

https://dspace.org/

A Comparative Study of Water Utility Management in the Steve Tshwete Local Municipality, Mpumalanga

Shotholo, Benjamin

2025
University of the Witwatersrand, Johannesburg
https://hdl.handle.net/10539/50242

Shotholo, Benjamin. (2025). A Comparative Study of Water Utility Management in the Steve Tshwete Local Municipality, Mpumalanga [Master's dissertation, University of the Witwatersrand, Johannesburg]. WIReDSpace. https://hdl.handle.net/10539/50242

Downloaded from a DSpace repository. https://dspace.org/

Governance Research





A COMPARATIVE STUDY OF WATER UTILITY MANAGEMENT IN THE STEVE TSHWETE LOCAL MUNICIPALITY, MPUMALANGA

By

BENJAMIN SHOTHOLO

STUDENT NUMBER: 1491482

A THESIS SUBMITTED TO THE FACULTY OF COMMERCE LAW AND MANAGEMENT, UNIVERSITY OF THE WITWATERSRAND, IN PARTIAL FULFILLMENT OF THE DEGREE, MASTER OF MANAGEMENT IN GOVERNANCE (WITH SPECIALISATION IN MONITORING AND EVALUATION)

09/10/2024

Supervisor: Prof. Mike Muller

ABSTRACT

Municipalities in South Africa, as the implementation arm of the three spheres of government, are responsible for the provision of basic service delivery to the citizens of the country. Among these basic services, is the supply of good quality water in sufficient quantity to meet the daily needs of the citizens. The constitution of the Republic mandates access to good quality water that is not harmful to the people. Municipalities must therefore take necessary actions to ensure that water supplied to communities meets the standards set by authorities responsible for water services and water quality management. The Water Services Act (Act No. 108 of 1997) provides for the setting of national service standards and water service development plans, and it also provides a framework for water service institutions and water service authorities.

Most municipality-operated water utilities in the country, if not all, operate in a monopoly where there is no competition or comparison of performance among these utilities. This results in most of these utilities underperforming to the detriment of water service provision to communities they are responsible for. The Municipal Benchmarking Initiative (2015) and the recently published blue drop report, showed that most municipalities (water service providers) are underperforming with regards to the provision of water services. These two initiatives utilise performance indicators which are used to compare the performance of water by awarding scores for the municipalities in that specific indicator. These initiatives are a perfect example of how municipalities can learn from each other and improve their performance.

Benchmarking provides a tool with which water utilities can learn from each other to improve their performance. The aim is for the utilities that are classified as underperforming to learn from those that are regarded as top performers. There are a number of ways in which benchmarking can be carried out by water utilities, namely, process benchmarking, functional benchmarking, competitive benchmarking, internal benchmarking, and customer survey benchmarking. For the purpose of this study, process benchmarking and customer survey benchmarking were used.

Process benchmarking focuses on the selected process of the organization rather than the whole organisation. This method was selected to identify factors that affect the performance of water utilities using pre-selected performance indicators. A data collection tool in the form of a water

utility management questionnaire with open- and closed-ended questions was prepared and administered to the management of participating water utilities. Customer survey benchmarking was also selected for the study, and this was mainly to get the perception of the respondents about water service in their area. An interview schedule with open- and closed-ended was also prepared and used as a data collection tool.

Steve Tshwete Local municipality consist of four areas, namely, the town of Middelburg, which include the Mhluzi township, and Eskom villages, namely, Arnot (Rietkuil), Hendrinah (Pullense hope) and Komati. All these four areas are supplied with drinking water from their own water treatment plants. The Middelburg water treatment plant, the Vaalbank water treatment plant abstract water from the Middelburg dam, of which the quality of the water is affected by coal mining and industrial activities take place in the area. All Eskom water treatment plants are supplied with water through the Komati water distribution scheme, which abstracts water from the Vygeboom and Nooidtgedacht dams. Due to the mining and industrial activities in the Middelburg area, the water from the Middelburg was found to be difficult to treat as compared to water from the Komati water distribution scheme. Water from the Middelburg dam was found to have high Total Dissolved Solid (TDS) and manganese concentrations as compared to water from the Komati water distribution scheme.

Through the application of process benchmarking and customer survey benchmarking, it is the findings of this study that there are four factors that have an impact in the performance of water utilities in the Steve Tshwete Local municipality. These factors are: 1) Human resources. Plant operation personnel need to have the capabilities to take corrective whenever there is a change in the quality of raw water. The operator needs to be able to troubleshoot and investigate ways to improve the quality of final water. 2) Raw water quality. In the event that raw water quality has deteriorated to levels where treatment using the current conventional water treatment design does not work, alternatives should be investigated. These can include looking for an alternative water source, or upgrading the plant to include advanced water treatment process. 3)Regulatory oversight. The monitoring of municipality performance by authorities, e.g. COGTA and DWS, is important to ensure where municipalities fail to perform to required standards, intervention can be devised to ensure that water of good quality is supplied to customers at all times. 4) Financial support. Deterioration of water resources necessitates that the water treatment plant be upgraded to add advanced water treatment process to remove pollutants

from water. This study recommends that further investigations be conducted on advanced water treatment processes that can improve water quality in the Steve Tshwete local municipality.
Keywords: *Benchmarking, water utility performance, performance indicator, drinking water quality, water services*

DECLARATION

I, **BENJAMIN SHOTHOLO,** declare that this thesis, submitted for the degree of Master of Management in Governance (with specialization in Monitoring and Evaluation), contains no material accepted for an award of any other degree or diploma in any University or other institution. Tothe best of my knowledge, it contains no material previously published or written by another person except where due reference is made in the text of this thesis.



09/10/2024

Signature **Date**

ACKNOWLEDGEMENTS

First, I would like the Almighty God and our Lord and Saviour Jesus Christ for bringing me this far in life and in my career. It is through HIS grace and mercy that I have achieved everything so far, “HE WHO STRENGTHENS ME”.

Secondly, I would like to thank my supervisor, Prof. Mike Muller, whose excellent guidance and advice throughout this journey made the completion of this project possible. I will forever be grateful.

Thirdly, I would like the former Municipal Manager of Steve Tshwete Local Municipality for approving that study be conducted.

Fourthly, I would like thank the employees of all water utilities that were part of the study for the information that they shared and by so doing making this study a success.

Fifthly, I would like to thank all the respondents to the interviews that were conducted from the different communities.

Sixthly, I will not forget my cheerleading team, my family, my wife Malebo, and my kids Tshepo, Bontle, Rethabile, and Thabo. I also like to thank my brothers and sister, and nephew who always encourage me to continue improving myself.

A very special thank you goes to my Brother, Matome Francis Shotholo, with whom we have been walking this journey together. It is our talks and the decision that we took together about education and our family years ago that has brought us to where we are today. Let’s continue with this journey and reach even greater heights.

DEDICATION

I dedicate this thesis to my entire family, from Soshanguve, Thembisa, Alexandra, Mamelodi, Centurion, Dukuza, Botlokwa, and Rustenburg.

Table of Contents

ABSTRACT 2
DECLARATION 5
ACKNOWLEDGEMENTS 6
DEDICATION 7
CHAPTER 1 12
INTRODUCTION 12
1.1. OVERVIEW 12
1.2. PROBLEM STATEMENT 14
1.3. PURPOSE 15
1.4. RESEARCH QUESTION: 15
1.5. THESIS STRUCTURE 15
CHAPTER 2 16
LITERATURE REVIEW 16
2.1. INTRODUCTION 16
2.2. WATER SERVICE PROVISION IN SOUTH AFRICA 18
2.2.1. INSTITUTIONAL STRUCTURES FOR DELIVERING WATER SERVICES. 19
2.2.2. NORMS AND STANDARDS FOR WATER SERVICES IN SOUTH AFRICA 19
2.2.3. CROSS-CUTTING LEVELS OF SERVICES 20
2.3. PERFORMANCE MANAGEMENT OF WATER UTILITIES 22
2.4. BENCHMARKING 23
2.4.1. INTERNAL BENCHMARKING 23
2.4.2. COMPETITIVE BENCHMARKING 24
2.4.3. FUNCTIONAL BENCHMARKING 24
2.4.4. PROCESS BENCHMARKING 25
2.4.5. OTHER BENCHMARKING METHODOLOGIES 25
2.5. PERFORMANCE INDICATORS FOR WATER UTILITIES 26
2.5.1. WATER CONSERVATION WATER DEMAND MANAGEMENT (WC/WDM) 26
2.5.2. PERSONNEL AND STAFFING INDICATORS 28
2.5.3. PHYSICAL AND ASSET INDICATORS 29
2.5.4. PRODUCT QUALITY INDICATORS 30

CHAPTER 3 33
RESEARCH METHODOLOGY 33
3.1. STUDY AREA 33
3.2. RESEARCH APPROACH 35
3.3. RESEARCH TOOLS AND THEIR APPLICATION 36
3.4. SAMPLING 37
3.5. PROCESS OF ANALYSIS 38
3.6. LIMITATIONS, FEASIBILITY, AND POSITIONALITY 38
3.7. ETHICS 39
3.8. VALIDITY, RELIABILITY, AND DEPENDABILITY 39
CHAPTER 4 40
RESULTS 40
4.1. INTRODUCTION 40
4.2. WATER UTILITY PERFORMANCE INDICATORS 40
4.2.1. WATER SERVICE DELIVERY 40
4.2.2. OPERATION AND MAINTENANCE 42
4.2.3. PERSONNEL AND STAFFING 43
4.2.4. PRODUCT QUALITY 44
4.3. CUSTOMER SATISFACTION SURVEY 52
4.3.1. CUSTOMERS KNOW THE MUNICIPALITY'S WATER AND SANITATION NUMBER 52
4.3.2. NOTIFICATION OF WATER SUPPLY INTERRUPTIONS 52
4.3.3. MAXIMUM HOURS OF INTERRUPTION EXPERIENCED BY HOUSEHOLDS 52
4.3.4. CUSTOMER PERCEPTION OF WATER QUALITY 53
4.3.5. DO CUSTOMERS BUY COMMERCIALLY SOLD WATER 53
4.3.6. TAP WATER USE IN HOUSEHOLDS 53
4.4. CONCLUSION 54
CHAPTER 5 55
DISCUSSION AND CONCLUSION 55
5.1. INTRODUCTION 55
5.2. WATER UTILITY PERFORMANCE INDICATORS 55
5.2.1. WATER SERVICE DELIVERY 55
5.2.2. OPERATIONS AND MAINTENANCE 56
5.2.3. PERSONNEL AND STAFFING 57
5.2.4. PRODUCT QUALITY 58
5.3. CUSTOMER SATISFACTION SURVEY 60

5.4. IMPLICATIONS OF THE STUDY 62
5.5. RECOMMENDATIONS 63
5.5.1. FINDINGS OF THE STUDY 63
5.5.2. RESEARCH RECOMMENDATIONS 65
REFERENCES 66
APPENDICES 69

Table of Figures

Figure 2. 1: Norms and standards for water supply services 20
Figure 2. 2: Cross-cutting norms and standards for supply services 21
Figure 2. 3: The elements and components of WC/WDM. 28
Figure 2. 4: SANS241:2015 water quality standards. 32

Figure 3. 1: Nkangala district municipality and local municipalities within the Mpumalanga province 33
Figure 3. 2: Map of water sources for Steve Tshwete Local Municipality Water Treatment Plants. 34

Figure 4. 1: Percentage coverage of households with piped water services. 40
Figure 4. 2: Water service interruptions experienced by households according to water utility management. 41
Figure 4. 3: Water pressure problems experienced by households. 42
Figure 4. 4: Water service staff with the correct skill/qualification. 43
Figure 4. 5: Qualifications and skills of staff responsible for water services. 44
Figure 4. 6: Turbidity in raw and final water samples from water treatment plant in Steve Tshwete Local Municipality 46
Figure 4. 7: Total Dissolved Solids (TDS) of raw and final water in the Steve Tshwete Local Municipality Water Treatment Plants. 47
Figure 4. 8: pH of raw and final water in the Steve Tshwete Local Municipality Water Treatment Plants. 48
Figure 4. 9: Free Chlorine of Water Treatment Plants in the Steve Tshwete Local Municipality. 49
Figure 4. 10: The concentration of iron in raw and final water of water treatment plants in the Steve Tshwete Local Municipality. 50
Figure 4. 11: Manganese concentration in raw and final water of the Water Treatment Plants in the Steve Tshwete Local Municipality. 51

CHAPTER 1
INTRODUCTION

1.1. OVERVIEW

Municipalities in South Africa and elsewhere around the world are entrusted with the responsibility of providing water services to their citizens. “The availability of an acceptable quantity and quality of water for health, livelihood, ecosystems, and production coupled with an acceptable level of water-related risks to people, environments and economies” has been termed “water security” (Grey and Sadoff, 2007, quoted in Rietveld et al., 2016: 152). When the Municipality does not achieve water security, service delivery protest and non-payment of water services become the routes citizens take to voice their dissatisfaction. Non-payment of water services impacts water utilities negatively because they depend on revenue from the services they provide, especially for operational costs. In most cases, water utilities are managed by municipalities which have to ensure that adequate water of good quality is supplied to their customers.

After the Millennium Developmental Goals (MDGs) of 2015, UNICEF and the WHO estimated that more than 660 million people, of which half are in Sub-Saharan Africa, were still subjected to unimproved drinking water sources (Shersen et al., 2016; Kayaga, Kingdom, Jalakam, 2018). “Common barriers to providing good levels of service are unclear roles, and responsibilities, limited autonomy, and accountability, low levels of cost recovery, lack of commercial and customer orientation, and the weak professional capacity” (Baiettie et al., 2006, quoted in Kayaga, Kingdom, Jalakam, 2018: 49). These barriers create a situation where utilities are unable to meet the need of the people they serve. One possible action that utilities can take to turn around their performance is to change their mindset from asset management to one that is focused on their customers' needs (Soppe, Janson, Piantini, 2017). Regular feedback from water users will ensure that water utility managers are informed on whether they meet the requirements of the end-user and what can be done to improve performance.

According to Tutusaus and Schwartz (2018), many small urban centres operate on water supply infrastructure inherited from the colonial/apartheid regime of the past. Under colonial rule, small urban centers were allowed to expand if they were strategic to the exploitation of raw materials and agricultural activities (Tutusaus and Schwartz, 2018). The post-colonial era saw the migration

of people from rural areas to these small urban centres searching for work and a better life. The rapid growth in population in these urban centres, coupled with aging infrastructure, rendered most municipalities unable to meet the water needs of the people they serve. Water in South Africa is a basic human right, when people feel that their water needs are not met, they usually take to the streets to voice their dissatisfaction. This results in protest action which in most cases turns violent and destructive to properties and infrastructure.

Weighing in on the approaches to improve the performance of the water utilities, the World Bank has promoted a three-pronged approach (Soppe, Janson, Piantini, 2018): i) Strengthening operational efficiency of the utility, ii) Improving the governing environment, and iii) Improving access to funding.

There are many factors that require synchronization for the effective and sustainable performance of a water utility. Technical and commercial operations require other utility management elements, including organization and strategy, human resource management, and financial management (Soppe, Janson, Piantini, 2018). “Water utilities need a systematic, coordinated, and prioritized approach to improve their operational and management capacities while mitigating the negative impacts that the political environment may have on their performance” (Soppe, Janson, Piantini, 2018: 12).

According to Heider, Sadiq, and Tesfamarian (2014), one mechanism for evaluating water utility performance is establishing benchmarks through cross-comparison with similar utilities. Benchmarking utilizes a systems approach to develop performance indicators (PI) considering the size and conditions of the water utility. “A PI system usually consists of general asset information, baseline data variables, the categorisation of given PIs, linkage between data variables and PI’s, the formulae or equations to calculate the PI, and the comparison with benchmarks” (Heider, Sadiq, and Tesfamarian, 2014: p2). Grouping the selected PIs provides a mechanism for the assessment of the water utility using categories (e.g. personnel, customer service, operations).

Steve Tshwete Local Municipality is classified as a category B1 municipality, a local municipality with a large town or city as its urban core (SALGA, 2015). The Municipality is a mining and industrial town with three power stations, coal mines, and a stainless-steel factory. The town of Middelburg, the local Municipality's urban core, is made up of the suburb of Aerorand and Mhluzi

township. The Municipality has had its fair share of service delivery protests, predominantly in the township of Mhluzi. Water services have been one of the complaints laid by the residents. Issues raised include water quality, water shortages, and water supply infrastructure, especially in informal settlements. In the Eskom villages, service delivery protests are rare, and water complaints are seldom heard of. Every power station has a water treatment plant to supply its town and surrounding areas. The quality of water in the Eskom villages has been perceived to be better than the water supplied by the municipality's water treatment plant. There also have been reports of extended water interruptions without notification of water users, especially in Mhluzi, the municipality's biggest area of supply.

This research utilizes benchmarking to compare water utilities' performance to understand the factors that affect the performance of water utilities in the Steve Tshwete Local Municipality. It seeks to identify factors that need to be prioritized to improve water utility performance and improve water service delivery.

1.2. PROBLEM STATEMENT

Different water provision levels have been experienced in the Steve Tshwete Local Municipality depending on i) location within the Municipality and ii) who is managing the water treatment plant. Steve Tshwete Local Municipality is made up of the Middelburg town and three Eskom villages, namely Arnot, Hendrina, and Komati. The Municipality has in the past been awarded the blue drop certification, which indicates that Steve Tshwete Municipality as a whole was supplying good quality water. This is in contrast to the views of the majority of the citizens of Middelburg town. They prefer bottled water or commercially sold water to tap water available in their homes for domestic use. People who reside in the Eskom villages do not have the problem of water like those raised by people in Middelburg. The factors responsible for these reasons for the different levels of performance are not apparent. An understanding of these factors may identify the reasons why people in other portions of the municipality perceive water services in their area as poor.

Benchmarking has been used globally as a continuous improvement tool by informing water utility managers about the comparative performance of water utilities and the factors responsible for differences in performance. Identifying and highlighting areas of performance

that results in poor water service provision in some areas of the municipality will assist water utility managers in prioritising these areas of performance and improving water service.

