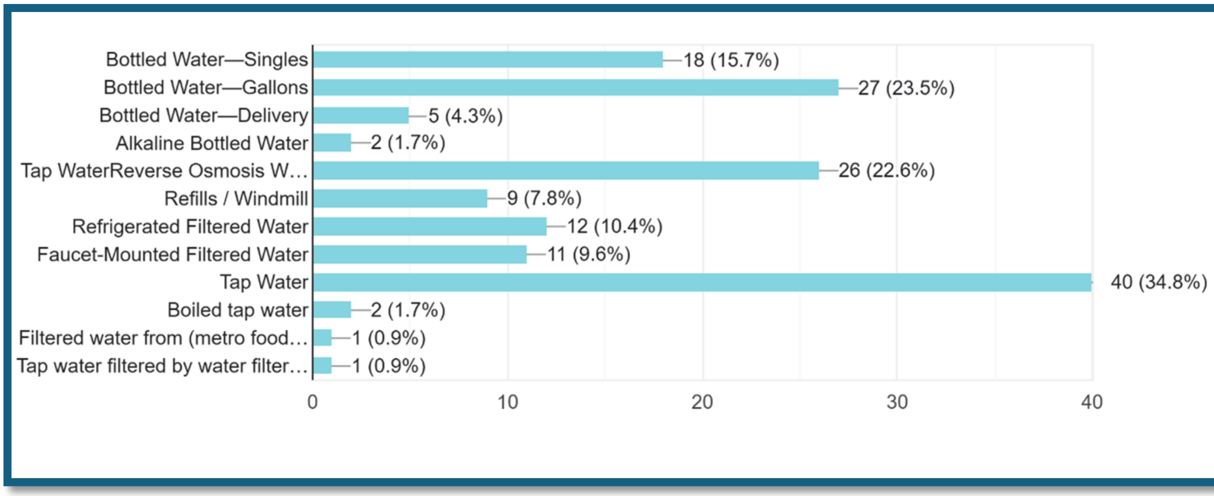

Figure 5.5: The percentage of the types of water the respondents typically drink

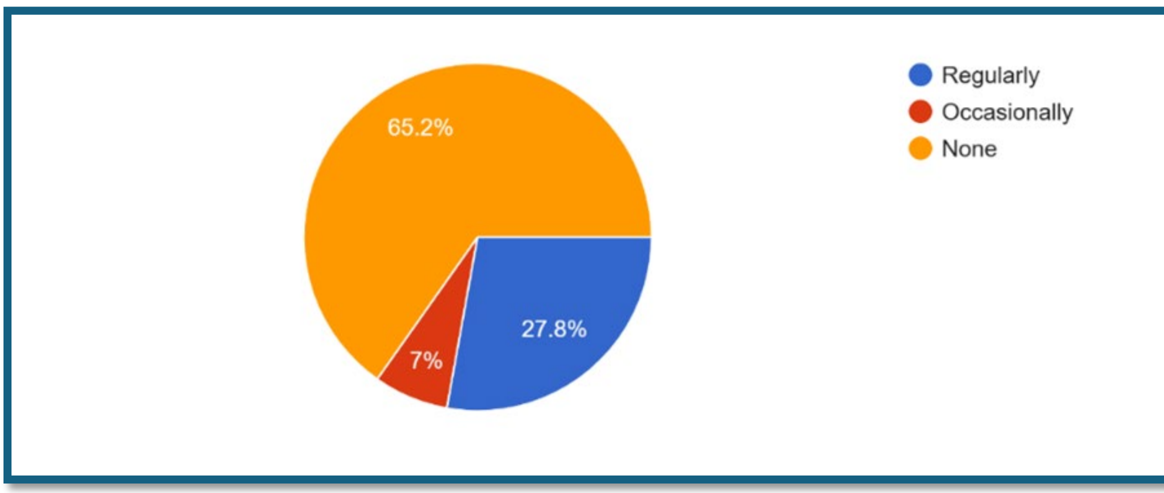

Figure 5.6: The percentage of respondents who use filtration systems at home

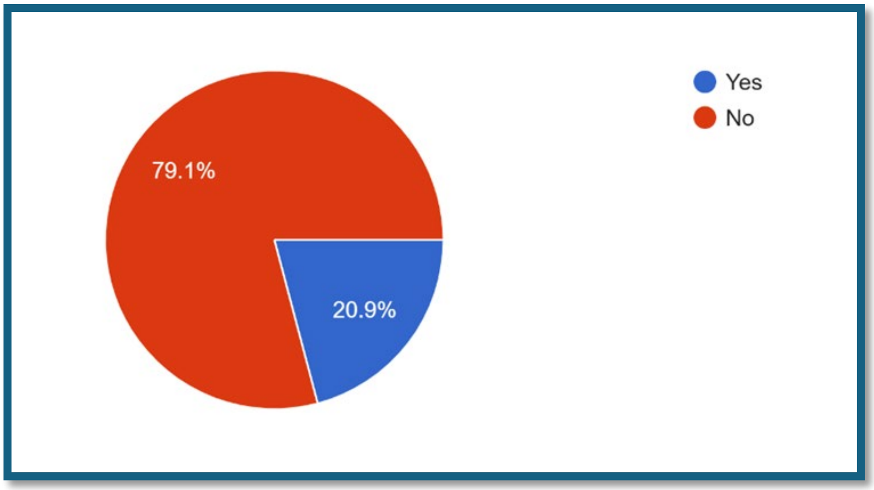

Figure 5.7: The percentage of respondents' satisfaction with communication from authorities

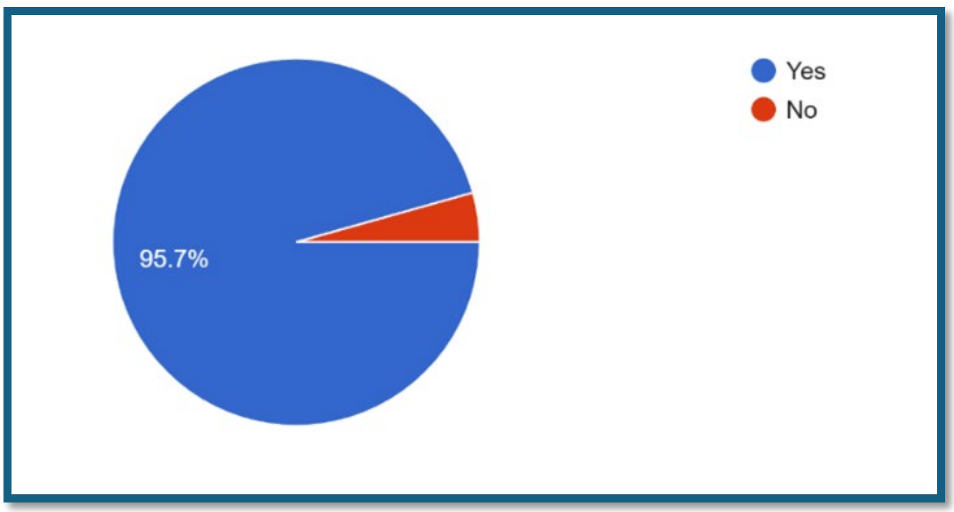

Figure 5.8: The percentages of respondents who have experienced water interruptions

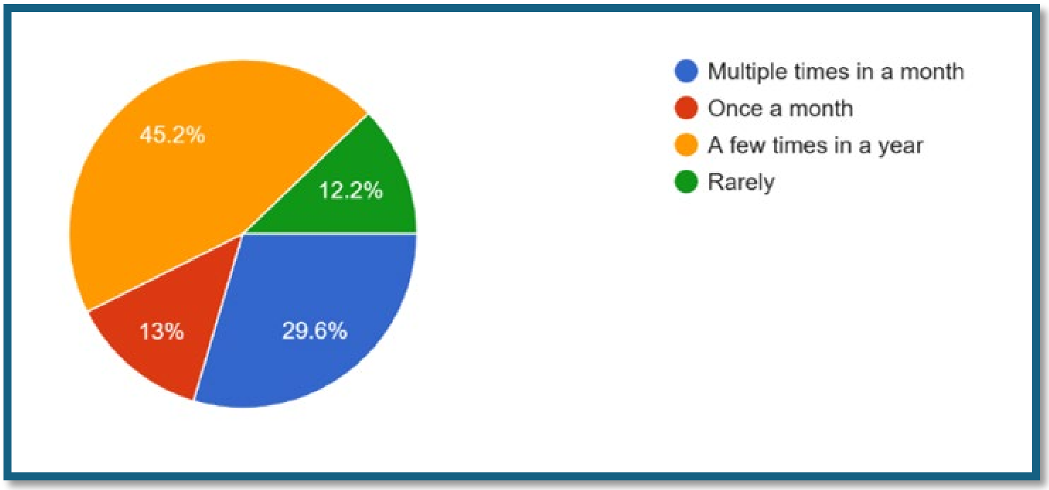

Figure 5.9: The percentages of how often respondents have experienced water interruptions