Benchmarking in South Africa has only been implemented at the national and Municipality levels, and there is no literature on benchmarking at the utility level within the same locality. According to Brettenny and Sharp (2018), three benchmarking initiatives have been implemented between 2004 and 2017 in South Africa. First was the National Benchmarking Initiative (NBI) between 2004 and 2007, which aimed to improve the performance, efficiency, and sustainability of Water Service Authorities (WSA's). In 2008, the Blue and Green Drop certification was implemented to improve potable water quality and treatment of wastewater at a municipal level, respectively. In 2012, the Municipal Benchmarking Initiative was implemented to identify the water sector's challenges (Bretteny and Sharp, 2018).

1.3. PURPOSE

The purpose of this research is to explore factors influencing the performance (e.g., management, financial or technical) of water utilities in the Steve Tshwete Local Municipality in ensuring improved water services for the community.

1.4. RESEARCH QUESTION:

What factors influence the performance of water utilities and the perception of the people on water services in the Steve Tshwete Local Municipality in the provision of good quality and sufficient quantity of water?

1.5. THESIS STRUCTURE

This thesis is divided into five chapters. Chapter 1 introduces the study. The chapter includes an overview of the study and outlines the problem statement. It further discusses the purpose of the study and the research question. Chapter 2 provides the literature review of water services performance measurement and management. It discusses water services provision in South Africa, performance management of water utilities, benchmarking as a tool for water utility performance improvement, also discusses the norms and standards for water services in South Africa. Chapter 3 provides the methodology used to conduct the study. It discusses the study area and the approach used for data collection and analysis. Chapter 4 presents the findings of the study. Chapter 5 provides a discussion of the finding and the conclusion of the study.

CHAPTER 2
LITERATURE REVIEW

2.1. INTRODUCTION

Publicly owned water utilities are identified by the level of government ownership and control (Kayaga, Kingdom, and Jalakam, 2018). As the implementation arm of government, Municipalities should perform in a way that ensures that people realise their right to good quality drinking water. There are barriers that municipalities are faced with for this right to be recognized. These include “unclear roles and responsibilities, limited autonomy and accountability, low levels of cost recovery, lack of commercial and customer orientation, and weak professional capacity” (Biaette et al., 2006 in Kagaya, Kingdom, and Jalakam, 2018). To perform optimally and supply sufficient quantities of good quality water, water utilities must breach these barriers and strive for continuous improvement.

Water utilities, in most cases, operate in a monopolized environment where there is no competition. Water utilities operate in an environment where performance management is often considered less relevant because success criteria are less evident and intuitively coherent. The natural monopoly diminishes the relevance of efficacy (Sattarov and Valkova, 2017). When there is a comparison among water utilities, non-performing utilities will be under pressure to continuously improve their performance. These utilities can identify indicators of good performance from those utilities that are doing well.

According to Sattarov and Valkova (2017), performance management for water utilities is challenging due to the number of indicators and parameters used for performance evaluation and rectification. Due to the complexity of evaluating the performance of water utilities, several methodologies have been developed to address specific performance issues (Akimov and Simshauser, 2020). Akimov and Simshauser (2010) mentioned Berg (2010) suggesting a typology of methods for water utility performance measurement.

First, are core or partial indicators methods. These indicators are ratios reflecting the operational and financial characteristics of an organization. For example, the ratio of connections per worker, the proportion of unaccounted water, or operating expenses per connection. These indicators have an inherent limitation of focusing on a certain segment of operations and under interpretation of the scale of economies and consequential impacts. To counter these limitations,

a number of indicators can be grouped and assessed simultaneously instead of individually (Akimov and Simshauser, 2020).

Secondly, are total methods that utilise performance scores based on production and cost estimates to measure the performance of an individual utility within a group of utilities. To identify the best and worst performing utilities within the group, a framework, which includes the selection of inputs or outputs and explanatory or dependent variables has to be created. Data analysis for total methods can be carried out using these methods: i) nonfrontier/statistical methods, such as ordinary least squares regressions or panel data techniques; ii) frontier parametric methods of stochastic frontier analysis (SFA); iii) frontier nonparametric methods, such as data envelopment analysis (DEA) (Akimov and Simshauser, 2020). These methods are used mostly by academia than used by governing bodies due to their complexity (Akimov and Simshauser, 2020).

Thirdly, is the less used engineering approach which utilised a utility's own modeled benchmark. The approach is based on the development of engineering and economic models for a specific utility according to its parameters, for example, population density, topology, and customer profile (Akimov and Simshauser, 2020).

Fourthly, is process benchmarking which involves a detailed analysis of operating characteristics. This method examines individual stages of production or service delivery to identify the problematic area and share best practices with other similar utilities. The method is not suitable for relative performance measurement and ranking (Akimov and Simshauser, 2020).

Finally, water utility performance measurement can be done using customer survey benchmarking. This method uses feedback from the users of the utility to evaluate the performance of the utility.

Steve Tshwete Local Municipality consists of medium to small water utilities. The performance of water in the Municipality varies depending on where the utility is located and who manages it. Water utility managers and decision-makers in non-performing utilities can learn from those presumed to perform well. Benchmarking of water utilities within the Municipality provides a mechanism to improve performance.

Benchmarking focuses on key performance indicators of a water utility (SALGA, 2015). Benchmarking can either be in the form of process benchmarking or metric benchmarking (SALGA, 2015; Bellaubi and Visscher, 2014). Process benchmarking involves identifying those entities (whether a municipality or water utility) perceived as good performers in a specific area of interest and adopt and/or adapt their procedures and way of doing things (SALGA, 2015; Bellaubi and Visscher, 2014). In metric benchmarking, information or data on specific performance indicators is used to identify improvement opportunities (SALGA, 2015; Bellaubi and Visscher, 2014). "The intrinsic problem when comparing water utilities is that results need to be put into perspective of the local situation" (Bellaubi and Visscher, 2014).

Indicators widely used globally for the assessment of the provision of water and wastewater services are contained in the International Benchmarking Network for Water and Sanitation Utilities (IBNET) of the World Bank and provides a "set of financial, technical and process indicators for the assessment of water utilities" (Bellubi and Visscher, 2014: p954). In the South African context, the Municipal Benchmarking Initiative set out indicators for supporting water services performance measurement and improvement (SALGA, 2015).

2.2. WATER SERVICE PROVISION IN SOUTH AFRICA

The water sector in South Africa gets its mandate to supply water to the country's population from the constitution of the Republic. The Department of Water and Sanitation (DWS) which is the custodian of the country's water resources is responsible for the formulation and implementation of policy governing the water sector (DST, undated). Through local government structures and institutions, which are the implementation arm of the national government, water services are provided to the citizens of the country. The framework for the delivery of these water services is provided for in the Constitution (Act 108 of 1996); the National Water Act (NWA) (Act 36 of 1998); the Water Services Act (WSA) (Act 108 of 1998); the Municipal Structures Act (Act 117 of 1998), the Public Finance Management Act (Act 1 of 1999) and the Municipal Finance Management Act (Act 56 of 2003).

The right to sufficient drinking water of good quality in South Africa is enshrined in sections 24 and 27 of the bill of rights. Section 27 states that "everyone has the right to have access to sufficient water" and that "the state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of these rights" (the Constitution of

South Africa, 1996)). According to the NWA and the WSA, the establishment, monitoring, and regulation of the guidelines to address the national water and sanitation policies are the responsibility of the Minister in the DWS (DWS, 2017). However, the constitution of the Republic assigns the actual delivery of water and sanitation services to local governments (DWS, 2017).

2.2.1. INSTITUTIONAL STRUCTURES FOR DELIVERING WATER SERVICES.

On the 17th of September 2003, the cabinet approved the Strategic Framework for the provision of water services which outlines the changes of approach needed to achieve policy goals for the water sector. The development of the Strategic Framework included a consultative process with a wide range of stakeholders around the country (DWAF, 2003). The Strategic Framework acknowledges that water is key to the eradication of poverty and economic development. It is for this reason that the Strategic Framework was developed on the concepts of sustainability and economic development (DWAF, 2003). DWAF (2003: p2) states that "the Strategic Framework provides a comprehensive summary of policy with respect to the water sector in South Africa and provides a strategic framework for its implementation over the next ten years".

The Constitution of South Africa (1996) provides for three spheres of government, namely, the national, provincial, and local governments. Sections 43 and 44 read with Schedules 4 and 5 provides for the legislative competencies of the national parliament; section 104 read with the same schedules, provides for the legislative competencies of provincial governments; and Part B of Schedule 4 provides for local governments (municipalities). Part B of Schedule 4 rests the executive authority and the responsibility to administer water and sanitation services to municipalities. "The Constitution states that the object of local governments is to ensure the provision of basic services to communities in a sustainable manner, to promote social and economic development, and to promote a safe and healthy environment" (Murombo and Poole, 2009: p 13)

2.2.2. NORMS AND STANDARDS FOR WATER SERVICES IN SOUTH AFRICA

On the 8th of September 2017, the Department of Water and Sanitation (DWS) in collaboration with the Council for Scientific and Industrial Research (CSIR) gazetted the national norms and standards for domestic water and sanitation services. The development of the norms and standards was guided by the relevant water policies which included the National Water Act, the Water Services Act, and the National Sanitation Policy (DWS, 2017). The national norms and standards for domestic water and sanitation services are divided into four parts. PART ONE

outlines the Norms and Standards for Water Supply Services, PART TWO outlines the Norms and standards for Sanitation Services, PART THREE outlines monitoring, reporting and regulating norms and standards, and PART FOUR is the conclusion.

Figure 2.1 illustrates the norm and standards for water supply services and outlined in the national norms and standards for water supply and sanitation. The norms and standards consist of cross-cutting levels of services, water ladder which outliness the different levels of water supply and the supporting levels of service to ensure the supply of water.

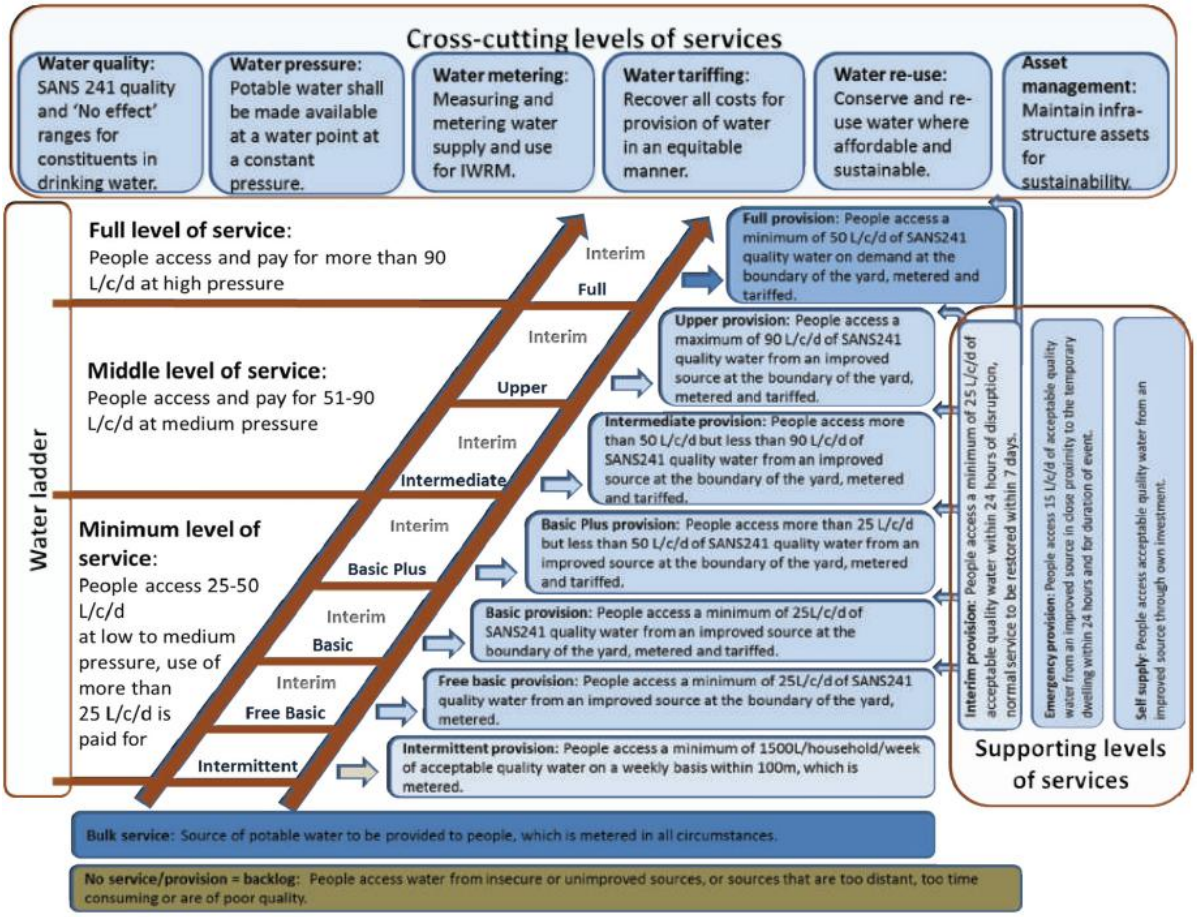


FIGURE 2. 1: NORMS AND STANDARDS FOR WATER SUPPLY SERVICES (SOURCE: DWS, 2017).

2.2.3. CROSS-CUTTING LEVELS OF SERVICES

Cross-cutting issues are those issues that must be considered in conjunction with other related issues to be fully addressed. Cross-cutting norms and standards for water supply service are shown in Figure 2.2., and they are water quality, water pressure, water metering, water tarrifing, water re-use, and asset management.

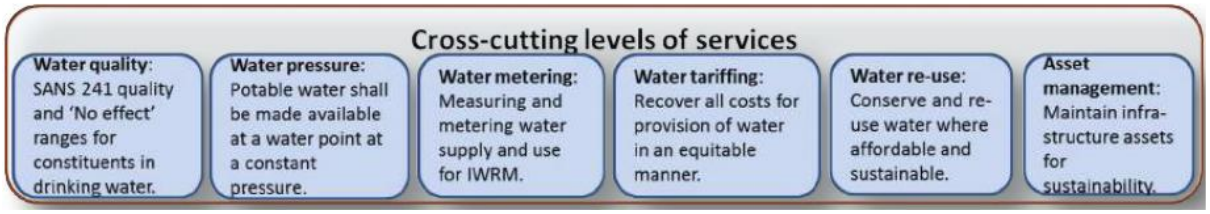


FIGURE 2. 2: CROSS-CUTTING NORMS AND STANDARDS FOR SUPPLY SERVICES (SOURCE: DWS 2017)

Water quality

Water quality refers to the constituents in the water that renders it fit to be used for different purposes. Different water uses has different requirement for water quality. The norms and standards for water supply service stipulate the water should meet the quality standards relevant to that use, for example, human consumption, industrial purposes, or for the maintenance of ecosystems. The goal of these norms and standards is to ensure that people "have access to potable water that is fit for human use and comply with the national water quality standards" (DWS, 2017: p 15).

Pressure in a distribution system

The norms and standards for water supply services as guided by the National Water Service Act state that water reticulation systems should operate at a pressure of less than 900 kPa (DWS, 2017). The goal is to ensure that "people have access to potable water for human use at a constant pressure" (DWS, 2017: p 16).

Water metering

The Government Notice, R 22355 published on the 8th of June 2011 titled The Regulations relating to Compulsory National Standards and Measures to Conserve Water, mandates the measuring of water to any consumer using a water-volume measuring device. The goal is to ensure that "all water use is measured and metered to enable Integrated Water Resource Management for ensuring sustainable and effective water use" (DWS, 2017: p 16).

Water tariffing

Tarifs are set to recover the costs associated with the provision of service. Setting the correct price for water is seen as a mechanism to ensure that water is valued and promote its effective and productive. The goal is to ensure that "all water use is charged for to enable effective and productive water use" (DWS, 2017: p 17).

Water re-use and recycling

As a water scarce country, South Africa needs to conserve water and the Minister of the DWS advocates the need for an 'integrated water approach'. This approach includes measures such as reduction in demand of freshwater through investigation and advocating for water-wise landscaping, rainwater harvesting and water-efficient appliances. It includes the use of greywater from baths, showers and hand basins for gardening, car washing and pavement cleaning. "Increasing water re-use can assist in providing more resilience to managing the insecurity of water supply as a result of climate change" (DWS, 2017: p 19)

Asset management

The ownership and management of water service infrastructure in South Africa are grouped into four categories (Stephenson, et al., 2001). These are state-owned infrastructure administered primarily by DWS; parastatal infrastructure owned and administered by Water Boards and divisional authorities; municipal/ local government assets; and community/private assets. The management of water service infrastructure is important to ensure a continuous supply of water. Water legislation such as National Water Act and the Water Service Act together with Municipal Service Act and the Municipal Finance Management Act outlines the requirements and obligations of the administration and management of water services assets (Stephenson, et al., 2001).

2.3. PERFORMANCE MANAGEMENT OF WATER UTILITIES

The performance of water utilities has been under immense perusal, and this is due to the many factors affecting the water service sector. According to Ananda and Pawsey (2019), the water service sector encompasses two distinctive areas: the quality of the product (i.e. potable water) and the quality of the water service (i.e. supply interruptions, leakage, response to interruptions, or customer complaints). It is therefore imperative that an optimal balance is struck between the two in order for a water utility to perform at its best. However, performance is derailed by the monopoly in which water utilities operate. The lack of competition in the water services sector deteriorates the quality of service provided by water utilities. Water utilities operate only to meet the norms and standards which have been set, and they seldom meet these norms and standards. Therefore, the concept of benchmarking was introduced in the water sector for water

utilities to compare their performance with other water utilities and to highlight areas that can be improved so as to improve their performance.

Although the concept of benchmarking has a long history dating as far as the 1970s, "the identification of benchmarking as a corporate strategy to promote both internal improvements and external competition is modern" (Fibuch and van Way, 2013: p28). Several definitions of benchmarking can be found in the literature. For example, Elmuti and Kathawala (1997) defines benchmarking as a process of identifying the highest standards of excellence for a product, service, or process and then making the improvements necessary to reach those standards commonly called best practices. Fibuch and van Way (2013) on the other hand defines benchmarking as a process of reviewing organisational performance in terms of a measurable quantity that can be tracked over time compared to industry-wide standards. The most recent definition of benchmarking was published in the benchmarking manual developed by IWA and AWWA which defines benchmarking as "a tool for performance improvement through systematic search and adaptation of leading practices" (Haskins and Brueck, 2019). It is clear from the definitions above that the main aim of benchmarking is performance improvement.

Four types of benchmarking, namely, internal benchmarking, competitive benchmarking, functional or industry benchmarking, and process or generic benchmarking, can be distinguished (Elmuti and Kathawala, 1997; Fibuch and van Way, 2013).

2.4. BENCHMARKING

2.4.1. INTERNAL BENCHMARKING

Internal benchmarking involves looking within the organisation for best practices and methods of conducting business (https://www.valuemetrics.co.uk/internal-benchmarking). It is the simplest benchmarking method since the data used is readily available and a multitude of information can be shared (Elmuti and Kathawala, 1997). Elmuti and Kathawala (1997) state that by identifying the best internal procedures, organisations are able to share these procedures with the rest of the organisation and thereby improving the performance of the organisation. However, Fibuch and van Way (2013) argues that internal benchmarking tends to create companies that retain an introverted view and have a weak strategic vision.

Internal benchmarking identifies best practices within the organisation by comparing metrics (performance benchmarking) and/or practice (practice benchmarking) from different units,

departments, or production lines (Harper, 2019). Performance benchmarking usually identifies gaps in the organisation's performance using quantitative data. Standard measures and/or key performance indicators are used to extract, collect, and analyse data about the performance of the organisation. In practice benchmarking, qualitative data is collected and analysed through people, processes, or technology about activity in the organisation. Process mapping is a commonly used method to collect and analyse data in practice benchmarking (Harper, 2019). Practice benchmarking identifies gaps in the performance of the organisation and also highlights best practices that can be transferred to other areas of the organisation.

2.4.2. COMPETITIVE BENCHMARKING

Competitive benchmarking involves comparing an organization's performance with those of other organisations, especially those considered the best performers within the same industry. The goal is to identify what other organisations are doing to adapt this to the organisation's products, services, processes, and outcomes to improve performance and gain a competitive advantage (Fibuch and van Way, 2013). It allows an organisation to evaluate its overall performance, identify industry best practices and inform planning that allows an organisation to maintain an edge over the competition.

There are three categories encompassed in competitive benchmarking, namely, strategic benchmarking, process benchmarking, and performance benchmarking (Rorigue, 2021). Strategic benchmarking compares models and strategies. It analyses trends in the performance of other organisations over time to inform the long-term direction of the organisation. Process benchmarking compares business and operational processes. Selected production processes in the business are compared with the performance of similar processes from competitors. It is presumed that by identifying and analysing best practices from other organisations, managers can plan better to improve sub-systems within the organisation leading to improved organisational performance (https://www.ib-net.org/) .

2.4.3. FUNCTIONAL BENCHMARKING

In functional benchmarking, organisations within and outside the industry share information and ideas on their performance, especially those that are performing well (Elmuti and Kathawala, 1997; Fibuch and van Way, 2013). The aim is for organisations to learn from those regarded as best performers or industry leaders in functional operation. Elmuti and Kathawala (1997) recommend benchmarking partners should organisartions that share common technological and

market characteristics. They further recommend that competitors be avoided to ensure that benchmarking partners are willing to share information.

2.4.4. PROCESS BENCHMARKING

Process benchmarking focuses on selected process of the organisation rather than the organisation as a whole (https://www.ib-net.org/). The goal is to increase efficiency by learning from other organisations with similar production process who are performing well. Managers use process benchmarking because it can identify stages in the production process that need attention for improved performance (Berg and Corton, 2007). Process benchmarking, therefore, should start with a detailed examination of the production facilities and their operations.

Process benchmarking identifies specific work procedures that can be improved by learning what others in the industry are doing better on the same process (https://www.ib-net.org/). It involves adopting structure and methods that happen to be successful elsewhere, and reworking them to suit the organisation and ensure improved performance. The advantage of such detailed benchmarking is that it includes the comparison of engineering practices, data collection procedures, office routines, and performance indicators of each of the processes under study (https://www.ib-net.org/). The disadvantage is that it is management oriented which tends to be more time-consuming and requires the involvement of a third party who relies on the organisation for benchmarking information.

2.4.5. OTHER BENCHMARKING METHODOLOGIES

Customer survey benchmarking

Customer survey benchmarking evaluates performance based on the perceptions of the customers (Berg and Corton, 2007). Customer concerns, based on the complaints or appraisals captured in the survey are used to measure the organisation's performance. One widely-used model identifies five dimensions used to evaluate the quality as perceived by customers using a survey: external characteristics (tidy workplace, employee appearance), reliability (meeting deadlines, consistency in interaction), responsiveness (providing service promptly), consideration (personnel who are courteous, friendly and helpful), and empathy (giving individual care) (Berg and Corton, 2007).

Engineering-model company

The engineering-model company benchmarking methodology is an industry-oriented methodology that unlike other methodologies does not rely on the cross-comparison of organisations. The method is based on a design of a benchmark that responds to the need of the industry to satisfy its predicted demand. The approach combines both engineering efficiency (an analysis of the physical configuration of the network components of an industry) and economic efficiency (the application of the least cost function to determine the optimal operating cost) to design an optimised model of the industry or organisation (https://www.ib-net.org/).

2.5. PERFORMANCE INDICATORS FOR WATER UTILITIES

Heider, Sadiq, and Tesfamarian (2014) differentiate between large and medium to small water utilities. Medium to small water utilities has fewer performance indicators due to their scope and coverage. Six indicator categories are proposed for medium to small utilities:

I. Water conservation and demand management,

II. Personnel and staffing indicators,

III. Physical and asset indicators,

IV. Operational indicators,

V. Water quality and public health indicators, and

VI. Quality of service indicators.

2.5.1. WATER CONSERVATION WATER DEMAND MANAGEMENT (WC/WDM)

Water conservation and demand management assess the practices in which water use is managed (SALGA, 2015). WC/WDM is rooted in the use of water so as to minimise loss and waste of water by using water efficiently and effectively (Mwiinga, Gumbo & Mkoka, 2008). It is an established fact that water is a scarce resource in South Africa and should be used sparingly. Non-revenue water (NRW) is one way of measuring the effectiveness of water conservation and demand. NRW is the difference between the water input of the utility and water billed from the households. The MBI (SALGA, 2015) reported the national NRW as 34% which is used as the baseline for municipalities.

The Water Services Act (Act 108 of 1997) requires municipalities that have been given the water service provider status, to develop a WC/WDM strategy and business plan which should be included in their water service development plan (WSDP) (Wegelin & Jacobs, 2012). The WC/WDM strategies are guided by three fundamental principles, which includes (Pott, et al., 2009):

i. Water institutions should endeavor to supply water in an efficient and effective manner by minimising losses and promoting WC/WDM to their consumers;
ii. Water users should endeavor to use efficiently; and
iii. WC/WDM should be considered as part of the planning process for water resources, water supply, and water services.

Many municipalities are still struggling to develop WC/WDM strategies and business plans, and this is attributed to a lack of planning and realizing the consequence and potential benefits of WC/WDM (Wegelin & Jacobs, 2012). Where an attempt has been made to develop strategies and business plans for WC/WDM, they have been found to be vague and of little value. There are various publications, books, manuals, and software packages that have been produced over the years to assist water service managers with the development of WC/WDM strategies but still, many municipalities do not have strategies in place (Wegelin & Jacobs, 2012).

WC/WDM strategies are developed to achieve a balance between social equity, economic efficiency, and environmental sustainability (Mwiinga, Gumbo & Mkoka, 2008). Water conservation refers to the use of water that reduces loss and waste, and that cares for and protects the resource. Water demand management on the hand requires strategies that control the amount of water used (Mwiinga, Gumbo & Mkoka, 2008). Figure 2.3. shows the elements and components of WC/WDM and how they benefit the social, economic, environmental, and health sectors. Of paramount importance, is the reduction of non-revenue water thereby increasing the water utility revenue and increasing the availability of water for areas in need.

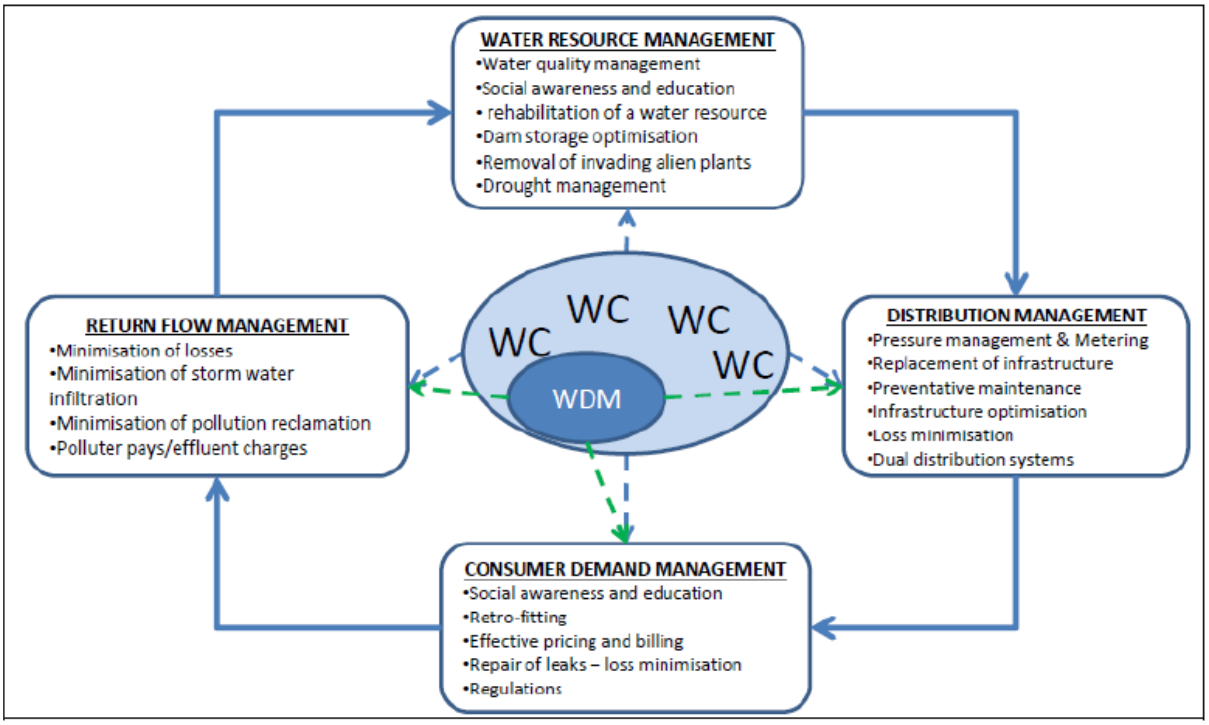


FIGURE 2. 3: THE ELEMENTS AND COMPONENTS OF WC/WDM (SOURCE: MWIINGA, GUMBO & MKOKA, 2008).

2.5.2. PERSONNEL AND STAFFING INDICATORS

Human resources are one of the most important determinants of the performance of an organization. The skills, qualifications, and experience of personnel responsible for the provision of service have a direct impact on the level of the services provided (Karia et al., 2016). The baseline determined by the MBI (SALGA, 2015) for the number of water staff is 3.4 staff per 1000 connections. The MBI (SALGA, 2015) provides a baseline for asset management indicators, operational indicators, and water quality indicators. The baseline for these indicators was developed by comparing the performance of municipalities.

It is acknowledged in the National Water and Sanitation Master Plan of South Africa that human resources are a prerequisite for the an effective water sector (OECD, 2021). The sector requires capacity at all different fuctions that make up the sector both in terms of numbers to meet the demand for specific skills; and competencies in terms of skills, qualifications, and experience (OECD, 2021). Research conducted by the Water Research Commission (WRC) and the Engineering Council of South Africa (ECSA), indicated that there exists a skill gap in the water sector institutions, including the Department of Water and Sanitation (DWS), Catchment Management Agencies (CMA's), Water Boards and Water Service Authorities (WSA's). ECSA

further reported that in South Africa in 2015 there was one engineer per 2600 people compared to the international standard of one engineer per 40 people (OECD, 2021).

To address the capacity gap in the water sector, the Organisation for Economic Cooperation and Development (OECD) suggests that the updated National Water Strategy at the national level and action plans at the city level should have a section dedicated to capacity building and development (OECD, 2021). The OECD Principle 4 of Water Governance states that the level of capacity required by institutions in the water sector should be adapted in line with the challenges that the institution has to address (OECD, 2021). These institutions ought to be supported will the resources need to ensure their success. Their working environment should ensure that trained personnel are retained.

2.5.3. PHYSICAL AND ASSET INDICATORS

Assets are the main mechanism of delivering water to the customers. To guarantee continuous supply of water, maintenance and renewal of asset is required. According to ADB (2013), maintenance of the asset, when carried out effectively, slow down its deteriotaion and extends the period before rehabilitation and replacement is required. Therefore, “a proper maintenance management system translates the targeted asset service and utilisation into a maintenance activities” (ADB, 2013: p13).

According to ADB (2013), maintenance information should be organised into a register. Information found in this register included among other things, operation and maintenance manuals, asset drawings and photos, manufacturer-recommended maintenance, failure modes of the asset, and maintenance priorities, to draw up its plans and procedures (ADB, 2013). Where this register can be computerised, scheduled inspections can be printed out to give effect to preventative maintenance. The quality of the information captured in this register will determine the effectiveness of the maintenance program.

Capital spending is an important aspect of water utility asset management. This is needed to i) cope with ever-growing demand, ii) be able to treat deteriorating raw water quality to acceptable drinking water standards, and iii) renew or replace existing assets (ADB, 2013). Demand forecasting, knowledge of the existing asset base, and both the condition of and expected level of service form the foundation of planning for capital spending for water utility asset

management. It is therefore imperative that long-term, that is, 3 to 20 years, plans are developed for capital spending.

Physical and asset indicators refer to the availability and reliability of the infrastructure required to supply water to customers.

2.5.4. PRODUCT QUALITY INDICATORS

Information required to make judgments about water use and other water quality management purposes in South Africa is provided in the South African Water Quality Guidelines (DWS, 1996). The South African Water Quality Guidelines consist of a series of documents that provides information regarding the quality of water required for specific water use. Volume 1 in the series, provides information on water quality for domestic water use. Domestic water use includes consumptive use such as drinking and cooking, and non-consumptive use such as bathing, gardening, cleaning, etc. The guidelines provide a more detailed account of the ideal quality of water for domestic use purposes; this is to assist users of the guidelines to make informed decisions about the fitness of water for use (DWS, 1996).

Water quality as denoted in the guidelines describes the physical, chemical, biological, and aesthetic properties of water which in turn determines its fitness for use (DWS, 1996). The properties of water refer to the concentration of different constituents found water in water. These constituents can be found in water either as dissolved or suspended. For each constituent found in water, depending on its concentration and its effect on humans, it can be categorised as no health effects, aesthetic effects, chronic effects, acute effects, or significant risk (DWS, 1996). For example, Table 1 shows the effect of magnesium at different concentrations found in water.

TABLE 2. 1: EFFECTS OF MAGNESIUM AT DIFFERENT CONCENTRATIONS FOUND IN WATER (SOURCE: DWS 1996).

Magnesium Range (mg/• as Mg)	Effects
Target Water Quality Range 0 - 30	*No bitter taste. No scaling problems. No health effects*
30 - 50	No bitter taste. Slight scaling problems may occur. No health effects
50 - 70	No bitter taste; No health effects; Scaling problems
70 - 100	Slight bitter taste. Taste threshold for magnesium is • 70 mg/•. Scaling problems. Diarrhoea in sensitive users
100 - 200	Water aesthetically unacceptable because of bitter taste. Increased scaling problems. Diarrhoea in most new users if sulphate present
200 - 400	Severe scaling problems. Diarrhoea in all new users
> 400	Severe scaling problems. Diarrhoea in all new users. Health problems may occur

SANS241:2015 water quality standards, as shown in Figure 2.4 , provides a list of all constituents found in water and their upper and lower acceptable limits. For some constituents, at or near the upper limit, the water already has an aesthetic appearance and this results in rejection of the water by consumers. Ideally, water should be treated to the target water quality range to be fit for domestic water use, especially for consumptive domestic water uses.

vinlab
your partner in quality wine making

DRINKING WATER FOR SANS 241:2015

The limits and associated risks for domestic water as determined by the South African National Standard (SANS) 241:2015 are as follows, where:

- Health risks: parameters falling outside these limits may cause acute or chronic health problems in individuals.
- Aesthetic risks: parameters falling outside these limits indicate that water is visually, aromatically or palatably unacceptable.
- Operational risks: parameters falling outside these limits may indicate that operational procedures to ensure water quality standards are met may have failed.