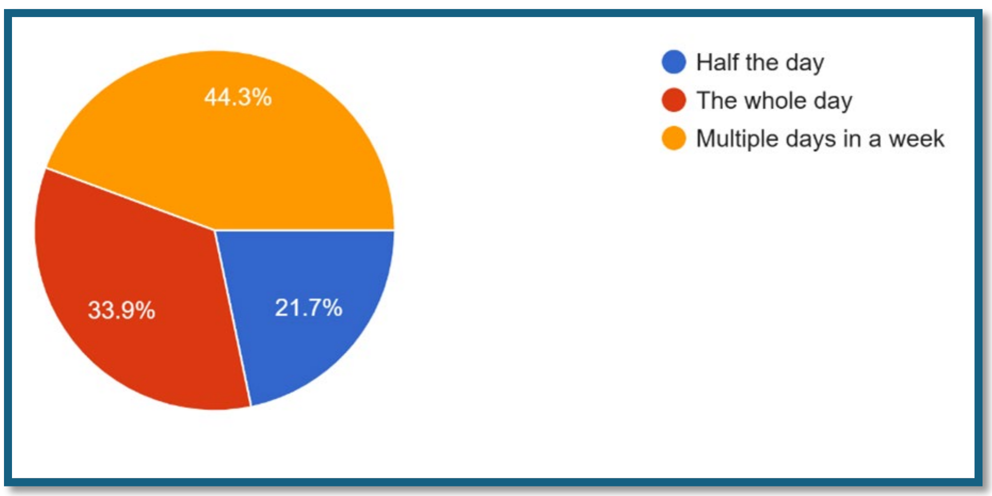

Figure 5.10: The percentage of how long water interruptions last as indicated by respondents

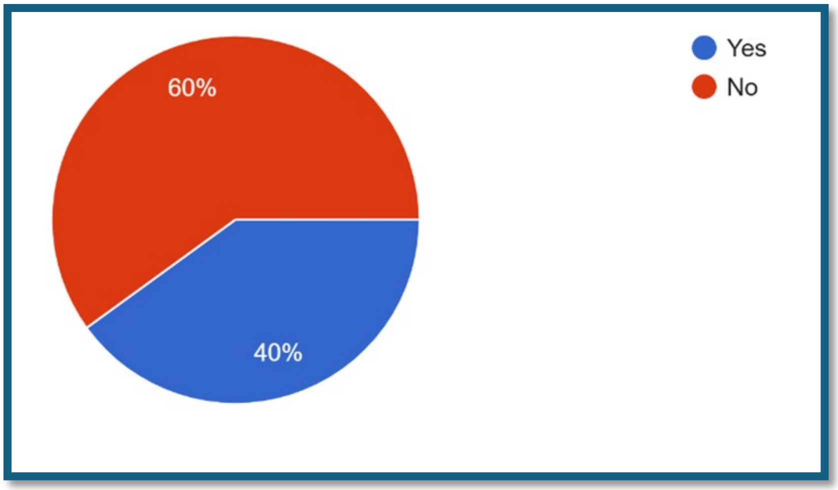

Figure 5.11: The percentage of the respondents who know where their raw water is sourced from

5.3.2 Perception of water quality

The following figures, namely 5.12 - 5.14, reflect respondents' ratings on a 10-point Likert scale (1 = very poor, 10 = very good) in terms of water -related issues.

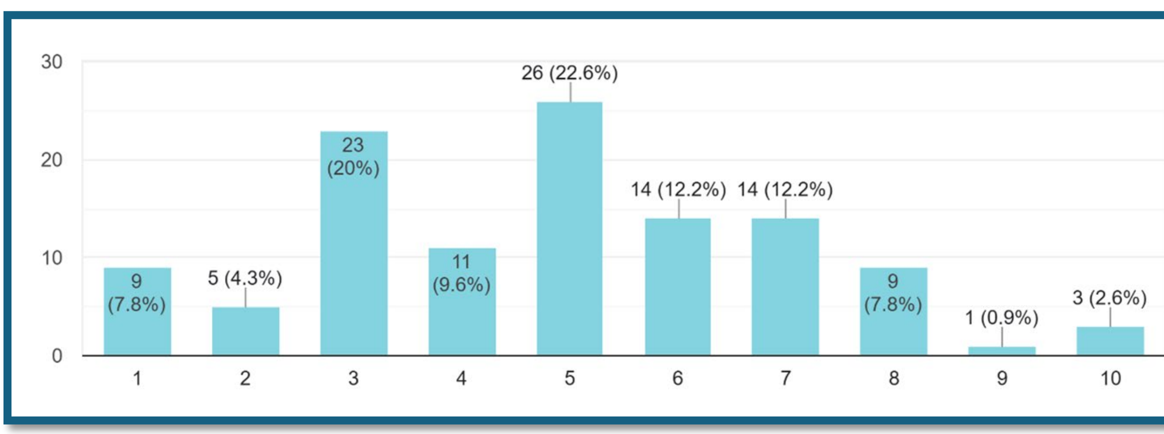

Figure 5.12: Likert scale scores for the overall quality of the water in the respondents' area

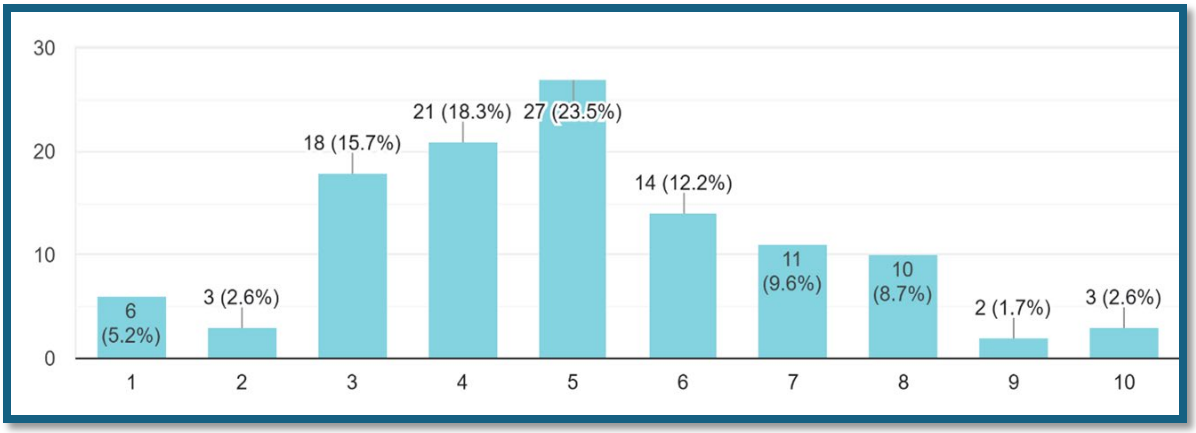

Figure 5.13: Likert scale scores for overall quality of the water before the water interruptions

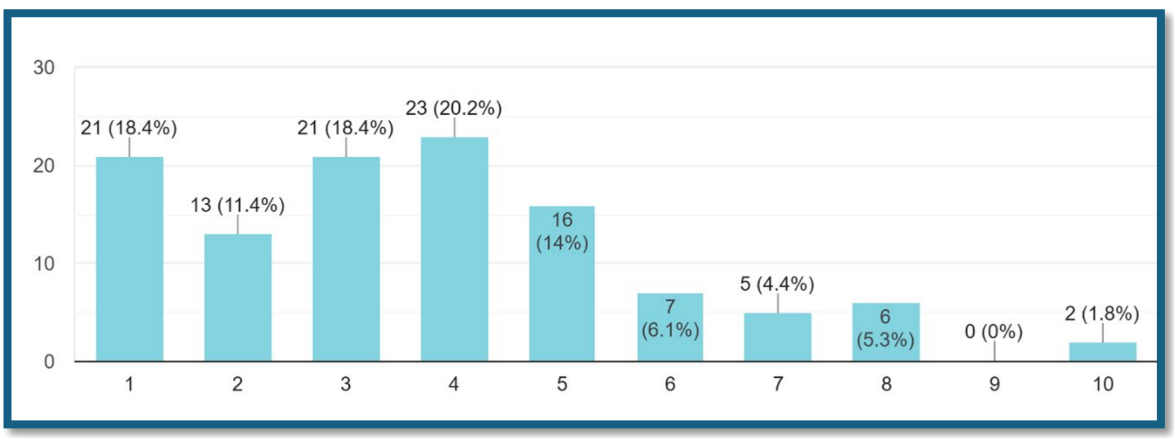

Figure 5.14: Respondents' ratings of overall quality of the water after the water interruptions