MICROBIOLOGICAL DETERMINANDS		
	Risk	Limits
E.coli or Fecal coliforms count/100ml	health	Not detected
Cytosporidium species count/10mL	health	Not detected
Giardia species count/10mL	health	Not detected
Total coliforms count/100ml.	operational	< 10
Heterotrophic plate count count/1ml	operational	< 1000
PHYSICAL, AESTHETIC, OPERATIONAL AND CHEMICAL DETERMINANDS		
Free chlorine mg/L	health	≤ 5
Monochloramine mg/L	health	≤ 3
Colour Pt-Co	aesthetic	< 15
Conductivity at 25degC mS/m	aesthetic	≤ 170
Total dissolved solids mg/L	aesthetic	≤ 1200
Turbidity	operational	≤ 1
	aesthetic	≤ 5
pH at 25degC	operational	≥ 5 and ≤ 9.7
Nitrate as N mg/L	health	≤ 11
Nitrite as N mg/L	health	≤ 0.9
Nitrate-Nitrite ratio		≤ 1
Sulfate as SO_4^- mg/L	health	≤ 500
	aesthetic	≤ 250
Fluoride as F^- mg/L	health	≤ 1.5
Ammonia as N mg/L	aesthetic	≤ 1.5

FIGURE 2. 4: SANS241:2015 WATER QUALITY STANDARDS.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. STUDY AREA

Steve Tshwete Local Municipality one of the six local municipalities, as shown in Figure 3.1, of Nkangala District municipality. It is located at the centre of Nkangala District Municipality borderded to the west by the Emalahleni and Thembisile Hani Local Municipalities; to the south, there is the Govan Mbeki and Msukaligwa local municipalities; the Emakhazeni and the Chief Albert Luthuli Local Municipalities; to the north is the Elias Motswaledi Local which is part of the Sekhukhune District Municipality in Limpopo (STLM IDP, 2020/2021).

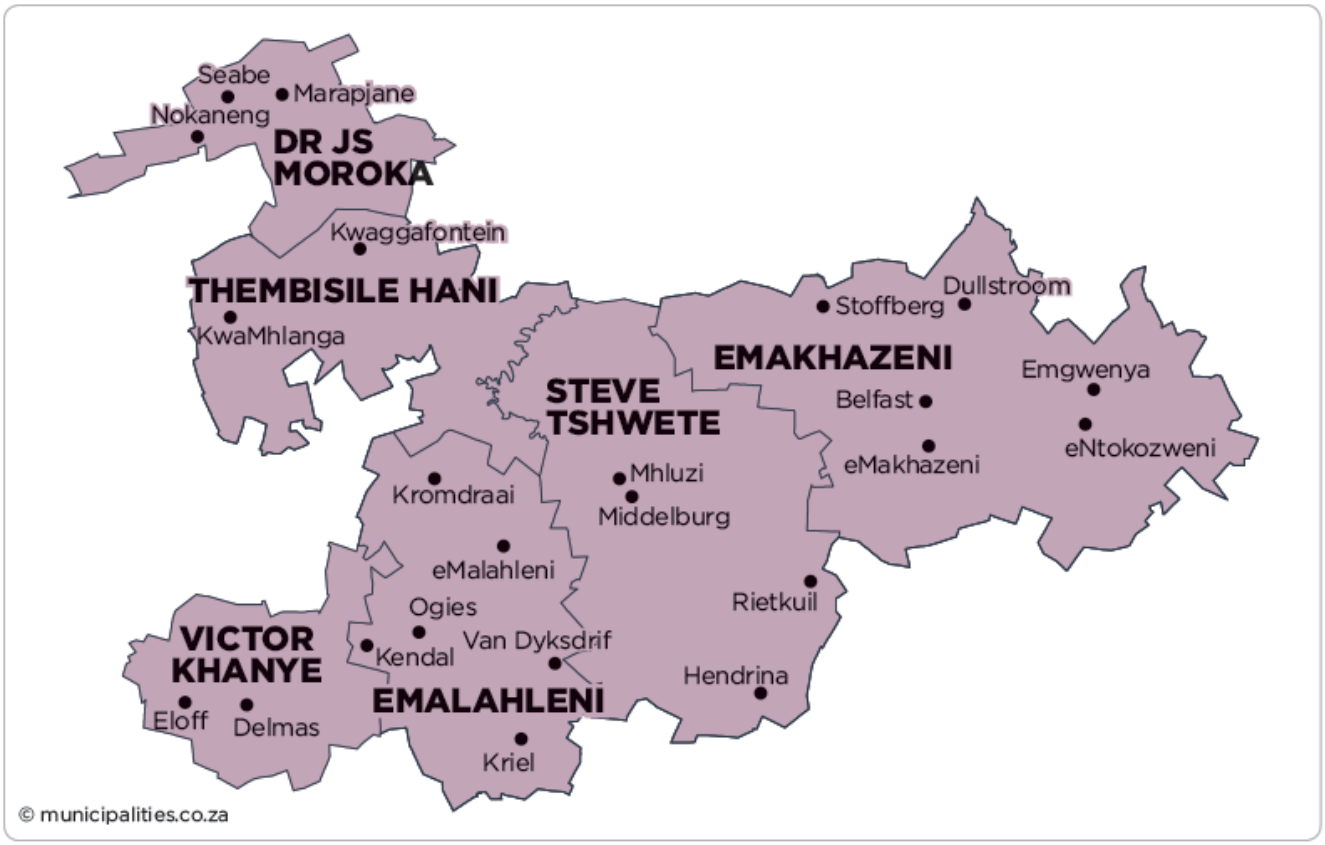


FIGURE 3. 1: NKANGALA DISTRICT MUNICIPALITY AND LOCAL MUNICIPALITIES WITHIN THE MPUMALANGA PROVINCE (SOURCE: IDP, 2015).

The municipality consist of four residential areas, namely Middelburg, Hendrina, Arnot, Komati.

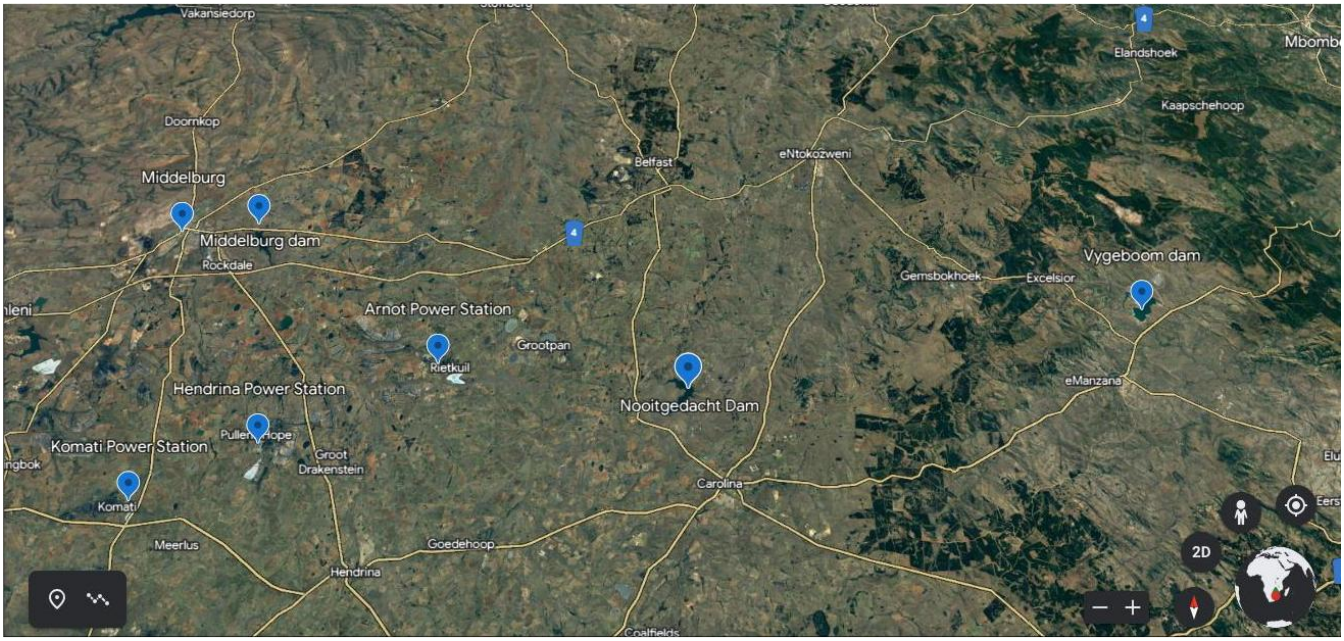


FIGURE 3. 2: MAP OF WATER SOURCES FOR STEVE TSHWETE LOCAL MUNICIPALITY WATER TREATMENT PLANTS.

Middelburg is the biggest residential in the municipality and is further devided into small residential area including Mhluzi, Earorand, Mineralia, Kanonkop and Doornkop in the northern part of the municipality. The town of Middelburg host a number of important economic activities such as power generation (Eskom Power Station), stainless steel manufacturing (Columbus Stainless), and coal mining. It also hosts the Nkangala District Municipality headquarters and various government departments. All the other residential areas of the municipality, that is, Hendrina, Arnot, and Komati are Eskom villages mainly providing accommodation for Eskom employees.

Middelburg, consists of different types of settlements, that is, the informal settlement of Avalon, the township of Mhluzi, the semi-suburb of Mineralia, and the suburb of Aerorand. In the informal settlement, the community depends on communal taps and toilets for water and sanitation service. Overflowing sewers and broken communal toilets present a health hazard to this community. Water and sanitation services in Mhluzi are well maintained by the municipality. In Mineralia and Aerorand, water and sanitation services are well maintained, and some of the houses even have boreholes in their yards. The major problem in all of Middelburg is the aging infrastructure which is prone to damages resulting in disruption in water supply.

Eskom Power Stations are responsible for providing water service for their respective villages. They are responsible for the operation and maintenance of the water treatments to ensure that

sufficient water of good quality is supplied to their respective area of supply. They are also responsible for ensuring that the distribution system of water is maintained and complaints are attended to. The municipality's responsibility in these areas is to ensure the metering and billing of water use. It also monitors the performance of the water utilities through the green drop, blue drop, and no-drop criteria. Regular meetings were held between the municipality and the water utilities before the discontinuation of the awards system.

Figure 3.2, shows water resources for water utilities in the Steve Tshwete Local Municipality. The Middelburg water treatment plant abstracts water for treatment for potable use from the Middelburg Dam. The Middelburg area is known for its extensive coal mining activities, which have the potential to contaminate water resources. The area also has some heavy industrial activities, such as steel manufacturing and power generation, which also have the potential to negatively impact water resources. Eskom power station, abstracts water from the Nooitgedacht and Vygeboom Dams, which are located east of the town of Middelburg. The area where these dams are located is characterised by timber plantations, paper mills, and timber processing plants. These activities have the potential to contaminate water resource with aroganic matter. Water supplied to the power station is a blend of the two dams.

3.2. RESEARCH APPROACH

The research utilizes benchmarking to assess the differences in water utility performance in the Steve Tshwete Local Municipality. Benchmarking is used in different industries and sectors globally to guide and support effective performance management by highlighting organizational and operational management parameters needing attention to ensure continuous improvement (SALGA, 2015). Indicators widely used globally for the assessment of the provision of water and wastewater services are contained in the International Benchmarking Network for Water and Sanitation Utilities (IBNET) of the World Bank and provides a "set of financial, technical and process indicators for the assessment of water utilities" (Bellubi and Visscher, 2014: p954). In the South African context, the Municipal Benchmarking Initiative set out indicators for supporting water services performance measurement and improvement (SALGA, 2015).

The study adopts a positivism paradigm to determine the factors that influence the performance of water utilities and the provision of water services in the Steve Tshwete Local Municipality. According to du Plooy-Cilliers (2014), positivist believes that when people educate themselves,

they can better understand and be able to improve their own world. Positivist researchers “insist that only objective, observable, and verifiable facts should be considered when attempting to understand and explain natural and social phenomena” (du Plooy-Cilliers, 2014: 25). Performance indicators were used to explore the effect of water utility performance on the provision of water services.

Primary and secondary data on the selected performance indicators was collected. Primary data was collected through interviews with utility managers. The categories of performance indicators for the interview schedule of utility managers were focused on operation and maintenance, human resources, and water service delivery. Another interview schedule for the beneficiaries of water services in the municipality was used to collect data on the perception of water service delivery. Secondary data was collected using desktop research from journal articles, municipality documents, and other sources with information on water service delivery in the Steve Tshwete Local Municipality.

3.3. RESEARCH TOOLS AND THEIR APPLICATION

The study utilised both quantitative and qualitative research data collection methods. Quantitative data on performance indicators of water utilities was collected through structured interviews. Structured interviews consist of a set of standards, closed-ended questions which respondents must answer (du Plooy-Cilliers and Cronje, 2014). These interviews were mainly focused on data related to utility management and performance. On the other hand, qualitative data included open-ended questions to capture the perceptions of the beneficiaries of water services. Semi-structured interviews, which consist of open-ended questions, allow the researcher to gather information deemed necessary for the study while also recording the views and opinions of the respondents (du Plooy-Cilliers and Cronje, 2014). These questionnaires were administered by the researcher and also by enumerators with thorough instructions to ensure that relevant follow-up questions were asked.

The Municipal Benchmarking Initiative (MBI) (2015) has a list of performance indicators grouped into six categories for every municipal category. Due to the high number of indicators related to water services, this study will focus on three categories of indicators. Within a category, indicators that will provide the data to achieve the study's objectives are selected. Categories to be included in the study are water service delivery, Human resources, Operation and

maintenance, and Finances. Table 1 shows indicators within the Categories and the source of data for the indicator.

As shown in Appendix 1, each indicator had questions in the questionnaire, either open- or closed-ended, relevant to the indicator. In the event where enumerators administer questionnaires, instructions on follow-up questions were included in the questionnaire to ensure a standard questioning format.

TABLE 3. 1: INDICATORS AND DATA SOURCES OF WATER UTILITY PERFORMANCE.

Category of indicators	Performance indicators	Source of data
Water service delivery (WSD)	Coverage (% of households with piped water services)	utility records
	Continuity (water availability per 24hrs)	Utility records/ Interviews
	Quality (taste and smell)	Interviews
	Customer complaints (medium to raise complaints, frequency, turnaround time	Utility records
Staffing and personnel	Number of water services staff	Utility records
Operation and Maintenance	Inspection and maintenance of Asset	Utility records
	Water losses	Utility records
	Water metering efficiency	Utility records
Product Quality	Water quality monitoring	Utility records
	Water quality compliance	Utility records

3.4. SAMPLING

Steve Tshwete local municipality consists of small- to medium-size water utilities. For this study, utilities recognized as the primary water service supplier for a given area were sampled. For example, the town of Middelburg consists of two water treatment plants: the Krugerdam water treatment plant and the Vaalbank water treatment. The Vaalbank water treatment has a bigger capacity and is the primary supplier of water in Middelburg. Therefore, it was sampled for the study. The Arnot Power Station and Hendrina Power Station, as the sole suppliers of water to their respective towns, were also included in the sample.

Sampling for the beneficiaries of water services in the study area adopted a convenience sampling method. Convenience sampling is preferred due to time limitations, and the interviews' results represented the respondents' opinions and could not b generalized as the opinion of the entire community. In each town, ten people or households were interviewed.

3.5. PROCESS OF ANALYSIS

Responses to the questionnaires from interviews with both water utility personnel and beneficiaries of water service was populated and stored on an excel database to be developed. Some indicators, especially those for water utility performance, was analysed as a single score and compared with the performance of other utilities. The analysis indicators included examining the indicator in the context of the water utility. For example, quantity as an indicator was reported as the amount of water per capita or household rather than the amount of water supplied by the water utility.

Data collected was presented and analysed in the form of graphs which showed the variations between different water utilities for a specific indicator.

3.6. LIMITATIONS, FEASIBILITY, AND POSITIONALITY

The major limitation of the study is the time allocation for the completion of the research. A full assessment of the performance of water utilities requires a more extended period since there is a high number of performance indicators to be considered. As a result, fewer indicators, which present the effect of water utility operations on water service delivery have been selected.

The study can be carried out within the resources and time allocated. The water utilities selected for the research are within 40km of each other. Except for the town of Middelburg, Arnot and Hendrina towns covers a small area, with just over 900 houses. Middelburg town is bigger with just over 42 000 houses. Interviews in the town of Middelburg will be done in public places such as churches and malls.

As a resident of the municipality with a passion for water treatment, water utility management, and water service delivery, much consideration will be taken to ensure that data guide the results and findings of the research. As a Professional Natural Scientist in Water Resource Science, the researcher has extensive water treatment, water utility, and quality management experience. The research methodology applied is informed by expertise and passion for the water sector.

3.7. ETHICS

Respondents to the research were assured confidentiality. An ethics schedule was submitted to the Wits University Ethics Committee and was reviewed and approved. The rights of all participants of the study were protected.

3.8. VALIDITY, RELIABILITY, AND DEPENDABILITY

The methods used in this study were informed by literature on water utility performance assessment and management, e.g., the Municipal Benchmarking Initiative. Internal validity was assured as the methods have been tested. The study's findings were used to understand (Phenomenology) the perception of the people of Steve Tshwete local municipality on water service delivery.

“Reliability refers to the fact that different research participants being tested by the same instrument at different times should respond identically to the instrument” (Mouton, 1996, in Koonin, 2014: 253). The benchmarking approach adopted for the study was developed by the Municipal Benchmarking Initiative (2015) and was deemed successful in evaluating the performance of water utilities at the municipal level.

CHAPTER 4
RESULTS

4.1. INTRODUCTION

This chapter presents the results emanating from a survey of water utility management and interviews with the water service beneficiaries in the Steve Tshwete Local Municipality. The water utility management questionnaire was self-administered by the researcher while the water services beneficiary interviews were administered by the enumerators.

4.2. WATER UTILITY PERFORMANCE INDICATORS

4.2.1. WATER SERVICE DELIVERY

Figure 4.1 indicates the percentage coverage of piped water service for the areas supplied by each of the water utilities within the Steve Tshwete Local Municipality. According to the municipality's IDP 2020/21, Middelburg consist of 42 201 dwellings, Komati has 471 dwellings, Arnot 919, while Hendrina (Pullenshope) has 905 dwellings. At Komati, Arnot, and Pullenshope, 100% of the houses have piped water service on their premises, while Middelburg's piped water service coverage stands at about 95.6% (IDP, 2020/21). The backlog, which is about 4.31%, is mainly in rural areas where boreholes and water transported in tankers are used as a source.