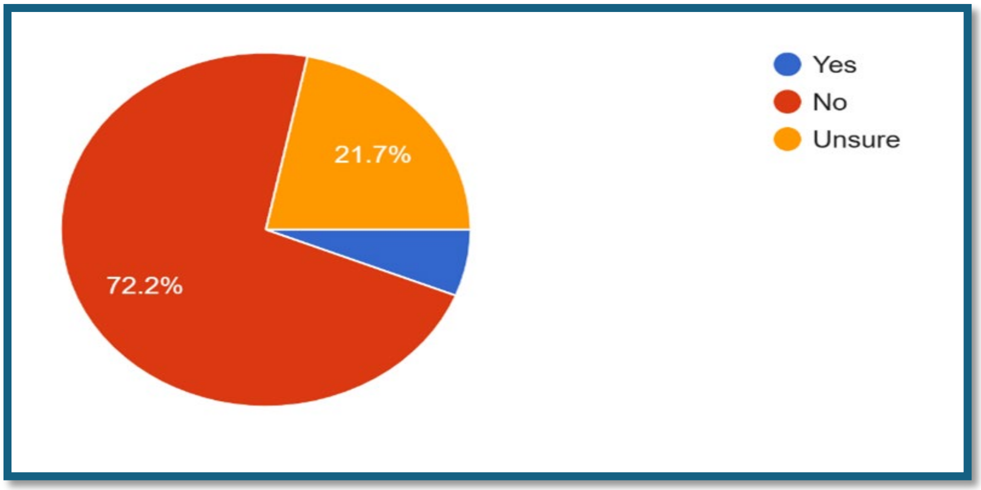

Figure 5.15: The percentages of respondents who trust the quality of the water

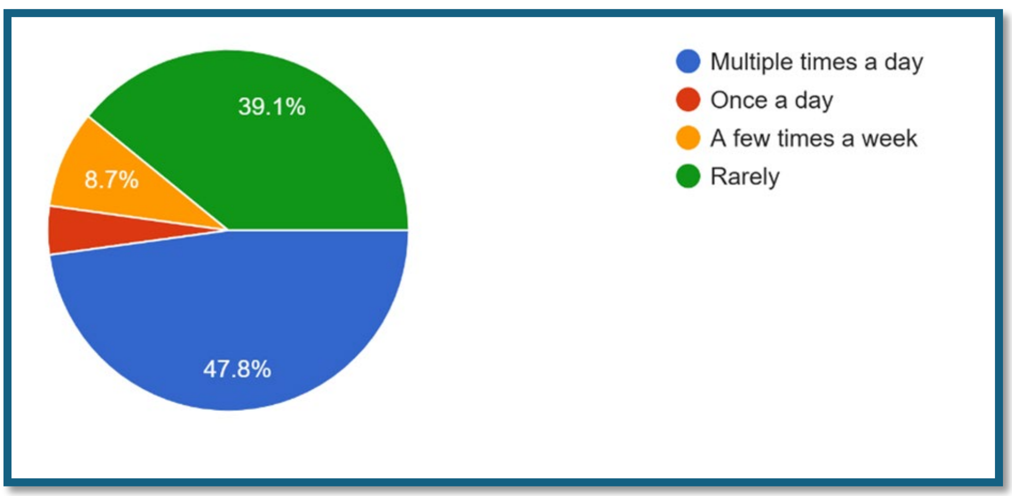

Figure 5.16: The percentage of respondents who consume tap water in their households

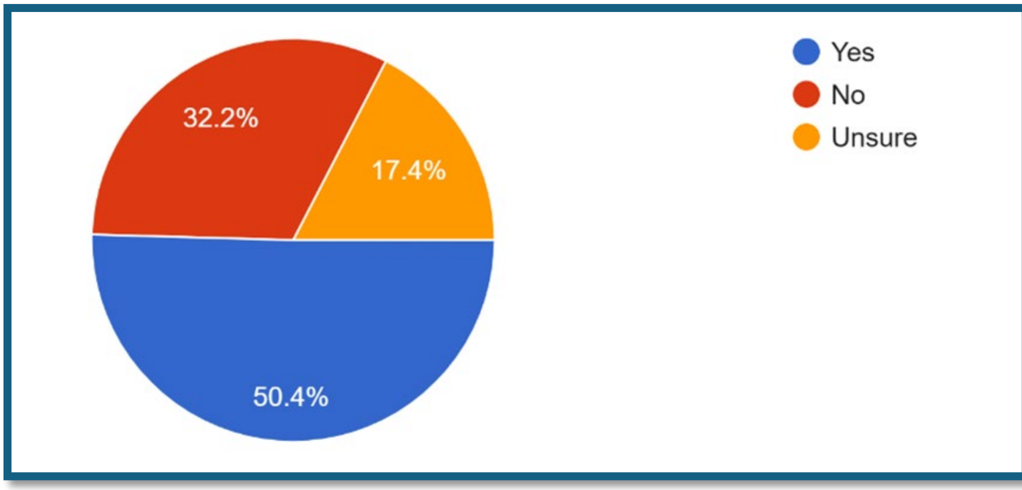

Figure 5.17: Percentage distribution of perceptions of strange odour in water

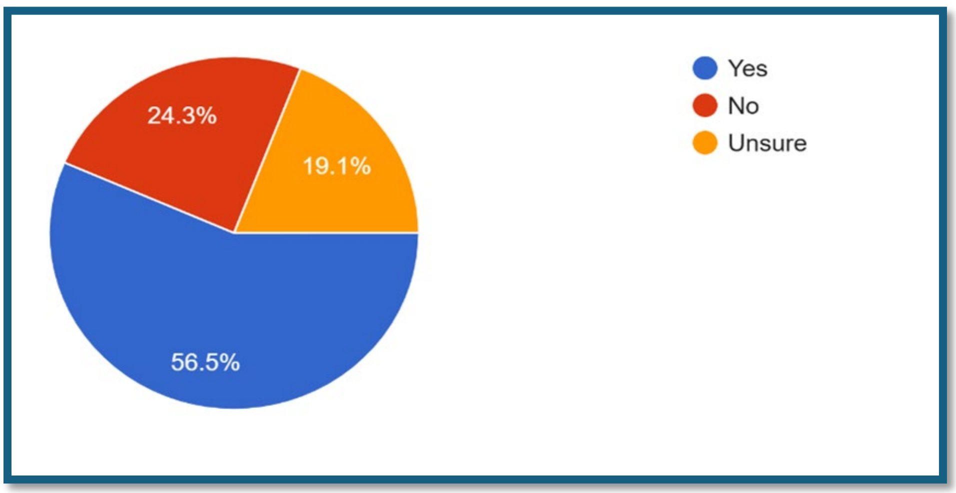

Figure 5.18: Percentage distribution of perceptions of strange taste in water

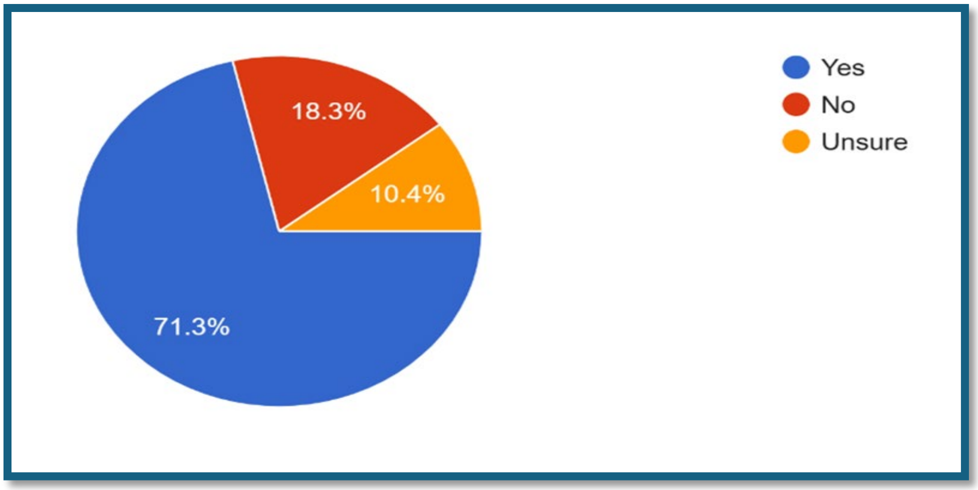

Figure 5.19: Percentage distribution of perceptions of strange discolouration in water

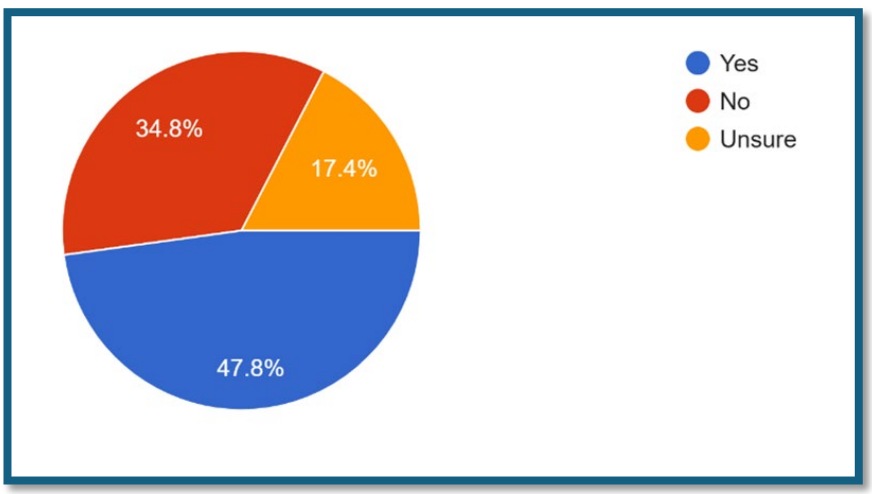

Figure 5.20: Percentage distribution of perceptions of noticeable particles in water