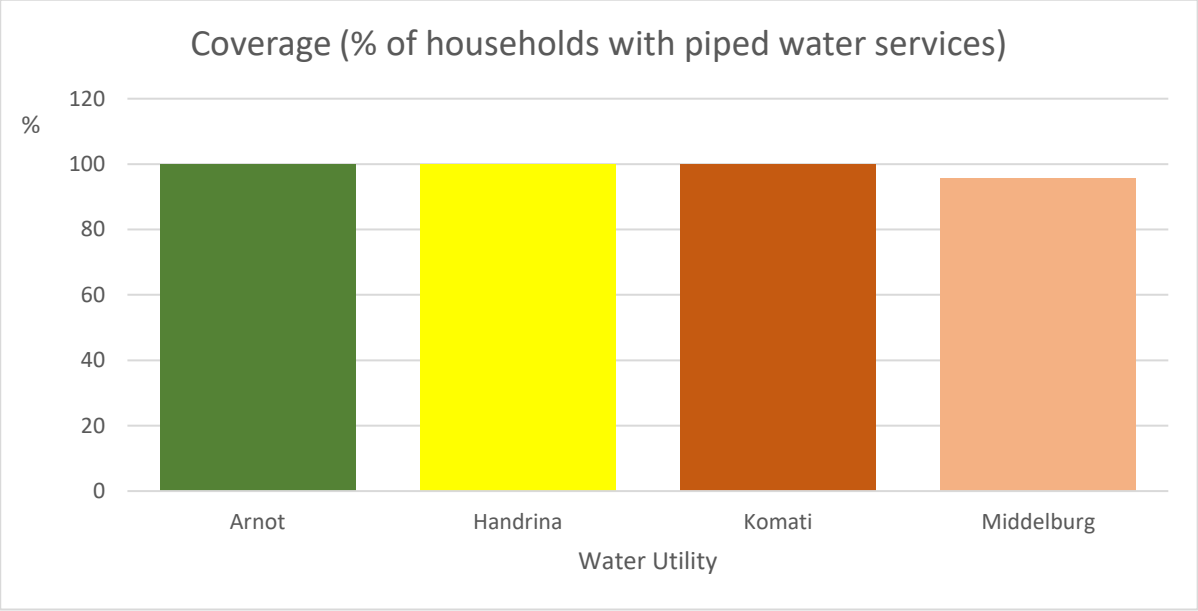


FIGURE 4. 1: PERCENTAGE COVERAGE OF HOUSEHOLDS WITH PIPED WATER SERVICES.

Many factors can cause water interruptions. These include plant outages, abnormalities in the distribution system, unavailability of water, pump failures, and quality issues. Therefore, it is imperative that when there are interruptions in the water supply, the cause of the interruption

is promptly identified and repaired. The Municipal Benchmarking Initiative (MBI) (2015) suggests the acceptable service interruption for water service to be less than 48 hours per event cumulative for 15 days per year. Figure 4.2 shows the percentage of household's experience of water interruption according to the water utility management staff. Middelburg, Hendrina, and Arnot reported that about 50 percent of households had experienced unacceptable service interruption. In Middelburg, the long water interruptions were attributed to the slope of the area. Reservoirs located in higher portions of the area took longer to fill up when there are outages. At Arnot and Hendrina, the water utility management attributed the longer outages to the size of the reservoir. They reported that whenever there is an outage, households far from the reservoir receive water last as those close to the reservoir use water. Komati, on the other hand, said that more than 90 percent of the households had experienced an acceptable service interruption, while only ten percent had experienced unacceptable water interruptions.

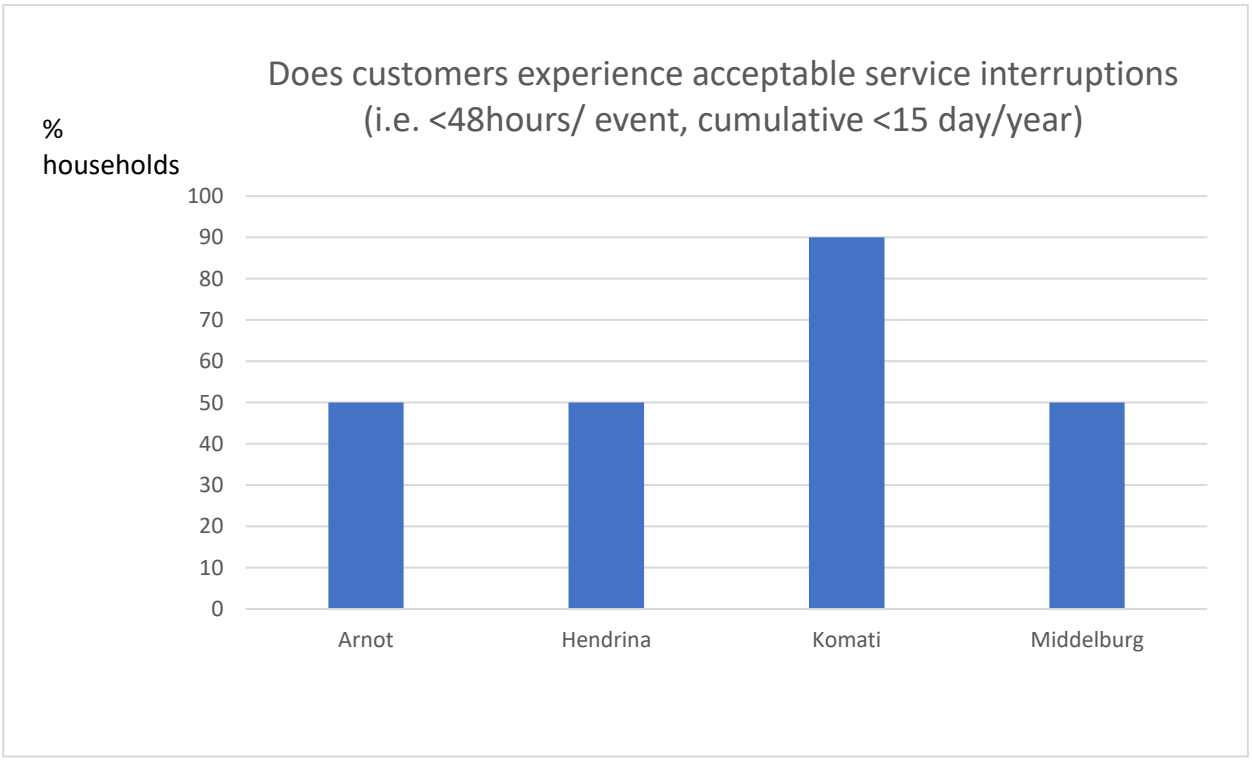


FIGURE 4. 2: WATER SERVICE INTERRUPTIONS EXPERIENCED BY HOUSEHOLDS ACCORDING TO WATER UTILITY MANAGEMENT.

Low pressure, if not intentionally induced, can be indicative of failures in the distribution system. MBI (2015) defines low pressure in terms of flow as no flow or flow less than 10 L/min. As shown in figure 4.3, at Komati and Hendrina, it is reported that less than ten percent of households had

experience low pressure. However, in Middelburg, less than 25 percent of households experienced low pressure, especially those in elevated areas of the town. On the other hand, the Arnot water plant reported that more than 50 percent of the households had experienced low pressure, which is attributed to the size of the reservoir. Low pressure is usually experienced after outages when the reservoir fills up.

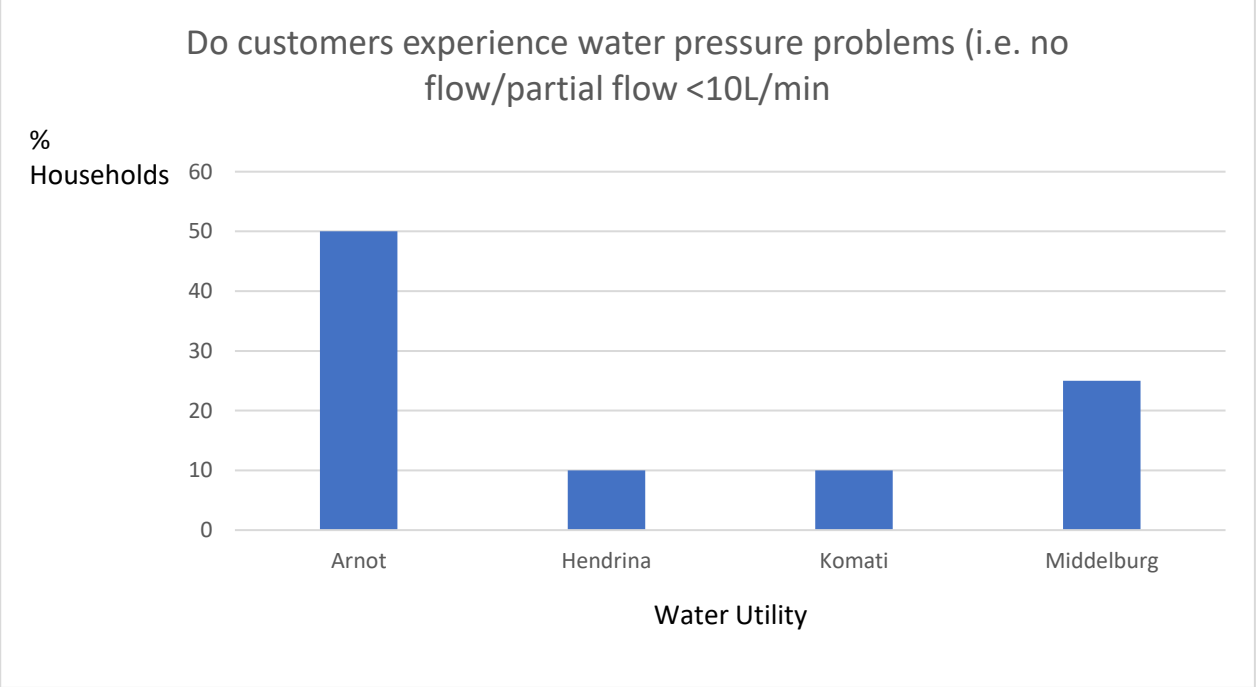


FIGURE 4. 3: WATER PRESSURE PROBLEMS EXPERIENCED BY HOUSEHOLDS.

Prompt response to complaints raised by customers is imperative to ensure trust in the water service provider. The MBI (2015) recommends that complaints should be attended to within 24 hours of the call. Except for Komati water utility which reported that they don't know how many complaints are attended within 24 hours, all the other three water utilities respond to more than 75% of the call-outs within 24 hours. Middelburg, which covers a larger area than other water utilities, has a 24 hours operated call centre where all complaints can be logged. In addition, there is always a team on standby to attend to complaints and call-outs. In the Eskom villages, complaints are logged through the local controller desk of the power station and attended to when the maintenance team is available.

4.2.2. OPERATION AND MAINTENANCE

Operation and maintenance were measured in terms of infrastructure asset management. Operation and maintenance include the daily running of the water services infrastructure to

reliably supply water in quantities and qualities demanded by customers. Proactive and predictive maintenance is critical to ensuring continuity of supply of water. Water supply infrastructure in old towns such as Middelburg and the Eskom villages in the Steve Tshwete requires an infrastructure asset management plan to be updated so that it is always current and relevant. Arnot, Hendrina, and Komati water treatment plants reported that they have infrastructure asset management plans which are updated and current. However, although Middelburg water treatment has an infrastructure asset management plan, it was last updated in 2016 and is therefore not relevant to the current status of water services.

At the municipal level, non-revenue water has been identified as a concern for the loss of revenue and is due to aging infrastructure. Therefore, the municipality embarked on a project to improve water metering as means to reduce water losses. The project identified faulty meters with an impact on water billing. In Middelburg, 5425 meters were found to be faulty; in Komati, 34 meters were faulty; in Arnot, 45 were faulty; and in Hendrina (Pullenshope), 80 meters were faulty (IDP, 2020/2021). Infrastructure asset management of water utilities is essential to minimize equipment breakdowns and optimize cost recovery. All water utilities reported that spending on infrastructure maintenance is 10% or more of the total operating cost.

4.2.3. PERSONNEL AND STAFFING

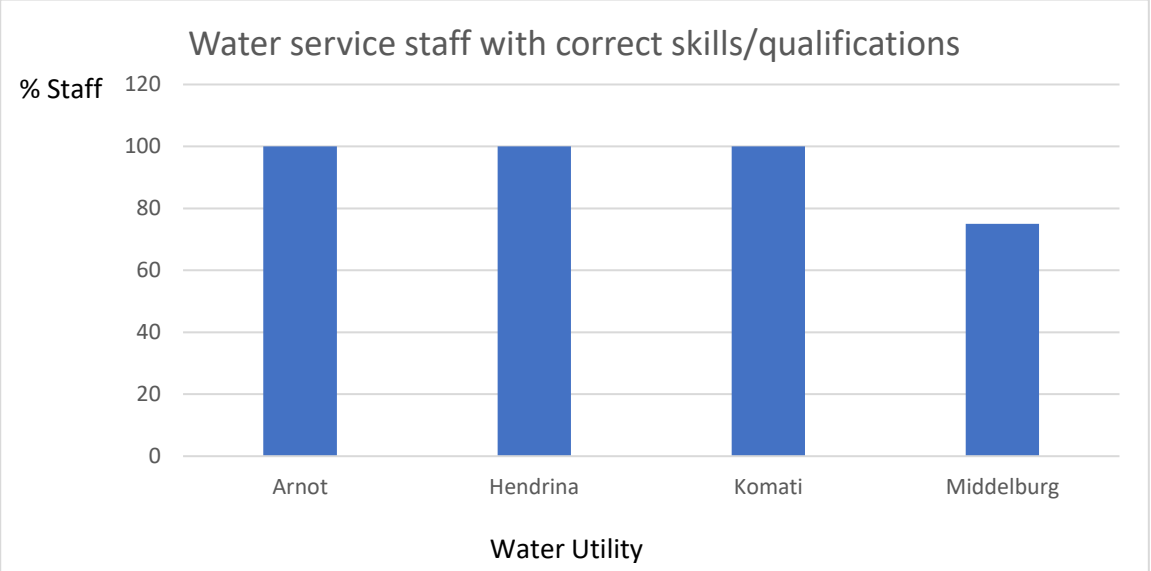


FIGURE 4. 4: WATER SERVICE STAFF WITH THE CORRECT SKILL/QUALIFICATION.

The quality of performance of a water utility can be enhanced by the recruitment of staff with the correct skills and qualifications. There is a plethora of evidence in research that supports the

notion that human resources are the most vital resource for any organization and it is the source of attaining competitive advantage. Water utilities are no different. Recruitment of skilled and correctly qualified personnel is important for ensuring good quality water is produced and supplied to the people. Staff member with the correct qualification and skills are required to ensure that the reticulation and distribution system is well maintained and always available.

In the Steve Tshwete local municipality, as shown in Figure 4.5, Eskom water treatment plants reported that 100 percent of the staff responsible for water service have the correct skills and qualifications. In Middelburg, 75 percent of the staff have the correct skills and qualifications. The minimum qualification required for operating staff at Eskom is Grade 12 of N3 with a minimum one-year operating experience. To be appointed at the technician level at Eskom, a minimum qualification required is a National Diploma with a minimum of two years of working experience. In Middelburg, N3 qualification coupled with Class 3 DWS classification is a minimum requirement for operating, while a National Diploma is required for appointment as a technician.

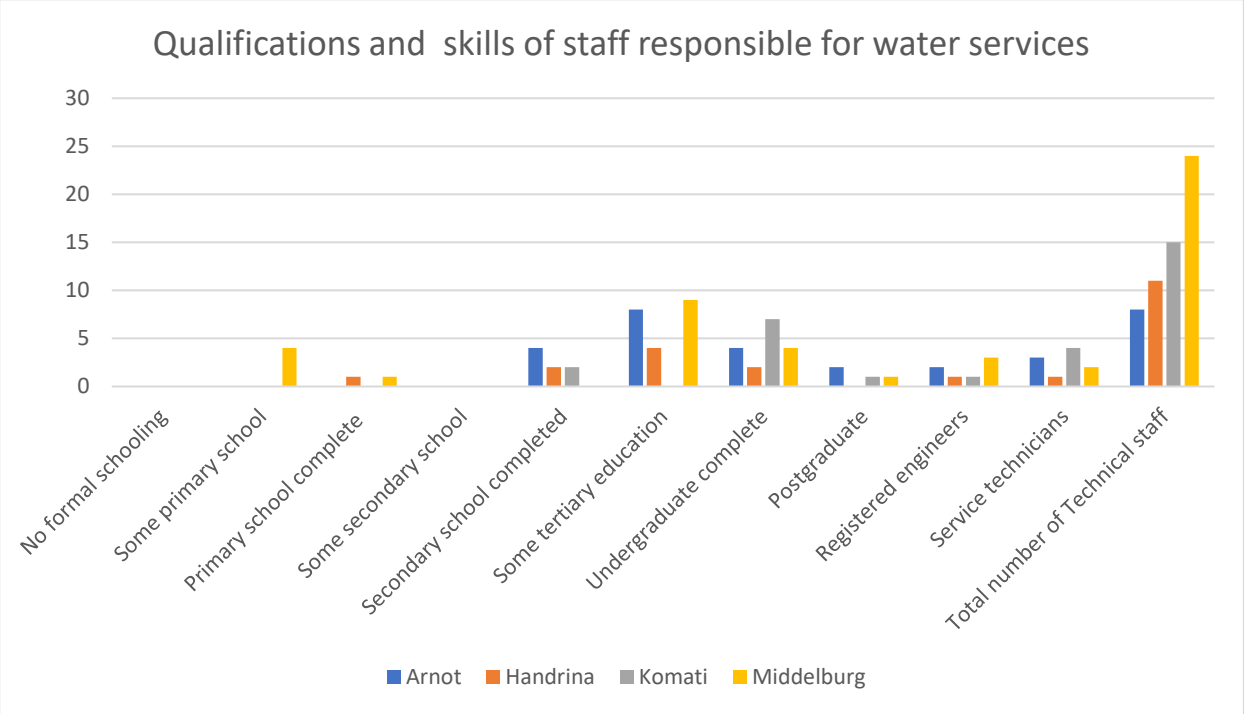


FIGURE 4. 5: QUALIFICATIONS AND SKILLS OF STAFF RESPONSIBLE FOR WATER SERVICES.