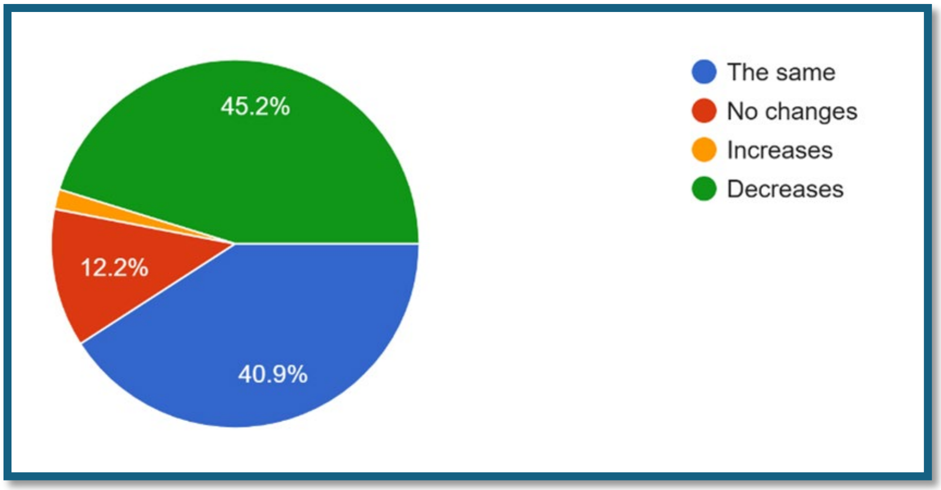

Figure 5.21: Percentage distribution of perceptions of frequencies of changes in water pressure

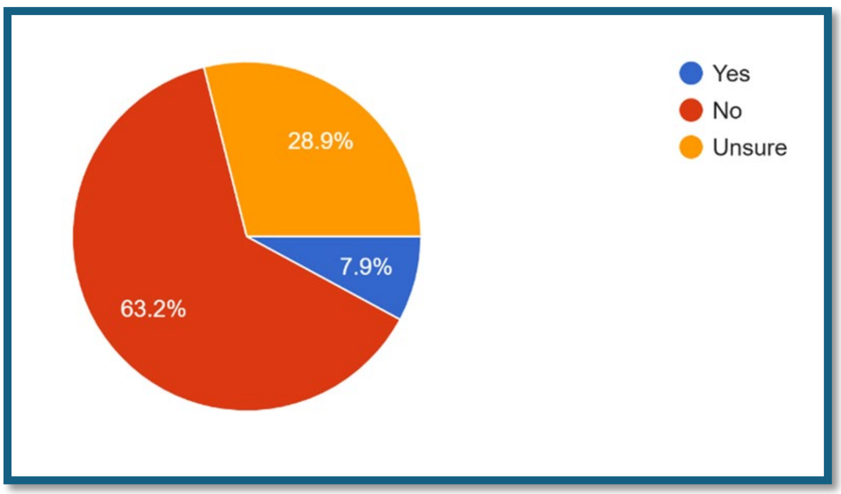

Figure 5.22: Percentage distribution of perceptions of the Municipality's improvement of water quality

Table 5.4 Descriptive statistics on the overall quality of water

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Water_quality	115	1	10	554	4.82	2.154	4.642	.171	.226
Valid N (listwise)	115								

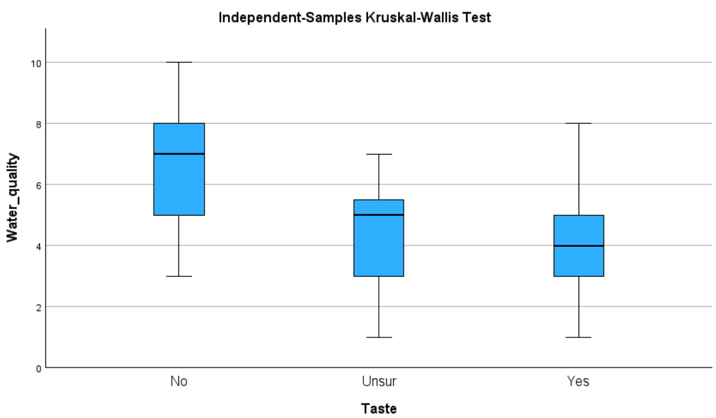

Figure 5.23.a

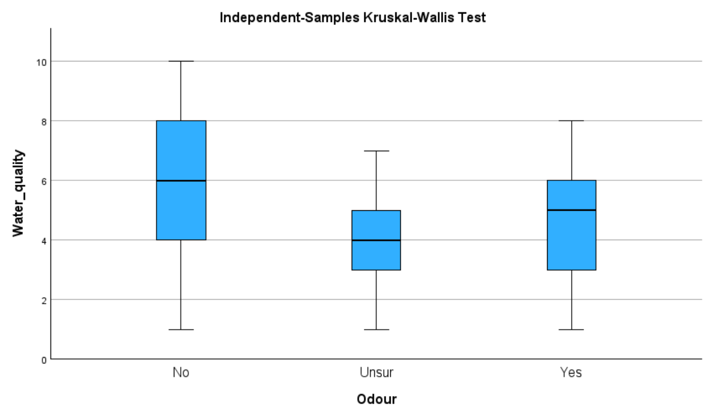

Figure 5.23.b

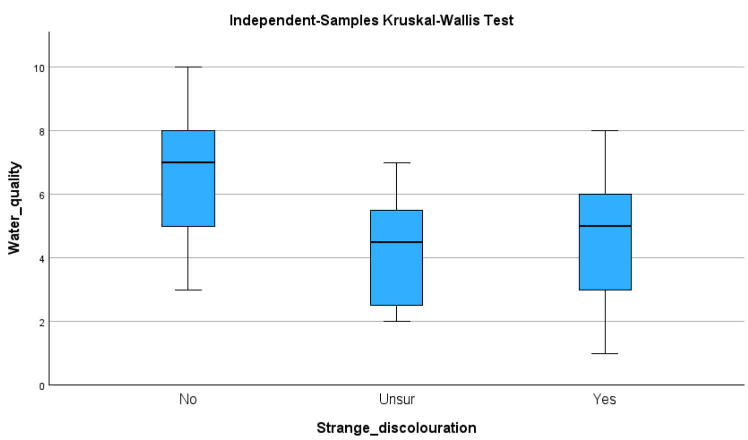

Figure 5.23.c

Figure 5.23 consists of box plots of perceived overall water quality across a) taste, b) odour, and c) strange discolouration. The statistical method used (Krustal-Wallis test, illustrated with box plots).

CHAPTER 6: DISCUSSION

6.1 Introduction

This chapter presents the study's discussion of findings. The discussion was structured according to the research objectives and is divided into two sections: i) Water quality test findings, and ii) Questionnaire findings.

6.2 Discussion on quantitative water quality results

According to Table 5.2, the results of the faecal coliforms and the *E. coli* are greater than the limits detected, though smaller than 1 MPN/100ml, which indicates contamination.

Physicochemical parameters: The colour level in sample P02 was taken from the location at the Bloemfontein CBD, which was 21 Pt-Co, which was greater than the SANS limit of ≤ 15 Pt-Co.

Trace metals parameters: The Zinc levels for both water samples from the two different locations of Bloemfontein had exceeded the SANS recommended level limit of 0.005 mg/L.

Microbial parameters: the *E. coli* and faecal coliforms were detected in both water samples from two different locations. The water samples resulted in a level of < 1 MPN/100ml, which is an infringement on the SANS standard requirement of "no detection". Since Zinc is a vital trace metal for survival, it is recommended to take 11mg/day and 8mg/day for men and women, respectively. Excessive oral Zinc exposure can lead to gastrointestinal effects with symptoms like nausea and vomiting, abdominal cramps, and diarrhoea. Zinc is also known to be a causative agent for cancer development (Plum, et al., 2010).

All the key findings show that the water in the water distribution system where the samples were taken was contaminated. Prolonged exposure to faecal coliforms and Escherichia coli (*E. coli*) causes persistent diarrhoea, chronic dehydration, and an increased risk of long-term gastrointestinal disorders (Edokpayi et al., 2018). Certain *E. coli* strains cause kidney damage, urinary tract infections, and haemolytic uremic syndrome (HUS) (CDC, 2024; Thomas & Elliott, 2013). The high level of turbidity in water is caused by the water distribution system from the Caledon and Modder rivers, which tends to experience ongoing high levels of sediment runoff and increased suspended solids (Koning, et al., 2000). Additionally, poor water infrastructure systems and aging pipelines also contribute to the high levels of turbidity and colour (Israel et al., 2011). The Bloemfontein distribution system's water sample was revealed to be polluted, demonstrating multiple SANS standard violations. Chronic dehydration, long-term gastrointestinal issues, catastrophic conditions like haemolytic uremic syndrome (HUS), and persistent diarrhoea are among the major health risks associated with contact with these bacteria. Furthermore, physicochemical investigation found increased colour levels (21 Pt-Co at sample P02, breaking the < 15 Pt-Co limit), a condition commonly connected to poor water infrastructure and substantial silt discharge from source rivers. Zinc levels surpassed the SANS limit of 0.005 mg/L in both locations, according to trace metal analysis; excessive oral zinc intake is linked to gastrointestinal side effects such as nausea and diarrhoea, and is recognized to be a causative agent for the development of cancer.