4.2.4. PRODUCT QUALITY

The quality of water produced by water utilities depends on the quality of the raw water supplied by the source and the effectiveness of the unit process to remove the impurities found in raw water. Raw water quality is affected by the activities taking place within the catchment area in

which the raw water source is found. Mpumalanga and the Steve Tshwete Local Municipality in which these water utilities are found is characterised by coal mining and other industries such as paper mills and agriculture. These activities add different contaminants to the surface and groundwater source both directly, through point sources of contamination and indirectly through non-point sources of pollution. Water quality is therefore measured by quantifying these contaminants or parameters in water.

Eskom water treatment plants receive water from the Nooitgedcht and Vygeboom dams which are managed under the Komati Water Distribution Scheme (KWDS). The dams are located east of the town of Middelburg. The area is characterised by timber plantations and timber processing plants. The Middelburg water treatment plant, on the other hand, abstracts water from the Middelburg Dam. The main land use activity in the area is coal mining which has the potential to contaminate water resources. As shown in Appendix 2.1, the Middelburg Dam has high total dissolved (TDS) (1064 mg/L) and high total dissolved carbon (TOC) (8.08 mg/L) as compared to water supplied by the KWDS. Water from the Nooitgedacht and Vygeboom Dams, as shown in Appendix 2.2, has a TDS of 76 mg/L and TOC of 2.76 mg/L. Water is supplied as a blend to Eskom water treatment plants from these two dams. The percentage abstracted from each of the dams depends on the quality of water in each of the dams. This is done to ensure that better quality raw water is supplied to the power stations.

Parameters measured in water to determine the quality of water and its fitness for use are grouped into three categories, namely, physical, chemical, and microbiological properties. Physical parameters include properties such as temperature, pH, electrical conductivity, and turbidity. Chemical parameters which usually dissolved in water included parameters such as iron, manganese, calcium and magnesium hardness, sodium, etc. There is a wide range of microbiological contaminants that can be measured to determine the microbiological quality of water. Normally, to determine the microbiological quality, parameters associated with faecal contamination are measured. These parameters include faecal coliforms, total coliforms, *E.coli*, cryptosporidium, and heterotrophic plate count which indicates the general bacterial contamination of a water sample.

In most cases, because of the long list of contaminants found in water, a selection is made of parameters that will provide a general view of quality water. This selection normally depends on activities taking place in the area, contaminants that are known to dominate or to be problematic

in water in the area, or contaminants that are of concern due to their impact on human health, industrial processes, or aquatic health. For the purpose of this study, five parameters have been chosen to determine the quality of drinking water in the Steve Tshwete Local Municipality. These parameters are turbidity, pH, Total Dissolved Solids, iron, and manganese.

The South African Water Guidelines: Volume 1 of 1996 and SANS241 Standards of 2015 provide the criteria and specifications for different parameters found in drinking water. To meet this criteria and specification, chemicals and water treatment unit processes are used to remove these contaminants. Chemical dosing needs to be optimised to ensure that these contaminants are removed from water.

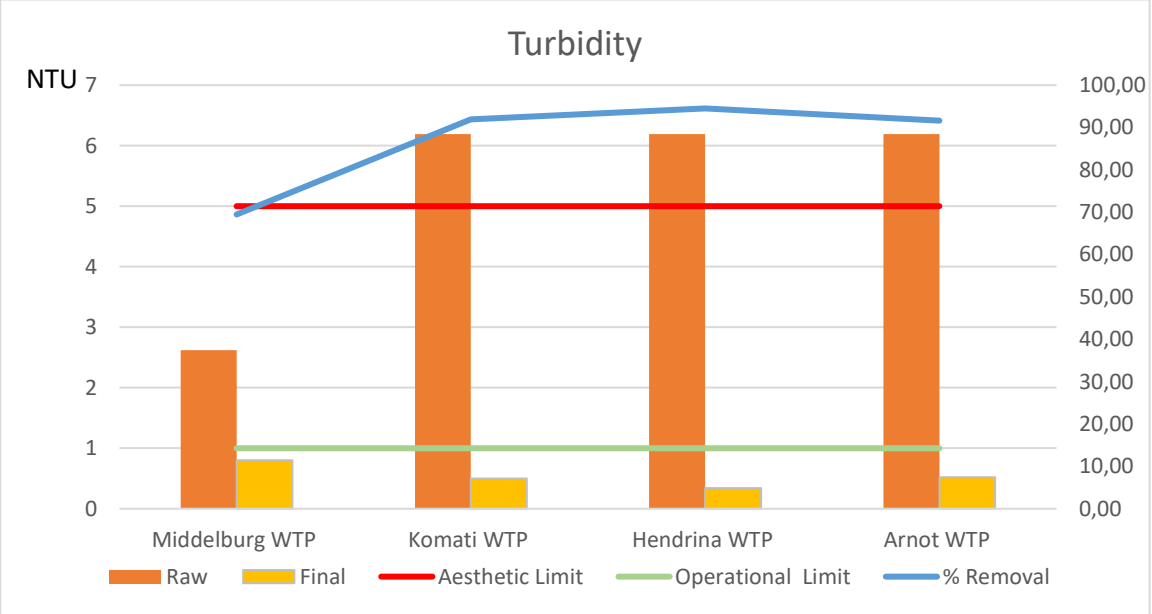


FIGURE 4. 6: TURBIDITY IN RAW AND FINAL WATER SAMPLES FROM WATER TREATMENT PLANT IN STEVE TSHWETE LOCAL MUNICIPALITY.

Figure 4.6, shows the turbidity in raw and final water samples from the different water treatment plants in the Steve Tshwete. Turbidity-forming particles found in water are usually particulate matter suspended in water and include organic matter such as clay and soil particles and inorganic matter particles. Turbidity is also related to the clarity and transparency of the water. Turbidity in water is removed by the process of coagulation and flocculation. Turbidity-forming particles are suspended in water because they carry a negative charge and, therefore cannot agglomerate naturally and form a bigger, readily settleable particle. Coagulation, the addition of a positively charged, usually aluminium or iron, molecule, neutralises the negative charge and

creates a destabilised particle. Flocculation, the addition of a high molecular weight polymer, agglomerates the destabilised particles and forms a bigger particle that is readily settleable.

According to the South African Water Quality Guidelines: Volume 1, the operational specification for turbidity is 1 NTU and the aesthetic specification is 5 NTU. Figure 4.6 shows that all the water treatment plants in the Steve Tshwete municipality operate below the operational limit of 1 NTU. The water treatment plant in Middelburg (Vaalbank Water Treatment Plant) achieve a final NTU of 0.8 which is very close to the 1 NTU operational limit. This leaves little room for reaching the operational limit when deviations are experienced.

Figure 4.7 also indicates that the water from source that supply the Middelburg water treatment plant is difficult to treat. Particulate matter is easily removed by coagulation and flocculation, followed by filtration. The percentage removal for turbidity in the Middelburg water treatment plant is also low compared to other water treatment plants. The Middelburg water treatment plant achieve a turbidity removal of 69.5% compared to 91 to almost 95 % achieved by other water treatment plants in the municipality. This is a clear indication that water from the source that feeds Middelburg water treatment has more dissolved solids than water that feed the Eskom water treatment plant. The removal of turbidity can be improved by optimisation of chemical dosing and the proper operation of the sand filtration process. Furthermore, other treatment options such as lime softening, reverse osmosis, and change of raw water source can be explored.

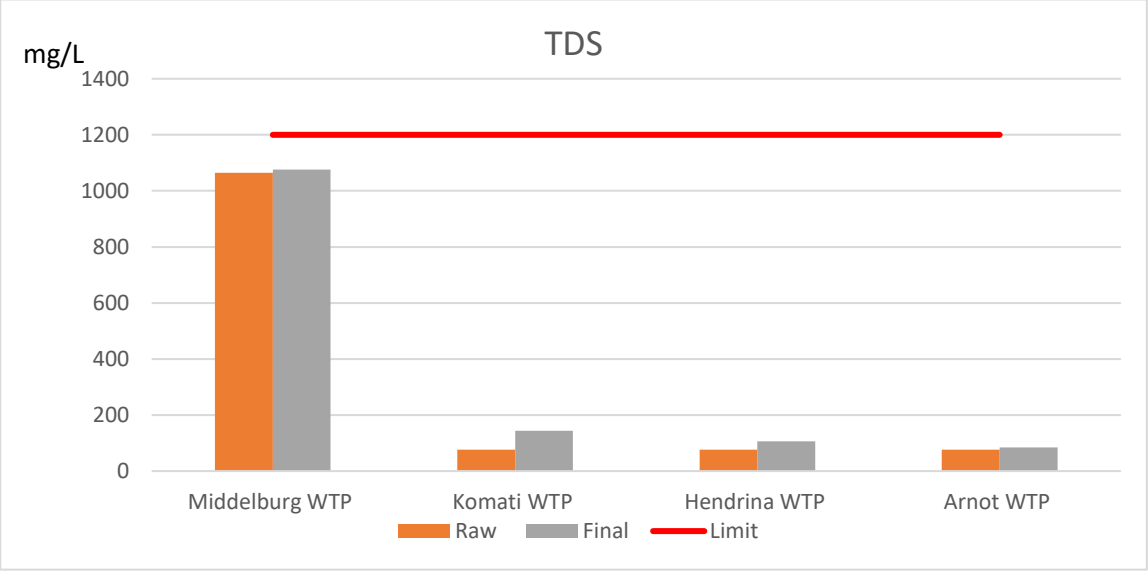


FIGURE 4. 7: TOTAL DISSOLVED SOLIDS (TDS) OF RAW AND FINAL WATER IN THE STEVE TSHWETE LOCAL MUNICIPALITY WATER TREATMENT PLANTS.

Total Dissolved Solid (TDS) quantifies that the amount of organic and inorganic salts found in water. These salts are dissolved in water and are directly proportional to the electrical conductivity of the water. Electrical conductivity (EC) is the measure of the ability to conduct electrical current. EC is affected by ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium, and magnesium, all of which carry an electrical charge.

The removal of most of these ions depends on the pH of the water. At certain pH values, these ions react with other constituents to form precipitates that settle. For example, at a pH above 9.8, calcium and magnesium react with bicarbonate to form calcium carbonate ($CaCO_3$) and magnesium hydroxide precipitate.

Figure 4.7 clearly shows that the Middelburg dam has high TDS as compared to the Vygeboom and Nooitgedacht dams. TDS affects the taste of water due to the dissolved salts present in water. Treatment processes at all water treatment plants in the municipality have no effect on the TDS of the water. At all water treatment plants, there is no significant change in the concentration of TDS in raw and final water.

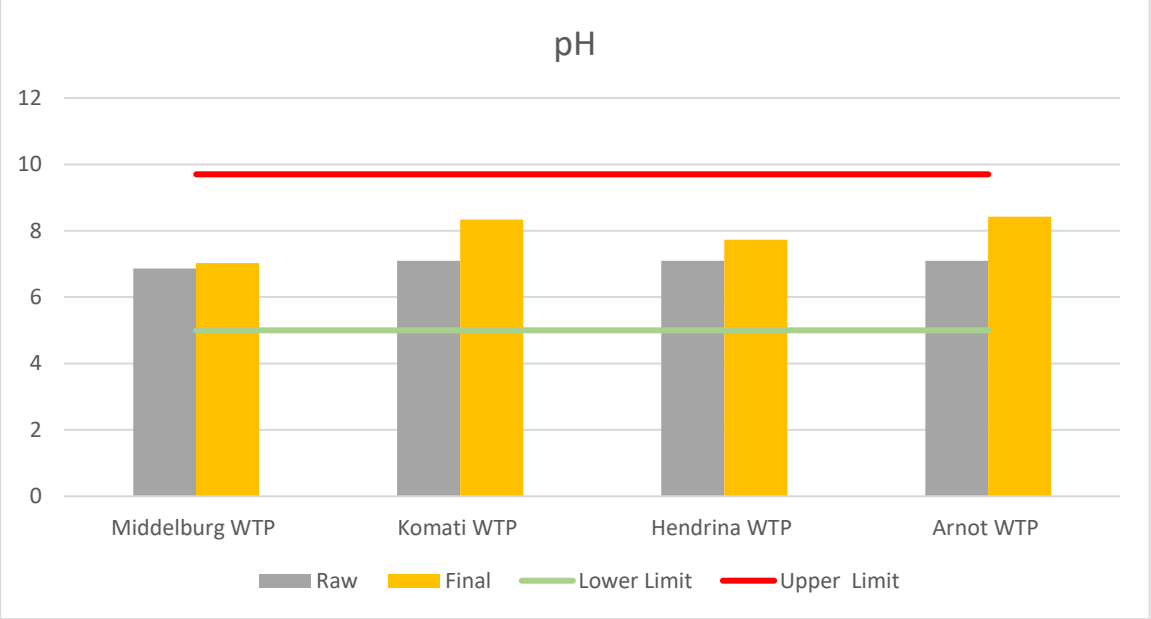


FIGURE 4. 8: PH OF RAW AND FINAL WATER IN THE STEVE TSHWETE LOCAL MUNICIPALITY WATER TREATMENT PLANTS.

pH is the measure of the acidity or alkalinity of a solution. The pH of natural waters is affected by the various dissolved compounds, mainly the carbon – dioxide – bicarbonate - carbonate equilibrium system, which is also affected by the temperature. Other factors that have an

influence on the pH of natural waters include discharged effluents, acid mine drainage, acid precipitation, runoff, microbial activity, and decay processes. It has no direct impact on the health of humans except at extremes. The major issue associated with pH in water is the solubilisation of toxic heavy metals and the protonation and deprotonation of ions at certain pH values.

Middelburg dam, as shown in Figure 4.9, has a slightly lower pH than the Vygeboom and Nooitgedacht dams. This can be attributed to the coal mining activities in Middelburg and surrounding areas. The pH of water can be adjusted by adding an acidic or alkaline-based compound. Soda ash is added to the final water in the water treatment plants in the Steve Tshwete Local Municipality to adjust the pH. Komati and Arnot Water Treatment Plants, as shown in Figure 4.9, increase the pH of the final water to above 8.

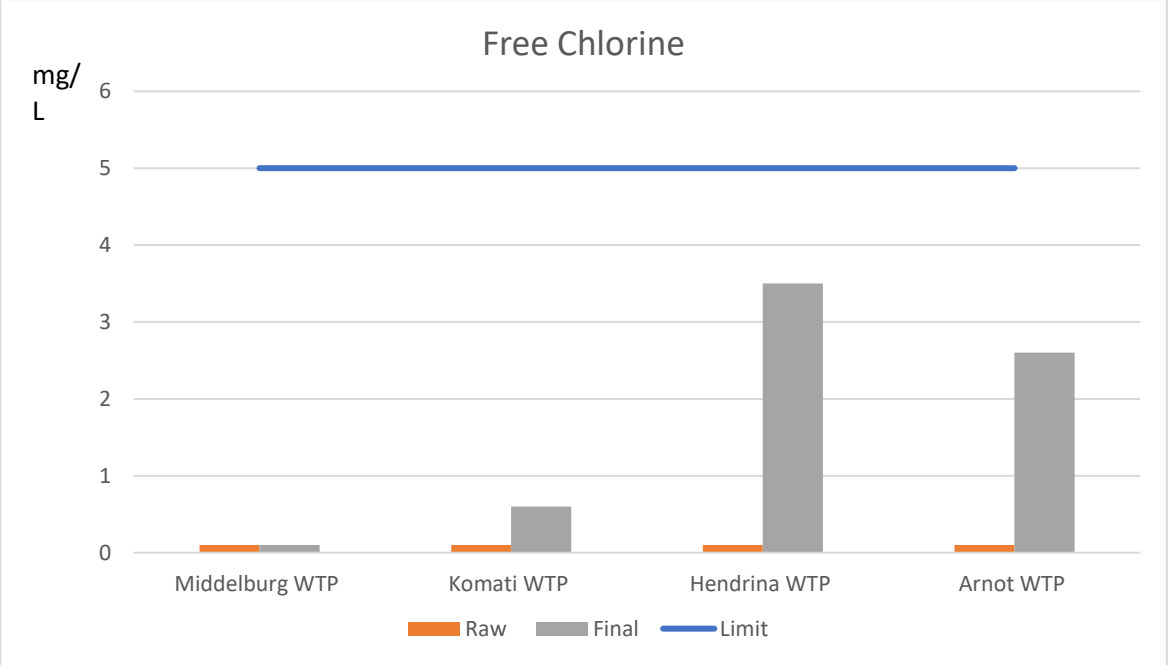


FIGURE 4. 9: FREE CHLORINE OF WATER TREATMENT PLANTS IN THE STEVE TSHWETE LOCAL MUNICIPALITY.

Chlorine is used as a disinfectant in all water treatment plants within the municipality. It is dosed in water in gaseous form and it is volatile. It is therefore important to maintain a residual of chlorine throughout the distribution system of drinking water. As an oxidizing biocide, chlorine kills all form bacteria found in water by changing the molecules that make up their cells, thereby killing them.

Chlorine reacts with organic matter in the water to form trihalomethanes (THMs). THMs are regarded are carcinogenic compounds and in this group of contaminants chloroform ($CHCl_3$),

bromodichloromethane (CH_2ClBr), dibromochloromethane (CH_2ClBr), and bromoform ($CHBr_3$) are considered a major health risk to humans (DWS, 1996). THMs are released to the atmosphere when water is aerated or boiled.

Free chlorine in the Middelburg Water Treatment Plant, as shown in Figure 4.9, was found to be less than 0.1 mg/L which indicates that the water was not disinfected. This poses a risk to the health of the consumer as pathogens can proliferate under this condition. On the other hand, overdosing of chlorine as well creates a foul smell that may not resonate well with consumers.