6.3 Discussion on knowledge of water usage

The respondents were also asked how they pay for their water. Figure 5.2 shows clearly that most respondents (52.2%) pay for their water through a prepaid water system. The system was developed by the government to cut costs on debt incurred by municipalities (Business Tech, 2019). Respondents who pay the municipal bill number 27.8%. Moreover, respondents were also asked about the age of their home. The majority of respondents (54.8%) noted their houses were between 21 and 50 years old, 20% noted their houses were between 11 and 20 years old, while a minority (11.3%) believed that their houses were older than 50 years. According to Schnoor (2016), older pipelines with stagnation and corrosion can lead to metal contamination of tap water.

It was also revealed that the majority of respondents (92.2%) have not tested the water in their houses since occupying the household, as shown in Figure 5.4, and only 7.8 %

have tested the water since moving into the household. Compared to a study that was done in Canada, 40% of residents had their water tested once or twice a year. They noted that extended non-monitoring of household water can lead to microbial or metal contamination that may go undetected for a long period of time. Therefore, water not tested for long periods of time can lead to health risks (Jones et al.,2006).

In relation to what the local community typically drinks, Figure 5.5 shows that most respondents (34.8%) drink tap water, followed by bottled water in gallons (23.5%) and tap water through reverse osmosis (22.6%). The least number of respondents typically drink alkaline water (1.7%), boiled tap water (1.7%), and filtered water (0.9%). Residents of North-West Ethiopia depend on piped water supplies. Researchers found that a significant percentage also use stored water or alternative sources, depending on supply issues or outages (Gebremichael et al., 2012). Residents' use of other sources of water makes water management complex by complicating any blanket policy or monitoring approach.

In relation to the use of any filtration system at home (Figure 5.6), most respondents (65.2%) do not use a water filtration system at home, 34.8 % use a water filtration system occasionally (7%) and regularly (27.8%).

In addition, there is a lack of adequate communication from the authorities regarding water quality issues in the area. Figure 5.7 shows that the majority of respondents (79.1%) believe that the authorities are not adequately communicating water quality issues in the area, while 20.9% believe that they are. A study showed that a lack of information and easily accessible water testing regimes makes residents less likely to test water for safety. Therefore, water-management systems and policies should include water community education and easily accessible testing (Tarannum & Kansal, 2012). Regarding water interruptions in the area (Figure 5.8), most respondents (95.7%) have experienced water interruptions, and only 4.3% have not experienced water interruptions.

In relation to how water interruptions often occur in the area (Figure 5.9), the majority of respondents have experienced water interruptions at varying frequencies, with 87.8% (45.2% + 29.6% + 13%) reporting interruptions at various levels. The study also revealed that water interruptions can last long. Figure 5.11 shows that the majority of respondents (44.3%) have interruptions lasting multiple days in a week, while 33.9% noted that they experience them for the whole day. Only 21.7% experience water interruptions for half a day only. Concerning where raw water comes from, Figure 5.11 shows that the majority of respondents (60%) do not know where their raw water is sourced from, while only 40% of the respondents know where their raw water is sourced from.

6.4 Discussion on perception of water quality

In relation to the overall quality of the water in their area, Figure 5.12 shows that the majority of respondents, namely 26, chose 5, indicating that many participants leaned toward a neutral view. This was followed by rating 3, selected by 20% of the respondents, and ratings 6 and 7, each chosen by 12.2% of the respondents. The lower ratings (1–2) were chosen less frequently, with 7.8% selecting 1 and 4.3% selecting 2. High-end ratings were very low, with only one respondent selecting 9 and three respondents selecting 10. The spread suggests a balanced but slight tendency toward a neutral perception. Respondents were generally clustered on the moderate to slightly positive ratings (3–8).

Moreover, the respondents were also asked to rate the overall quality of the water before the water interruptions. The majority of respondents, namely 27, chose 5, indicating that many participants leaned toward a neutral view. This was followed by rating 3, selected by 15.7% of the respondents, and ratings 4 and 6, chosen by 18.2% and 12.2% of the respondents, respectively. This was followed by 11 and 10 respondents choosing ratings 7 and 8. The lower ratings (1–2) were chosen less frequently, with 2.6% selecting 2 and 5.2% selecting 1. High ratings were very low, with two respondents selecting 9 and three respondents selecting 10. The spread suggests a balanced but slight tendency toward a lower negative perception. Respondents were generally clustered on the moderate to slightly poor ratings (8–3).

From Table 5.4, the results show that the mean quality score was 4.82, which suggests that the perceived water quality was rated slightly below the middle of the scale. The standard deviation of 2.15 shows a moderate spread among respondents. This means individual perceptions varied considerably. A skewness value of 0.17 indicated that the scores were not heavily skewed towards very low or very high perceptions, though there might be a tendency towards lower quality ratings. Overall, this concludes mild dissatisfaction with water quality and that water is perceived to be unreliable rather than critically poor.

The respondents were also asked to rate the overall quality of the water after the water interruptions. Figure 5.14 shows that the majority of respondents, namely 21 chose 4, indicating that many participants leaned toward a negative view. This was followed by rating 3, selected by 18.4% of the respondents, and ratings 1 and 2, each chosen by 18.4% and 11.4% of the respondents, respectively. This was followed by 14%, 6.1%, 4.4%, and 5.3% respondents choosing 5,6,7, and 8, respectively. High ratings were very low, with two respondents selecting 10 and no respondents selecting 9. The spread suggests a clear negative skew, indicating a general dissatisfaction with the overall quality of the water after the water interruptions. Evaluations of piped-water systems in underdeveloped countries show that inhabitants are often forced to store water in tanks or containers owing to inconsistent supply, which can result in bacterial contamination when cleanliness and maintenance are insufficient. Safe storage methods, routine tank and container cleaning, and public education are all necessary interventions (Chalchisa et al., 2018)

It was also revealed that most respondents (72.2%) selected" Yes", 21.7% of the respondents were unsure, and very few selected "No". This indicates that most respondents do not trust the tap water. In relation to how often respondents consume tap water in their household, Figure 5.16 shows that the majority of respondents (47.8.1%) consume tap water in their household multiple times a day. On the other hand, 39.1% of the respondents rarely consume tap water in their household. The lowest percentage of respondents (8.7%) consume tap water a few times a week, and 4.4% consume tap water in their household once daily. These results indicate that the majority of respondents rely heavily on tap water.

Concerning the strange odour in water sources, the study revealed that respondents' water did have a strange odour. Figure 5.17 shows that the majority of respondents (50.4%) have noticed the water has a strange odour, which suggests a significant concern for the water quality. Conversely, 32.2% respondents reported they had not noticed water having a strange odour, and 17.4% of the respondents reported that they were unsure. These results indicate a clear division in residents' perception of the water's smell.

The study also revealed that most of the respondents' water had a strange taste. Figure 5.18 shows that the majority of respondents (56.5%) have noticed the water has a strange taste, which suggests a significant concern for the water quality. Conversely, 24.3% respondents reported they had not noticed the water having a strange taste, and 19.1% of the respondents reported that they were unsure.

Regarding the strange discolouration of the respondents' water, Figure 5.19 shows that the majority of respondents (71.3%) have noticed the water has a strange discolouration, which suggests a significant concern for the water quality. On the other hand, a very low percentage of respondents (18.3%) reported that they have not noticed water having a strange discolouration, and 10.4% of the respondents reported that they were unsure. These results indicate a significant concern for the water having a strange discolouration.

Concerning the noticeable particles in respondents' water, Figure 5.20 shows that the majority of respondents (40.7%) have noticed the water has noticeable particles, which suggests a significant concern for the water quality. However, 34.8% respondents reported they had not noticed water having noticeable particles, and 17.4% of the respondents reported that they were unsure. These results indicate a clear division in residents' perception of the water having noticeable particles. Perceived drinking-water safety was shown to be significantly correlated with organoleptic qualities rather than socioeconomic or demographic factors in repeated national research conducted in South Africa. Therefore, it is advisable to undertake periodic objective testing in addition to perception-based assessments (Wright, Yang, Rivett, Gundry, 2012).

In relation to the water pressure in a week, Figure 5.21 reveals striking results, with 45.2% respondents reporting a decrease in water pressure, while 40.9% of respondents reported that the water pressure stays the same, and 12.2% reported no changes. Therefore, the majority have reported that the water pressure does not change.

Concerning the respondents' perceptions of the Municipality’s efforts to improve water quality, Figure 5.22 shows that the majority of respondents do not believe that the Municipality is doing enough, with 63.2% answering "No." Only a small percentage, namely 7.9%, responded "Yes," indicating a general dissatisfaction with current water quality. Furthermore, 28.9% were "Unsure," indicating a substantial portion of the population remains undecided or uninformed on the ability of the Municipality's actions.

Many homes do not frequently test or treat their water. People mostly use tap or stored water, often using multiple sources, depending on disruptions. Storage, handling, supply disruptions, and poor communication significantly increase the danger of microbial and perhaps chemical contamination. Although perception (taste, odour, sight) is a poor indication of safety, it usually fosters trust or distrust. Therefore, a comprehensive strategy that includes not just treatment at the plant but also routine monitoring, a dependable supply, consumer-accessible testing, safe storage procedures, and public education is required for effective water-quality management.

6.5 Summary

The study revealed that the water distribution system in Bloemfontein is polluted by trace metals, physicochemical, and microbial parameters, with the presence of *E.coli* and faecal coliforms, increased colour levels, and zinc concentrations exceeding SANS limits. Exposure to poor-quality water is further increased by household activities such as reliance on untreated water and stored water, owing to frequent disruptions and insufficient water testing. The results indicate that the deterioration of water quality occurs within the water treatment distribution network and is strongly affected by deteriorating and aging infrastructure, intermittent supply of water, and inadequate maintenance of the water treatment plants. Public awareness and communication barriers between the public and the municipality have contributed to the distrust and reliance on perception rather than scientific assessment of water safety.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The overall aim of the study was to investigate the source of contaminated and poor water quality supplied by Vaal Central Water and the MMM to the residents of Bloemfontein. The research into Bloemfontein's water infrastructure finds that the water treatment works' water distribution is considerably impaired by aging resources, backlogs in maintenance, and structural constraints, which can lead to poor water quality at the point of use.

Objective 1: To get the community's perceptions of supplied water quality using statistical methods

Conclusion: The study indicates that the people of Bloemfontein hold a considerably negative impression of the supplied water quality, principally driven by the unpleasant state of the water's organoleptic qualities and an intense lack of trust in the Municipality's competence to manage the water system.

Objective 2: To investigate the water quality in localities within Bloemfontein

Conclusion: The results from the water samples (P_{01} and P_{02}) showed strong evidence of contamination that exceeds SANS 241 criteria for the core dimensions of water quality, i.e., microbiological parameters, physicochemical, and trace metals, and suggested localized flaws in the water system distribution.

7.2 Recommendations

The following recommendations can be made:

- It is necessary to expand water quality monitoring to rural areas in Bloemfontein;

- Stakeholders and municipal managers need to address aging infrastructure and maintenance backlogs in the water distribution system;
- The wastewater treatment managers and municipality should find capital investment for water treatment works and have ring-fenced funding for water services so that the water services revenue does not compete for funding with other departments;
- Municipal managers should implement awareness programmes to address communication gaps and to inform communities of disruptions and contingency plans, as well as communicating water interruptions and incidents in rural and urban communities promptly. They need to improve on transparency and involve communities in challenges experienced to build trust.
- The Municipality must implement water conservation and water management programmes to curb high volumes of water lost owing to burst pipes and leaks. It is important to ensure resource sustainability;
- The evaluation of health and behavioural impact on communities from contaminated water distribution systems should be assessed; and

The identification of perceptions of infrastructure conditions with high resident distrust for targeted repairs is necessary to improve public trust and tariff compliance.

REFERENCES

7 Dams Conservancy, 2025. *7 Dams*. [Online] Available at: https://7dams.co.za/conservancy/ [Accessed 26 August 2025].

Agilent Technologies Incorporated, 2026a. *An introduction to the principles of inductively coupled plasma–mass spectrometry (ICP-MS)*. [Online] Available at: https://www.agilent.com/en/product/atomic-spectroscopy/inductively-coupled-plasma-mass-spectrometry-icp-ms/what-is-icp-ms-icp-ms-faqs [Accessed 10 April 2026].

Agilent Technologies Incorporated, 2026b. *An introduction to the principles of inductively coupled plasma–optical emission spectroscopy (ICP-OES)*. [Online] Available at: https://www.agilent.com/en/support/atomic-spectroscopy/inductively-coupled-plasma-optical-emission-spectroscopy-icp-oes/icp-oes-faq [Accessed 10 April 2026].

Agoro, M.A., Okoh, O.O., Adefisoye, M.A. and Okoh, A.I., 2018. *Physicochemical properties of wastewater in three typical South African sewage works*. *Polish Journal of Environmental Studies*, 27(2), pp. 491–499.

Ali, N.M., Khan, M.K., Mazhar, B. and Mustafa, M., 2025. *Impact of water pollution on waterborne infections: emphasizing microbial contamination and associated health hazards in humans*. *Discovery Water*, 5(19).

Amp Tech Instruments, 2012. *IDEXX Colilert method instrumentation*. [Online] Available at: https://amptius.com/idexx-colilert-method-instrumentation-guide/ [Accessed 10 April 2026].

Artell, J., Ahtiainen, H. & Pouta, E., 2013. *Subjective vs. objective measures in the valuation of water quality*. *Journal of Environmental Management,* 30 November, Volume 130, pp. 288-296.

Ashbolt, N.J., 2004. “Microbial contamination of drinking water and disease outcomes in developing regions.” Toxicology 198, pp. 229 - 238.

Astoria-Pacific, 2011. *What is a discrete analyzer?* [Online] Available at: https://astoria-pacific.com/industrial/technology-industrial/what-is-discrete/ [Accessed 10 April 2026].

Banks, A., 2025. *What Is The Best pH Level For Prepared Water?* [Online]

Available at: https://manzi.co.za/2025/10/23/the-best-ph-level-for-prepared-water/

[Accessed 10 April 2026].

Bloem Water, 2018. *Business plan between Bloem Water and the Department of Water and Sanitation for the period 1 July 2019 to 30 June 2024*. Bloemfontein: Bloem Water.

Bloem Water, 2019. *Annual report 2018/2019*. Bloemfontein: Bloem Water.

Bloem Water, 2020. *Bloem Water*. [Online] Available at: https://www.bloemwater.co.za [Accessed 7 March 2020].

Botes, S.M., 2016. *"Water pure and wholesome": watervoorsiening in Bloemfontein gedurende die 19de eeu*. *New Contree*, 76, p. 30.

Britannica Editors, 2019. *Bloemfontein*. [Online] Available at: https://www.britannica.com/place/Bloemfontein [Accessed 25 November 2020].

Britannica Editors, 2020. *"Free State*". [Online] Available at: https://www.britannica.com/place/Free-State [Accessed 09 August 2025]

Business Tech, 2019. *New prepaid water system to be trialled in South Africa*. [Online] Available at: https://businesstech.co.za/news/government/351567/new-prepaid-water-system-to-be-trialled-in-south-africa/ [Accessed 19 November 2025].

Bwire, G., Sack, D.A., Kagirita, A., Obala, T. *et al.*, 2020. *The quality of drinking and domestic water from surface sources in cholera-prone communities of Uganda*. *BMC Public Health*, 20(1128).

Carmines, E.G. and Zeller, R.A., 1979. *Reliability and validity assessment*. Thousand Oaks, CA: SAGE Publications.

CDC, 2024. *About Escherichia coli Infection*. [Online] Available at: https://www.cdc.gov/ecoli/about/index.html [Accessed 26 November 2025].

Chalchisa, D., Megersa, M. and Beyene, A., 2018. *Assessment of drinking water quality in storage tanks and its implications*. *Environmental Systems Research*, 6(12).

Climate-Data.org, 2019. *Bloemfontein*. [Online] Available at: https://en.climate-data.org/africa/south-africa/free-state/bloemfontein-394/ [Accessed 26 August 2025].

Coetzee, H., Nell, W. and Bezuidenhout, C., 2016. *Assessment of perceptions, sources and uses of water*. *Water SA*, 42(3), pp. 432–441.

Department of Water Affairs and Forestry, 2002. *National Water Quality Management Framework Policy*, Pretoria: Department of Water Affairs and Forestry.

Department of Water and Sanitation, 2012. *Study area*. [Online] Available at: https://www.dws.gov.za/iwrp/Bloem/sa.aspx [Accessed 1 September 2025].

Department of Water and Sanitation, 2015. *The Blue Drop report: highlights and trends from 2009 to 2014*. Pretoria: Department of Water and Sanitation.

Department of Water and Sanitation, 2016. *Annual report 2016/17*. Pretoria: Department of Water and Sanitation.

Department of Water and Sanitation, 2020. *Revised strategic plan 2020/21–2024/25*. [Online] Available at: https://www.dws.gov.za/documents/Other/Strategic%20Plan [Accessed 18 September 2025].

Doria, M.D., Pidgeon, N. and Hunter, P., 2009. *Perceptions of drinking water quality and risk*. *Water Research*, 407(21), pp. 5455–5464.

Edokpayi, J.N., Odiyo, J.O. & Durowoju, O.S., 2020. *Impact of wastewater on surface water quality in developing countries: A case study of South Africa*. Water, 12(5), pp. 1–15.

Edokpayi JN, Odiyo JO, Msagati TA, Potgieter N.,2015. *Temporal variations in physico-chemical and microbiological characteristics of Mvudi river, South Africa*. Int J Environ Res Public Health, 12(4):4128-40.

Encyclopaedia Britannica, 2026. *pH*. [Online] Available at: https://www.britannica.com/science/pH [Accessed 10 April 2026].

Express News, 2019. *Bad tasting water not toxic*. [Online] Available at: https://m.news24.com/SouthAfrica/Local/Express-News/bad-tasting-water-not-toxic-20190205 [Accessed 27 May 2020].

Fondriest Environmental, Inc., 2013. pH of water. [Online] Available at: https://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/ [Accessed 10 April 2026].

Gebremichael, S.G., Yismaw, E., Tsegaw, B. and Shibeshi, A.D., 2012. *Determinants of water source use and quality. PLoS ONE*, 16(4).

Government Communications, 2019. South African Yearbook 2018/19. 26 ed. Pretoria: Government Communications (GCIS).

Green Overall, 2018. *Bloemfontein water availability and quality*. [Online] Available at: https://greenbloemfontein.co.za [Accessed 20 May 2020].