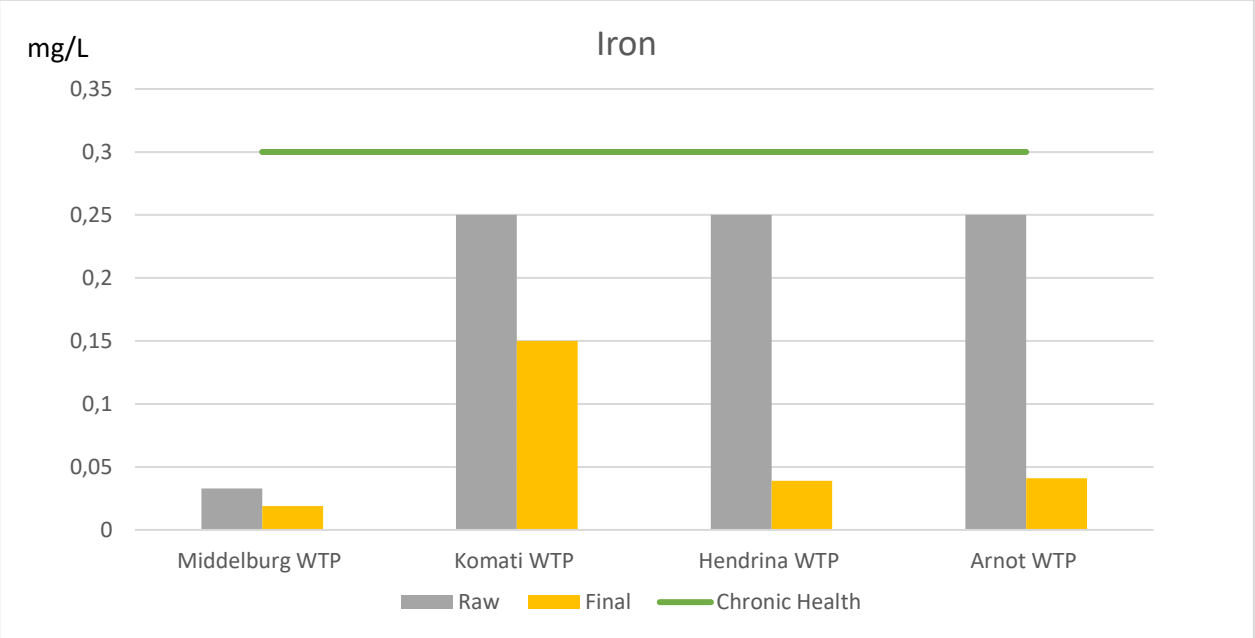


FIGURE 4. 10: THE CONCENTRATION OF IRON IN RAW AND FINAL WATER OF WATER TREATMENT PLANTS IN THE STEVE TSHWETE LOCAL MUNICIPALITY.

Iron is one of the most abunded elements in the earth's crust and its most common mineral is haematite (Fe_2O_3) (DWS, 1996). Pyrite (FeS_2) is another mineral of iron and is associated with coal formations. Iron (Fe) occurs in water in two oxidation states, namely the ferrous (Fe^{2+}) and the Ferric (Fe^{3+}) state. Fe^{3+} is found in dissolved form in water while Fe^{2+} is suspended and responsible for the yellowish color associated with Fe. At low concentrations, iron is an essential mineral for humans as it helps in the making of hemoglobin which is important for red cells which carry oxygen throughout the body. At high to extremely high concentrations, iron can lead to organ failure or even death.

Figure 4.10 shows that the Vygeboom and Nooitgedacht dams have a higher concentration of iron than the Middelburg dam, although it is below the chronic health specification. The removal of iron in water is pH dependent and requires optimisation. Iron in the Eskom water treatment plant is effectively removed by increasing the pH of the water to about 8.

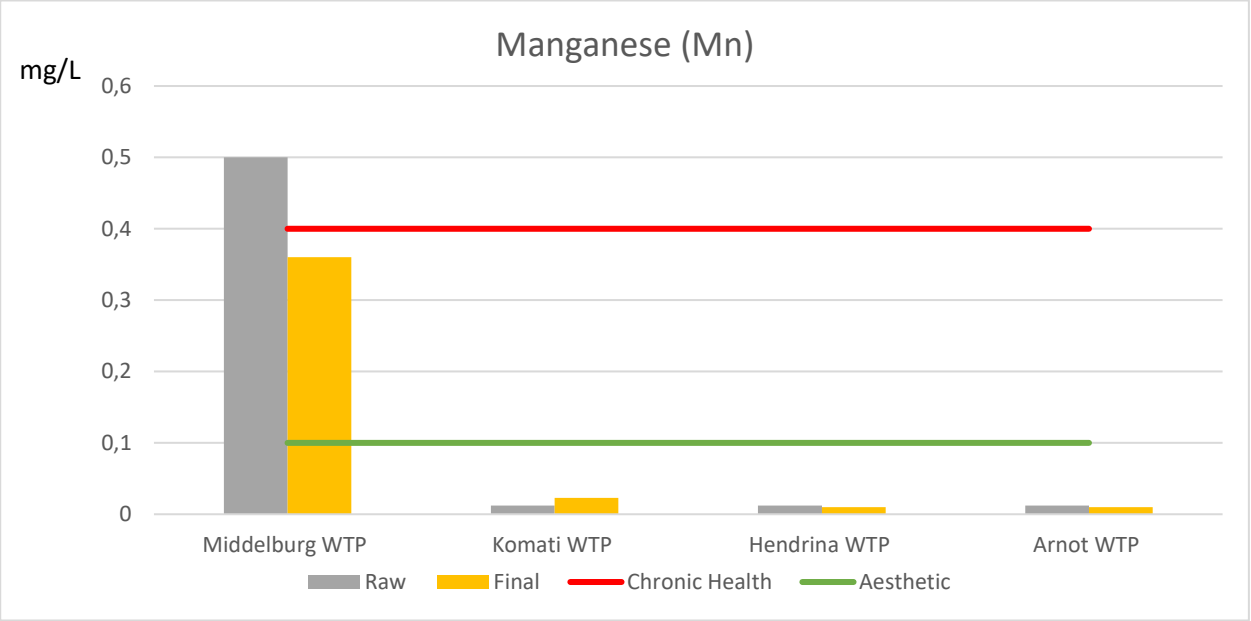


FIGURE 4. 11: MANGANESE CONCENTRATION IN RAW AND FINAL WATER OF THE WATER TREATMENT PLANTS IN THE STEVE TSHWETE LOCAL MUNICIPALITY.

Manganese is relatively abundant in the earth's crust, is an essential element for humans but neurotoxic in excessive amounts, and has an aesthetic rather than a toxic effect in humans (DWS, 1996). In aqueous solution, it occurs as a manganous (Mn^{2+}) ion which may be stabilised by complexation humic acid, and on oxidation to the manganic (Mn^{4+}) ion, it precipitates as a black hydrate oxide responsible for staining problems. The chemistry of manganese and that of iron are closely related in aquatic environments. These two elements tend to behave interdependently in their dissolution from sediments under oxygen-deficient environments and reprecipitate under oxygen-rich environments (DWS, 1996).

The Middelburg dam, as shown in Figure 4.11, has a high concentration of Manganese than the Vygeboom and Nooitgedacht dams. Figure 4.11 indicates that there is little to no effect of the treatment processes on the concentration of Manganese. Manganese seems to be more stable than iron. According to DWS (1996), manganese, once in solution, becomes more readily

stabilised by complexation than iron is, and is often difficult to remove from solution except at high pH, where it precipitates as a hydroxide.

4.3. CUSTOMER SATISFACTION SURVEY

4.3.1. CUSTOMERS KNOW THE MUNICIPALITY'S WATER AND SANITATION NUMBER

Failures and interruptions in water supply and sanitation services are normally reported through the customer services department which in most cases operates on a 24-hours basis. The respondents of the survey were asked if they know the customer services contact number for water and sanitation in their area. About 27 percent of the respondents indicated that they know the water and sanitation contact numbers in their area. This means that the majority of the respondents do not know what to do in cases where they encounter water and sanitation emergencies.

The municipality's contact numbers are displayed at all municipal offices, service stations, and other similar public places. The emergency contact numbers, including the water and sanitation desk, are also displayed on the municipality's website.

4.3.2. NOTIFICATION OF WATER SUPPLY INTERRUPTIONS

Notification of water supply interruption in water supply to customers is important to ensure that customers can prepare and have water during the interruption. Notification can be made in the form of text sent to customers via social media, short message service (SMS), pamphlets circulated within the community, or notices on notice boards of public places. Local radio stations can also be used to announce notices of interruptions in water supply. About 47 percent of the respondents indicated that they do receive notification of water supply interruption and this gives them an opportunity to prepare for the period of no water supply. Out of ten survey respondents from Middelburg, five indicated that they do receive notifications from the municipality whenever there are water supply interruption planned. Three responded that they are notified sometimes. At Arnot, only three out of ten respondents reported that they are notified about water supply interruption and six never received any notification.

4.3.3. MAXIMUM HOURS OF INTERRUPTION EXPERIENCED BY HOUSEHOLDS

In many instances, water service delivery protests are caused by extended periods of interruptions in the water supply. It is, therefore, imperative that when water supply interruptions are reported, they should be addressed as quickly as possible. The MBI (2015) recommends that water interruptions should not exceed 48 hours per event, cumulative less

than 15 days per annum. This means that water interruptions should be attended to within two days, and this should not happen for more than fifteen days within the same year. Most of the respondents reported water interruptions are attended to within 12 to 36 hours of being reported, although some of the respondents have reported up to 48 hrs of water interruptions. Only two respondents out of ten from Middelburg responded that they experienced 48 hours of water supply interruption and one reported 36 hours. In Arnot and Hendrina, all respondents reported water supply interruption of less than 24 hours.

4.3.4. CUSTOMER PERCEPTION OF WATER QUALITY

Water quality for customers refers to physical parameters such as the taste and smell of the water. Foul smell and bad taste result in customers developing a negative perception of water readily available from taps in their household. Most of the respondents, about 73 percent, regard the water in their households as good to very good. All respondents from Arnot and Hendrina reported that water tap water in their houses is good to very good. In Middelburg, six out the ten respondents reported tap water quality as poor to very bad while two respondents said it is fair and two said it is good to very good. The majority of the respondents complained about the colour and taste of the water. They reported that tap water had a dark colour and it is salty.

4.3.5. DO CUSTOMERS BUY COMMERCIALLY SOLD WATER

In most cases, the purchasing of commercially sold water for domestic water use indicates the distrust of tap water for consumptive use in households. This distrust is usually caused by the perception customers have of water quality which is exacerbated by the taste and smell of the water. The majority of the respondents, about 22 of the respondents, indicated that they do not buy commercially sold water for domestic water use; they use tap water for domestic consumption. All respondents from Arnot and Hendrina use tap water for consumptive use in their households. The eight respondents who buy commercially sold water for domestic consumptive use are from Middelburg. They indicated that they buy commercially sold water for consumptive use in their household. The respondents indicated that, due to the appearance, taste and smell of the water, they do not trust tap water for consumptive use.

4.3.6. TAP WATER USE IN HOUSEHOLDS

Respondents of the survey were asked what are the household uses of water do they feel comfortable using tap water for? Domestic water uses that were considered in the survey included drinking, cooking, bathing children, bathing adults, washing clothes, cleaning the house, flushing the toilet, or gardening. All respondents indicated that they feel comfortable using tap

water for non-consumptive water use such as bathing children and adults, washing clothes, cleaning the house, flushing toilets, and gardening. However, for consumptive water use, that is drinking and cooking, 24 of the respondents reported that they use tap water for drinking and 90 % said they use water for cooking. Six out ten respondents from Middelburg said that they do not use water drinking and seven are comfortable using tap water for cooking. Those who use water for cooking indicated that they prefer boiling the water before using it.

4.4. CONCLUSION

This chapter presented the results of the interviews of water service providers and responses to questionnaires from customers of these water service providers in the Steve Tshwete Local Municipality. The water service providers included water treatment plants from Arnot, Hendrina, Komati, and Middelburg. The results indicated a differentiated approach to water service provision between the water service providers. Eskom water treatment plants, that is Arnot, Hendrina, and Komati, have a more or less similar approach to water service provision. These water treatment plants have fewer connections as compared to the Middelburg water treatment plant which supplies a bigger area with more connections and more water treated daily. The quality of raw water for these plant is the same and is easier to treat than the source that supplies the Middelburg water treatment plant with raw water. The results presented in this chapter are discussed in the chapter that follow.

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1. INTRODUCTION

In this chapter, the results of the study are discussed, and the conclusion and recommendations are made. The chapter discusses the results on the performance of the water utilities by comparing data from the different water utilities and also discusses the views of the water utilities customers in the municipality. Although the data on water utility performance is water from four water treatment plans, namely, Middelburg, Arnot, Komati and Hendrina, water utility customers from Komati were not interviewed and therefore not included in the survey.

5.2. WATER UTILITY PERFORMANCE INDICATORS

5.2.1. WATER SERVICE DELIVERY

The Middelburg water treatment plant supplies a larger area with water than any other water treatment plant in the Steve Tshwete Local Municipality. This means that the plant has more connections as compared to other water treatment plants in the municipality. The town has 42 201 connections with a backlog of 4.31 % of dwellings without running water in their yards. This is the highest backlog in the municipality as compared to other areas. In areas such as Avalon, an informal settlement, communal taps are supplied and in rural areas water is supplied by water tankers. Although there is no piped water in the yard in these areas, people have other means to access water. All other areas in the municipality have 100 % coverage of tap water in their yards.

One of the major problems facing the municipality is the aging infrastructure which results in a high number of water supply interruptions due to pipe bursts. The water distribution system still utilizes asbestos pipes (STLM IDP, 2020/2021), which are prone to breakage and result in water supply interruption. This, therefore, results in a high number of reports from customers of water supply interruption, which in turn requires a prompt response from infrastructure maintenance teams. In Hendrina, Arnot, and Middelburg, the water service provider reported that more than 50 % of the reported water supply interruption are attended to within 48 hrs of being reported. This was corroborated by customers who, most of them indicated that the highest number of hours they spent without water was 48 hours. The majority of the respondents (77 %), reported less than 36 hours as the highest number of hours without water supply and 47 % of the

respondents reported less than 24 hrs of water supply interruption. This is a clear indication that the response to water interruptions in the Steve Tshwete Local Municipality is managed in accordance with the recommendation of the MBI (2015).

The data and information covered in this study indicate that provision of water in terms of service in the Steve Tshwete municipality as a whole is adequate. The major issue which needs attention, especially in the town of Middelburg is an investment in the distribution infrastructure. Quick fixes in order to restore the water services have proved to be unsustainable. Capital investment is needed to replace the current water distribution system made of asbestos. Asbestos is known to deteriorate over time which results in frequent breakages and disruption in the water supply.

5.2.2. OPERATIONS AND MAINTENANCE

It is important for water utilities to maintain an up-to-date asset management program to ensure the sustainability of water services. There are many ways in which asset management supports sustainability for water services, and these include (USEPA, 2022):

- Providing information on infrastructure capacity and its condition,
- Providing information regarding the repair, rehabilitation, and replacement of existing assets, and
- Providing information on the full life cycle cost of the existing asset.

The Middelburg water treatment plant abstracts water from the Middleburg dam which is pumped to the inlet of the water treatment. In Middelburg and surrounding areas, there are lots of mining activities taking place. The most mined mineral in the area is coal. Mining has a negative effect on the quality of both surface and groundwater. Although there is a plethora of evidence in the literature of the effects of mining on water resources, the Middelburg water treatment plant still employs conventional water treatment for potable water treatment.

Laboratory results, as shown in Appendix 2.1, of water from the Middelburg dam which feeds the Middelburg water treatment, indicate high Total Dissolved Solids and manganese concentrations. The results also show no disinfection of the final water as shown in Appendix 2.2. Physical parameters such as TDS, pH, and free chlorine need to be monitored regularly and form part of the plant check sheet. The operational laboratory which should be located at the plant, should at minimum have a desktop UV-VIS spectrometer, especially for plants like the Vaalbank water treatment with raw water that is of poor quality. Analysing parameters such as

iron and manganese will assist the operator in timeously identifying out-of-specification results and taking corrective actions.

The results presented in this report shows that the quality of water in the Middelburg dam has deteriorated and the water is difficult treat. It is therefore imperative that to improve the quality of water supplied to the community for domestic water use, alternatives should be explored. These alternatives may include, changing the source to one with better water quality for treatment, upgrading water treatment process by including advanced water process, e.g. reverse osmosis; training of plant personnel to able to make better decision in order to improve final water; and increase regulatory oversight to assist the municipality to make better decisions for water quality improvements.

Asset management should predict future needs for capital investment in the water service infrastructure, including the upgrading of the water treatment plant. The quality of raw water changes with time and the water treatment process used should be improved to treat water to the required standard. Research should be carried out frequently to investigate technological advancement in water treatment which can be beneficial. This will assist the municipality to plan capital investment for the improvement of water services.

5.2.3. PERSONNEL AND STAFFING

The importance of skilled and adequately qualified personnel for water services provision cannot be overemphasised. For water treatment plants, basic knowledge of water chemistry is important for water treatment plant operators and technicians. This will ensure that the operators and technicians know and understand the importance of plant optimisation and the application of chemicals used for water treatment. It also ensures that the operators and technicians are able to interpret the laboratory analysis and reports and take corrective action.

Water treatment is a multi-disciplinary effort where engineers, technicians, and scientists should work together to ensure quality service. Data collected indicates that all water treatment plants in the municipality have adequate numbers of engineers, operators, technicians, and scientists with relevant skills and qualifications. Coordination and cooperation between these professionals should be optimised to have an environment where everyone is able to raise their views pertaining to the improvement of water service.

5.2.4. PRODUCT QUALITY

Due to different land use around the Middelburg Dam which supplies Middelburg water treatment and Nooitgedacht and Vygeboom Dams which supplies water to Arnot, Hendrina and Komati water treatment plants, raw water quality is different. Middelburg dam is affected mainly by coal mining, power generation, and steel production occurring in the area. Vygeboom and Nooitgedacht dams are mainly affected by geological formations, forestry or timber, and paper mills found in the area. These natural and anthropogenic activities deposit different contaminants into surface and groundwater resources.