Hanjra, M.A. and Qureshi, M.E., 2010. *Global water crisis and food security*. *Food Policy*, 35(5), pp. 365–377.

Hedden, S. and Cilliers, J., 2014. *Parched prospects: the emerging water crisis in South Africa*. Pretoria: Institute for Security Studies.

Hewavisenti, S., 2020. *National municipal benchmarking initiative for water services*. [Online] Available at: https://businessmediamags.co.za [Accessed 15 June 2020].

Huizenga, J.M. & Harmse, J.T., 2005. *Geological and anthropogenic influences on the inorganic water chemistry of the Jukskei River, Gauteng, South Africa*. *South African Journal of Geology*, 108(3), pp.439–447.

Huizenga, J.M., 2011. *Characterisation of the inorganic chemistry of surface waters in South Africa. Water SA*, 37(3), pp.401–410

HunterLab, 2022. *What is a spectrophotometer and how does it work?* [Online].

IDP and OPM, 2024. *Reviewed draft IDP 2024–2025*.

Israel, S., Tredoux, G., Maherry, A., Engelbrecht, P., Wilsenacht, J., Germanis, J. & Jovanovic, N., 2011*. Nitrate removal for groundwater supply to rural communities.* WRC Report No. 1848/1/11. Pretoria: Water Research Commission.

Jones, A.Q., Dewey, C. E., Doré, K., Majowicz, S.E., McEwen, S.A., 2006. *Public perceptions of drinking water: a postal survey of residents with private water supplies*. *BMC Public Health,* Volume 6, p. 94.

Koning, N, JC Roos, and JU Grobbelaar. 2000. "Water Quality of the Modder River, South Africa." African Journal of Aquatic Science 25 (1): pp. 202–10.

Kumar, D., Singh, V.K. and Abed, S., 2023*. Electrical conductivity forecasting of surface water*. *Applied Water Science*, 13(192).

Kusakana, M. N., Coetzee, M. & Oke, S., 2019. *A Proposed Innovative Framework to Explore the Communication Challenges between BloemWater and the Mangaung Municipality*. *Open Innovations (OI),* pp. 104-108.

Larance, S., Wang, J., Mojtaba, A.D. and Fahs, M., 2025. *Effects of water temperature and dissolved oxygen*. *MDPI*, 12(1), p. 25.

Li, B., Ling, F., Chouari, R., Samoili, S., Giannakis, S. *et al.*, 2025. *Trace metals and microbial risk*. *npj Clean Water*, 8(8).

Luvhimbi, N., Tshitangano, T., Mabunda, J. and Olaniyi, F., 2022. *Water quality assessment in Limpopo*. *Scientific Reports*, 12.

Mackintosh, G. & Jack, U., 2008. *Assessment of the Occurrence and Key Causes of Drinking-Water Quality Failures within Non-Metropolitan Water Supply Systems in South Africa, and Guidelines for the Practical Management Thereof*, Gezina.

Mangaung Metropolitan Municipality, 2013. *Annual report 2013/14*. Bloemfontein: Mangaung Metropolitan Municipality.

Mangaung Metropolitan Municipality, 2023. *Annual report 2022/2023*. Bloemfontein: Mangaung Metropolitan Municipality.

Matlawe, M., 2023. *Clarivate Converis guideline*. [Online] Available at: https://cms.cut.ac.za [Accessed 10 May 2025].

Mshelia, Z.H. and Belle, J.A., 2024. *Flood risk assessment of Bloemfontein watershed*. *Geomatics, Natural Hazards and Risk*, 15(1).

Mugudamani, I., 2024. *Environmental health risk assessment of emerging contaminants in Bloemfontein*. Bloemfontein: Central University of Technology.

NCOP Finance, 2018. *IDP, LED & NDP: Mangaung & eThekwini Metropolitan Municipal briefing, PMG.* [Online] Available at: https://pmg.org.za/committee-meeting/26870/ [Accessed 10 June 2020]

Nelson, T.N., Poleacovschi, C., Weems, C.F. *et al.*, 2024. *Water quality perception scale development. Frontiers in Water*, 6.

Ofm News, 2019. *Pellissier residents report Mangaung to chapter nine institutions*. Bloemfontein: South Africa Human Rights Commission.

Oke, S., Mugudamani, I., Gumede, T. and Senbore, S., 2023. *Environmental risk assessment of contaminants in Bloemfontein*. *Journal of Harbin Engineering University*, 44, pp. 1077–1082.

Olowoyo, J., Chiliza, U., Selala, C. and Macheka, L., 2022. *Health risk of trace metals in bottled water*. *International Journal of Environmental Research and Public Health*, 19(22).

Plum L.M., Rink L., Haase H., 2010. *The essential toxin: impact of zinc on human health*. *Int J Environ Res Public Health*, 7(4), pp. 1342-65

Prouty, C. and Zhang, Q., 2016. *Perceptions of water quality in Uganda*. *Resources, Conservation and Recycling*, 109, pp. 24–33.

Ratikane, M., 2013. *Quality of drinking water sources in Bloemfontein*. Bloemfontein: Central University of Technology.

Ruzvidzo, S., 2020. *Effects of evapotranspiration on water quality*. Bloemfontein: Central University of Technology.

Sahoo, D. and Anandhi, A., 2023. *Conceptualizing turbidity in aquatic ecosystems*. *Environmental Sciences: Advances*, 2(9), pp. 1220–1234.

Schnoor, Jerald (2016) “Recognizing Drinking Water Pipes as Community Health Hazards,” Journal of Chemical Education. American Chemical Society (ACS). 93,pp 581-582.

Sarah Slabbert Associates, 2011. *South Africans’ perception of drinking water quality*. Pretoria: Water Research Commission.

Sershen, S; Rodda, N; Stenström, TA; Schmidt, S; Dent, M; Bux, F; Hanke, N; Buckley, CA; Fennemore, C., 2016. *Water security in South Africa*. *Water SA*, 42(3), pp. 456–465.

Shaw, Rachel L; Hiles, David R; West, Karen; Holland, Carol; Gwyther, Hollly., 2018. *Mixed methods research design*. *Health Psychology and Behavioral Medicine*, 6(1), pp. 226–244.

Shmeis, A. and Reham, M., 2018. Water chemistry and microbiology. *Elsevier*, 81(1), pp. 1–56.

Sigudu, T.T., Mundackal, A.J. and Makhubedu, M.M., 2024. Drinking water quality assessment. *Water*, 16(22).

South Africa Bureau of Standards (SABS), 2015. SANS 214-1:2015 *Drinking Water specification*, Pretoria: SABS.

South African Government, 1997. *Water Services Act*. [Online] Available at: https://www.gov.za [Accessed 14 October 2025].

South African Government, 1998. *National Environmental Management Act*. [Online] Available at: https://www.gov.za [Accessed 14 October 2025].

South African Government, 2000. *Municipal Systems Act*. [Online] Available at: https://www.gov.za [Accessed 14 October 2025].

South African Government, 2003. *National Health Act*. [Online] Available at: https://www.gov.za [Accessed 14 October 2025].

South African Local Government Association, 2024. *Survey of water services vulnerabilities assessment*. Free State: SALGA.

Statistics South Africa, 2011. *Bloemfontein*. [Online] Available at: https://www.statssa.gov.za [Accessed 20 October 2025].

Sure-BioChem Laboratories, 2026. *Understanding heterotrophic plate count (HPC)*. [Online] Available at: https://www.surebiochem.com [Accessed 10 April 2026].

Tarannum, F. and Kansal, A., 2012. Role of community perception in water management. *ResearchGate*, pp. 12–33.

The Southern African Legal Information Institute, 1998. [Online] Available at: https://www.saflii.org/za/legis/consol_act/nwa1998161.pdf [Accessed 14 October 2025].

Thomas, D. & Elliott, E., 2013. Interventions for preventing diarrhea-associated hemolytic uremic syndrome: Systematic review. BMC Public Health, 13(1), p. 799.

UNESCO, 2020. *United Nations World Water Development Report 2020*. Paris: UNESCO.

United States Environmental Protection Agency (EPA), 2021. *Development of user perception surveys*. [Online] Available at: https://www.epa.gov [Accessed 22 August 2025].

University of the Free State, 2012. *Bloemfontein campus*. [Online] Available at: https://ufs.ac.za [Accessed 12 March 2020].

Vaal Central Water, 2024. *Annual report 2022/2023*. Bloemfontein: Vaal Central Water.

Villiers, J. and B.G., 2008. Sedimentation modelling at Welbedacht Reservoir. *Journal of the South African Institution of Civil Engineers*, 49.

WHO, 2022. *Guidelines for drinking-water quality*. [Online] Available at: https://iris.who.int [Accessed 13 November 2025].

Wright, J.A., Yang, H., Rivett, U. and Gundry, S.G., 2012. *Public perception of drinking water safety in South Africa. BMC Public Health*, 12(556).

Appendix A Questionnaire

PERCEPTIONS AND INVESTIGATION OF POOR QUALITY WATER SUPPLIED TO THE RESIDENT OF THE CITY OF BLOEMFONTEIN

Age:

City:

1. Bloemfontein
2. Other

Suburb or locality:

Which other area within the Mangaung Metropolitan Municipality do you reside in?

Postal code:

Cellphone number:

Email address:

Section A: Water Source

1. What is the main source of household drinking water and preparing food?
   - Municipal water
   - Borehole water
   - Communal tap
   - Natural source of water (e.g., river, fountain, rainwater, or dam)
   - other

2. How are you paying for the water?
   - Prepaid
   - Municipality bill
   - Landlord

- Other

3. What is the approximate age of your home?

- 1 to 10 years
- 10 to 20 years
- 21 to 50 years
- Older

4. Have you had your water tested since moving into this home?

- Yes
- No

5. What water do you typically drink?

- Bottled water—Singles
- Bottled water—Gallons
- Bottled water—Delivery
- Alkaline bottled water
- Reverse osmosis water
- Refills / Windmill
- Refrigerated filtered water
- Faucet-mounted filtered water
- Tap water
- Other

6. Do you use any water filtration system at home?

- Regularly
- Occasionally
- None

7. Do you feel that there is adequate communication from authorities regarding water quality issues in your area?
    - Rarely
    - Sometimes
    - Often

8. Have you experienced water interruptions?
    - Yes
    - No

9. How often do you experience water interruptions?
    - Multiple times in a month
    - Once a month
    - A few times in a year
    - Rarely

10. How long does the water interruption usually last?
    - Half the day
    - The whole day
    - Multiple days in a week

11. Do you know where your raw water is sourced from?
    - Yes
    - No

Section B: Perception of water quality

The following 3 questions have to be rated from 1 to 10

1- Being very poor and 10- being very good

1. How would you rate the overall quality of the water in your area?

…………

2. How would you rate the overall quality of the water before water interruption?

…………

3. How would you rate the overall quality of the water after water interruption?

…………

4. Do you trust the quality of the tap water?
    - Yes
    - No
    - Unsure
5. How often do you consume tap water in your household?
    - Multiple times a day
    - Once a day
    - A few times a week
    - Rarely
6. Have you noticed your water has a strange odor?
    - Yes
    - No
    - Unsure
7. Have you noticed whether your water has a strange taste?
    - Yes
    - No
    - Unsure
8. Have you noticed whether your water has a strange discoloration?

- Yes
- No
- Unsure

9. Have you noticed whether your water contains noticeable particles?

- Yes
- No
- Unsure

10. Is the water pressure one of the following in a week?

- The same
- No changes
- Increases
- Decreases

11. Do you think the Municipality is doing enough to improve the water quality?

- Yes
- No
- Unsure

12. Additional comments or concerns regarding water quality: ……………………………………...

………

………..

………..

Thank you for your participation!

Your input will help us better understand community perspectives on water quality.

Appendix B Letter of consent

FACULTY OF HEALTH AND ENVIRONMENTAL SCIENCE

Department of Life Sciences

RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

DATE:

22/04/2024

TITLE OF THE RESEARCH PROJECT:

PERCEPTIONS AND INVESTIGATIONS OF POOR QUALITY WATER SUPPLIED TO THE RESIDENT OF THE CITY OF BLOEMFONTEIN.

PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):

Name: PALESA ADELINA MOJA Student no: 217001715 Contact No: 0833002934

FACULTY AND DEPARTMENT:

Faculty of Health and Environmental Sciences

Department of Life Sciences

STUDY LEADER(S) NAME:

Dr Thandi Gumedu Department of Life Sciences

Prof S Oke Department of Civil Engineering

WHAT IS THE AIM / PURPOSE OF THE STUDY?

The purpose of the study is to explore the existing water structure and infrastructure of Bloemfontein, the community perception on supplied water quality and the water quality in localities within Bloemfontein.

It is my hope that the study could assist the municipality to improve on developed public awareness and education initiatives to raise awareness of a variety of water efficiency issues.

To also assist stakeholders in understanding the existing water structures and infrastructure in Bloemfontein.

Through administering of questionnaire, the result will allow the government to get feedback from the community.

WHO IS CARRYNG THE RESEARCH?

This research is being conducted by Miss Palesa Adelina Moja (student number: 217001715). I am a Student in the Life Sciences department, at Central University of Technology, Free State I am currently studying towards a Health Sciences in Environment.

WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

You have been invited to participate in this study because you are a resident of Mangaung who actively utilizes the MMM service delivery. Your firsthand experience makes you an invaluable source for evaluating the perceptions of water quality supplied to the community.

WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?

Participation involves the following:

• The survey should take less than 15 minutes.

• The questions are about the water source and perceptions of the water quality used by the residents of MMM.

• The researcher will ask you the survey questions in the form of a questionnaire paper or respondent reply to the questions on Google.

• You will need to sign the consent form before starting the survey to protect your rights.

Possible Benefits to the participant

The participant will not receive any direct benefits, such as material or payment. The result of the research will assist the municipality to improve on developed public awareness and education initiatives to raise awareness of a variety of water efficiency issues. It will assist stakeholders in understanding the existing water structures and infrastructure in Bloemfontein,including allow the government to get feedback from the community.

Potential risks and discomfort

There will be no risks or discomforts in participating in the research. No person will be negatively impacted if they choose not to participate in the study.

THANK YOU FOR TAKING TIME TO READ THIS INFORMATION SHEET AND FOR PARTICIPATING IN THIS STUDY.

CONSENT TO PARTICIPATE IN THE STUDY (2024) PERCEPTIONS AND INVESTIGATIONS OF POOR QUALITY WATER SUPPLIED TO THE RESIDENT OF THE CITY OF BLOEMFONTEIN

I, _______________________________________ (participant name), confirm that the person asking my consent to take part in this research has informed me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study, as explained in the information sheet. I have had an opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty. I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings. I am fluent in English and understand these documents or I have had the information explained to me in a language that I understand well.

Indicate clearly by marking either Yes or No with an X

I agree to participate in the questionnaire	YES	NO
I agree that the information obtained from the questionnaire may be referenced	YES	NO
I wish to remain anonymous as far as possible	YES	NO
I have received a signed copy of the informed consent agreement.	YES	NO

Full Name of Participant: ____

Signature of Participant: ______________________________________ Date: _____________________

Full Name(s) of Researcher(s): PALESA ADELINA MOJA

Signature of Researcher: 22 April 2024

Central University of Technology, Free State

Appendix C HREC Approval Letter

Central University of Technology, Free State

05 July 2025

Ms P. Moja
pmoja@cut.ac.za
Faculty of Engineering and Built Environment and Information Technology
Degree: Master of Health Sciences in Environment
Risk Category: Low
Protocol Reference Number: CUT/REIC 2025/000703
Approval Date: 05 July 2025
Expiry Date: 04 July 2026

Project Title: Perceptions and Investigation of Poor Quality Water Supplied to the Resident of the City of Bloemfontein.

Dear Ms Moja,

This letter serves to notify you that your application for study for the above-mentioned title was reviewed by the CUT Human Research Ethics Committee (CUT HREC). I am pleased to inform you on behalf of the CUT HREC that the study has been approved, and you have been granted ethical clearance for your project.

Your ethical clearance number, to be used in all correspondence, is **CUT/REIC 2025/000703.**

The ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension using the Clarivate Converis System or contact the Research Ethics Office for assistance.

We request that any changes that may take place during your research project be submitted to the HREC for approval to ensure we are kept up to date with your progress and any ethical implications that may arise. This includes any serious adverse events and/or termination of the study.

All data collected by CUT applicants must be stored in a secure and encrypted storage cloud that has restricted access to only those researchers involved in the study. Please contact Ms Dora Ackerman (dora@cut.ac.za) on how to store data on the approved university repository.

NB: The decision or approval of this study does not supersede the compliance with the residence period and is only for data that is yet to be collected and not for retrospective approval.

Kind regards

Laetus O.K. Lategan Digitally signed by Laetus O.K. Lategan
Date: 2025.07.05 17:48:46 +02'00'

Prof. Laetus O.K Lategan
CUT HREC: Chairperson
Human Research Ethics Committee
Research Development Office
T: +27 (0)51 507 4328 | E: REIC@cut.ac.za

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Appendix D Gatekeeper letter

INSTITUTIONAL PLANNING AND QUALITY ENHANCEMENT

P MOJA

PERMISSION FOR PALESA MOJA TO CONDUCT HER RESEARCH AT CUT ENTITLED "PERCEPTIONS AND INVESTIGATION OF POOR QUALITY WATER SUPPLIED TO THE RESIDENT OF THE CITY OF BLOEMFONTEIN."

Dear Ms Moja

This is to confirm that you have been granted permission to conduct research at the Central University of Technology for your master's project entitled "Perceptions and Investigation of Poor Quality Water Supplied to the Resident of the City of Bloemfontein."

The conditions of the conditional permission are:

- The research will not interrupt any of the official activities at The Central University of Technology.
- You will supply us with the copy of your report.
- The cost of all related activities will be covered by yourself.
- Recruitment of participants is the sole responsibility of yourself.
- The voluntary nature of the potential participants decision to consent to participate should be strictly observed.
- You should not disclose a potential participant's decision to participate or otherwise to any other party.
- Permission does not compel, in any sense, participation of staff members or students in your research.

Senior Director: Institutional Planning and Quality Enhancement

Mr. NIE Mokhele

13/07/2025