Middelburg dam, as shown in Appendix 2.1, has low colloidal matter than the Vygeboom and Nooitgedacht dams, as shown in Appendix 2.3. Eskom water treatment plants are capable of removing more colloidal matter than the Middelburg water treatment plant. Turbidity removal efficiency of the Middelburg water treatment was found to be around 68% with a final water turbidity of 0.8 NTU, which is close to the operational limit of 1 NTU. This leaves little room to take corrective actions whenever deviations are experienced on the plant. The efficiency of removal of colloidal particles should be increased by optimising the chemical dosage for coagulation and flocculation. Jar tests should be conducted on a regular basis to ensure that the correct amounts of chemicals are dosed.

Total dissolved solids (TDS) is a measurement of all salt that are dissolved in water. The problem with high TDS concentration in water is that it imparts a salty taste to the water. Middelburg dam was found to have a high concentration of TDS compared to the Vygeboom and Nooitgedacht dams. This indicates the impacts of mining, power generation, and steel production on surface water quality. The removal of most of the salts found in water is pH dependent, and as shown in Figure 4.8 and Figure 4.9, conventional water treatment without pH adjustment during treatment has no effect on the TDS of the water. Most metals found in water also require elevated pH values to be precipitated out of the water. For example, manganese is precipitated in its hydroxide form at a pH of about 8.8.

Due to other processes in power generation that limit the adjustment of pH during the coagulation and flocculation processes, Eskom water treatment plants can only adjust the pH of the final water. For the Middelburg water treatment plant, which produces water solely for domestic water use, pH adjustment during the coagulation and flocculation processes can assist

in the removal of TDS. This will significantly reduce the foul taste of the water. It will also reduce the scaling and lathering impairment tendency of the water.

Disinfection is one of the most important processes in water treatment, especially for domestic water use. Bacteriological contamination of domestic water can result in water-borne diseases in humans which give rise to epidemics and can even lead to fatalities. It is therefore imperative to ensure that some level of chlorine residual is maintained in the water. Disinfection with chlorine or chlorine compounds is practiced in most water treatment facilities. If not dosed correctly, chlorine or chlorine byproducts can be carcinogenic. Chlorine in water treatment should be dosed to effect disinfenction and maintain free chlorine residual in the distribution system. Normally, a free chlorine residual of 0.5 to 1.5 mg/l is recommended in the final water tank before pumping to the distribution system. This is because water supply distribution systems are closed systems which should not have an ingress of microbiological contamination. If microbiological contamination is experienced in the distribution system is experienced, the source of the ingress should be investigated.

Chlorine is a volatile chemical and tends to diminish in water, especially where the distribution system of the water is large or the pipeline is long. This in most cases motivates the operator to dose a high dosage of chlorine and have higher free chlorine residual with the expectation of having some residual at the furthest point of the distribution system. However, this exposes consumers close to the chlorine dosing point or the water treatment plant to high concentrations of chlorine and the smell of chlorine in the water. Ideally, water distribution systems are closed and tight systems unless there is a leak experienced. And furthermore, pathogens found in water once they are killed in the disinfection process of the water treatment, do not reoccur or reproduce again. Therefore, water treatment plants should optimise chlorine dosage by identifying the optimal amount of chlorine and chlorine residual required for a maximum kill during water treatment. In addition, regular analysis of indicator organisms, for example, total coliforms, faecal coliforms, and *E. coli*., should be done as frequently as possible and should be reported with all other analysis. Mycrosystin, as currently reported as an indicator of microbiological activity, does not necessarily indicate faecal contamination of water.

Iron and Manganese co-exist in water. The removal of these two elements is pH dependent. At higher pH values, about 8.8, iron is removed through oxidation, and, consequently precipitation in the hydroxide form. Chlorine also has an oxidising effect on iron, forming an in-soluble $FeCl_3$

precipitate. Oxidation with chlorine has in the past been applied at the inlet of the water treatment process, but this has since been discouraged since it was discovered that it forms THMs. In the final water, it is also advised that chlorine should not be overdosed as this will affect the quality of water due to the formation of THMs and the smell of chlorine. High concentration of iron in water causes tissue damage due to accumulation in humans. Manganese is more difficult to remove in water than iron. For manganese removal, elevated pH of more than 9, is needed to precipitate manganese in its hydroxide form.

Middelburg dam has a high concentration of manganese and the removal efficiency of the water treatment plant is low. Although the concentration in the final water is below the chronic limit, as outlined in the SANS241 water quality standard, the concentration is too close to this limit. Increasing the pH of the water at the inlet of the water treatment process will have a significant effect on the concentration of manganese in the final water.

The differences in the quality of raw water treated by the different water treatment plants in the municipality show that water treatment plants can learn from each other and then develop strategies that can work for their specific plant. Water plants with a similar source, for example, Eskom water treatment plants, show similar performance and water quality of the final product. There are practices that the Middelburg water treatment plant can learn from the Eskom water treatment plant in order to improve water quality. These practices include, appointment of personnel with the ability to take decisive decisions to improve water quality; keeping the infrastructure asset management plan up-to-date; use of alternative water sources or water sources with better water quality that can be blended with water from the Middelburg dam; and optimisation of treatment processes or removal of contaminants of concern.

5.3. CUSTOMER SATISFACTION SURVEY

A customer satisfaction survey that utilised the questionnaire found in Appendix B, was used to determine the perception of the residents of Steve Tshwete local municipality on water services in municipality. The survey focused on issues such as the reporting of interruptions of water supply, perception on water quality and domestic water use. The reporting of interruption in water supply asked residents whether the know how and when to report interruption. Respondents we asked whether they knew the contacts of the water and sanitation complaints department of the municipality and whether they receive notifications whenever there are

interruptions of water supply. On the perception of residents on water quality, the respondents we asked to give their general perception of water quality in their area and whether do they prefer using bottled/ commercially sold water. The questionnaire also asked respondents if they feel comfortable using tap water for consumptive or non-consumptive water uses.

Although the municipality's contact numbers, including the water and sanitation complaints department, are displayed throughout the municipality, for example at filling station, municipal buildings, even on municipal bill letters, the majority of the respondents indicated that they do not know the contact details of the water and sanitation complaints department of the municipality. This indicates that the residents have no appetite to reading notifications that are displayed on notice boards or in letters. Recently the municipality has resorted to social media, that is, WhatsApp and Facebook, to put notifications about municipal notices. There are Ward WhatsApp groups which include residents, where ward councillors are able to inform residents about municipal notices. The effectiveness of social media as a medium of communication have shown to be effective in some portions of the municipality where people have access to social media.

Most of the respondents from Middelburg indicated that water quality in their area is poor. They complain mainly on the taste and smell of the water. The water quality analysis as shown in Appendix 2.2, shows that although TDS and manganese are within specifications as outlined in SANS241, the concentrations of these two parameters, as found in water from Middelburg water treatment plant impart a bad taste in the water. Conventional water treatment has shown to have little effect on the concentrations of these two parameters. It is therefore imperative that an investigation of advanced water treatment technologies be carried out for the reduction of these two parameters. Advance treatment technologies that can be investigated can include lime softening and oxidation process. Alternatively, the municipality should explore other water sources with better quality than the Middelburg dam. This can be done to save cost of treatment while providing good quality water.

Although chlorine is mainly used as a disinfectant, it can also help in the oxidation of iron and manganese. Laboratory results as found on the municipalities website, shows that free chlorine in water from the Middelburg water treatment was less 0.1 mg/L. Increasing free chlorine of the final water to 0.5 to 1.0 mg/L will have a significant effect in the reduction of manganese. However, due to the complex nature of the use of chlorine, its oxidation capabilities and the

formation of THMs, it is important that studies be conducted to investigate the reduction of TDS and manganese in water. Pre-chlorination, as was practiced in water treatment until the late 2000's, was found to form trihalomethanes (THMs) in water which have been said to be carcinogenic.

The majority of the respondents in Middelburg indicated that they are not comfortable using tap water for consumptive water uses such drinking and cooking. This is a clear indication that they do not trust water supplied by the municipality. Most the respondents from Middelburg use commercially sold water for drinking. This is attributed to the issues of taste and smell, as reported by the respondents from this area. Eskom water treatment plants treat water to meet the lower limits of the SANS241, and the respondents from areas supplied by these water treatment plants did not report any issue of bad taste and smell in the water. Therefore, the application of SANS241 by the Middelburg water treatment plant needs to be reviewed and decisions made as to how to improve the quality of water in this part of the municipality.

5.4. IMPLICATIONS OF THE STUDY

Benchmarking provides a tool for water utilities to learn from their peers and adapt best practices to improve their own performance. Performance indicators used in this study include water service delivery, operation and maintenance, personnel and staffing, and product quality. A customer satisfaction survey was also conducted to find out what the customer's perceptions are about water services in the municipality. The main aim of this study was to find out what factors influence the performance of water utilities and the perception of the people on water service in the Steve Tshwete Local Municipality.

Middelburg consists of 42 201 dwellings with a coverage of 96.5 % and a backlog of 4.31 %. This is the biggest area in the municipality, and the backlog is in the informal settlement and rural areas. Access to water in these areas is through communal taps and boreholes. Arnot, Hendrina (Pullenshope), and Komati have 919, 905, and 471 dwellings, respectively. Coverage in this area is 100 %. Water interruptions are well managed, with water utilities in Hendrina, Middelburg, and Arnot reporting that 50 % of interruptions occur for less than 48 hours per event, cumulative for 15 days per year. Komati reported that 90 % of interruptions occur for less than 48 hours per event, cumulative for 15 per year. Manipulation of less than 48 hours per event cumulative for 15 days per year means that water interruption should be less than 30 minutes per month.

The pressure at which water is supplied is one of the indicators of water service delivery. According to the MBI (2015), the pressure at which water is supplied should be constantly above 10 L/min. Komati and Hendrina reported that 10 % of their connection have experienced low pressure and in Middelburg, 25 % have experienced low pressure. At Arnot, due to the capacity of the water tower supplying the area, 50 % of the connections have experienced low pressure.

Infrastructure asset management is animportant factors for ensuring an uninterrupted supply of water. Areas with old infrastructure such as the one in Steve Tshwete Local Municipality need to maintain an up-to-date infrastructure management register for the Middelburg water treatment plant and also make capital available to refurbish the existing infrastructure. The replacement of faulty water meters is a great move by the municipality to reduce non-revenue water.

This study has found that the quality of water in the Middelburg dam has deteriorated more than the Nooitgedacht and the Vygeboom dams. This results in conventional water treatment processes in the Middelburg water treatment plant being unable to remove some constituents from the water, those that are dissolved. TDS and Manganese were found to be higher in the final water although they are below the aesthetic limit as denoted in the SANS241:2015 water quality standards. According to the South African Water Quality guidelines, at a concentration of above 450 mg/L TDS, water has a noticeable salty taste. TDS was found to be 1076 mg/L in water from the Middelburg water treatment plant. Similarly, manganese at concentrations above 0.1 mg/L Mn, water has a slightly staining effect and taste. Manganese was found to be 0.363 mg/L. These two parameters corroborate the view of the customers in Middelburg who complains about the taste and smell of the water.

Although water treatment plants that treat water for the Komati Water Distribution Scheme, that is, the Eskom water treatment plant, treat water of better quality, this study shows that constituents in water need to be treated to the target water quality standards as denoted in the South African Water Quality Guidelines: Volume 1. The consumers of water in Middelburg complain about the taste and smell of the water, therefore, interventions are needed to improve water services in Middelburg.

5.5. RECOMMENDATIONS

5.5.1. FINDINGS OF THE STUDY

Two benchmarking methods were used to carry out the study, namely, process benchmarking and customer satisfaction survey. Customer satisfaction survey found that the majority of

respondents supplied with water from the Middelburg water treatment had more complains about water services than those supplied from Eskom water treatment plants. Respondent complained mostly about the quality of water. They reported taste and smell as their biggest issues. Laboratory results obtained from the municipality's website showed that the final water from the Middelburg water treatment plant had high TDS and manganese as compared to the final water from the Eskom water treatment plants. The water was also found to have no chlorine residual, which means no disinfection. On the other hand, Eskom water treatment plants were found to have low TDS but had high free chlorine residual. Chlorine gas as a disinfectant imparts smell in water if overdosed. The results also showed that the raw water source for the Middelburg water treatment plant supplies water that is more difficult to treat than the raw water source that supply the Eskom water treatment plant.

Process benchmarking showed that there are four factors that result in different perceptions and performance in water utility management between water utilities in the Steve Tshwete Local municipality. These factors are:

i) **Human Resources**. Limited capability of the plant operator to take corrective actions to improve the quality of final water. It is a finding of this study that the plant operator in the Middelburg water treatment plant lacks the capability to take corrective action to ensure that the quality of water supplied to the community is good. The operator, guided by the SANS241 water quality standard, should ensure that the plant is optimised to remove the contaminants in water at least to or below the chronic specifications as outlined in the SANS241 water quality standard. From the result presented here, it is clear that raw water the from Middelburg dam is difficult treat, therefore, the operator should investigate alternatives that can lead to improvement in final water quality. The plant operator needs external support for decision making to improve the quality of supplied to consumer. This can be done through appointment of experts in water treatment or engagement with academic institution.

ii) **Raw water quality**. Raw water source quality for Middelburg water treatment plant is difficult to treat. It is the finding of this study that the water quality in the Middelburg dam has deteriorated and is difficult to treat than water from the Vygeboom and Nooidtgedacht dam. To improve the quality of final water from the Middelburg water treatment plant, an alternative source with better water quality

can be used as an alternative or blended with water from the Middelburg Dam to feed the Middelburg water treatment plant. It is also clear that the current conventional water treatment processes available at the Middelburg water treatment plant is incapable of treating water with the quality found in the Middelburg dam. Therefore, final water quality can also be improved by the addition of advanced water treatment processes, for example, reverse osmosis, oxidation, lime softening, or dissolved air flotation.

iii) **Regulatory oversite**. Regulatory oversight is important for municipalities to ensure that the quality of water supplied to communities meets the standards. At Eskom water treatment plants, there is a team of specialist and experts who supports the water treatment plant operators in issues related to water utility and water quality management. It is clear that the Middelburg water treatment lacks this kind of support. The Department of Water and Sanitation (DWS) and the Department of Cooperative Governance and Traditional Affairs (COGTA) should ensure that such oversight and support is available for municipalities.

iv) **Financial support.** Lack of investment in water treatment facilities. The deterioration of water quality in the Middelburg Dam necessitates the need for investment in the water treatment plant for the addition of processes capable to treat raw water to final water that is good for consumption. It is, therefore, imperative that the municipality invests in the upgrading of the Middelburg water treatment plant for the improvement of the final water. Funding can also be provided for the search and development of infrastructure for abstract water from alternative water sources.

5.5.2. RESEARCH RECOMMENDATIONS

It is recommended that research be conducted to investigate advanced water treatment options that can be added to conventional water treatment processes for the improvement of final water quality.

It also recommended that research be conducted to investigate the impact of managers, engineers, technicians, and operators with different qualifications and experience on the performance of water utilities.

REFERENCES

Akimov, A., Simshauser, P. (2019). Performance measurement in Australian water utilities. Current state and future directions. *Research and Evaluation*, Vol. 79, 111–142. DOI: 10.1111/1467-8500.12376.

Algotsson, E., Murombo, T., Davis, M., Poole, M. (2009).Water supply and sanitation in South Africa: Environmental right and municipal accountability. LHR publication series, Report No. 1/2009. Development Bank of Southern Africa.

Ananda, J., Pawsey, N. (2019). Benchmarking service quality in the urban water industry. *Journal of Productivity,* Vol. 51, 55-72. https://doi.org/10.1007/s11123-019-00545-w.

ADB, 2013. Water utility asset management: A guide for development practitioners. Asian Development Bank, The Phillipines. ISBN 978-92-9254-399-0

Bellaubi, F., Visscher, J. T. (2014). Water service delivery in Kenya and Ghana: an area-based assessment of water utility performance. *Water International,* Vol. 39 (7), 952–968. https://doi.org/10.1080/02508060.2015.985976.

Berg, S. V., Corton, M. L. (2007). Water utility benchmarking for managerial and policy decision: Lessons from developing countries. International Water Association Conference on Performance of Assessment of Urban Infrastructure Services (March 2008, Valencia, Spain).

Brettenny, W., Sharp, G. (2018). Evaluation of the effectiveness of the National Benchmarking Initiative (NBI) in improving the productivity of water services authorities in South Africa. *Water SA,* Vol, 44 (1), 37 – 44. http://dx.doi.org/10.4314/wsa.v44i1.05.

DST, undated, Water service delivery: Is it pumps and pipes or reliable access to water? Policy brief. Department of Science and technology, South Africa.

Du Plooy-Cilliers, F., Davies, C., Bezuidenhout, R. M. (eds) (2014). Research matters. Juta and company LTD, Cape Town, South Africa. ISBN 978-1-48510-201-4.

DWAF (1996). South African Water Quality Guidelines: Volume 1 Domestic water use (2nd Ed). Department of Water Affairs and Forestry, South Africa.

DWS (2017). National norms and standards for domestic water and sanitation services: Version 3-final. Government Gazette No. 982. Department of Water and Sanitation, South Africa.

Elmuti, D., Kathawala, Y. (1997). An overview of benchmarking process: a tool for continuous improvement and competitive advantage. *Benchmarking for Quality Mangement and Technology,* Vol. 4 (4), 229-243.

Fibuch, E., van Way, C. W. (2013). Benchmarking's role in driving performance. *Benchmarks.*

Heider, H., Sadiq, R., Tesfamariam, S. (2014). Performance indicators for small- and medium-sized water supply systems: a review. *Environmental Reviews*, Vol. 22*,* 1–40. http://dx.doi.org/10.4314/wsa.v44i1.05.

Harper, M. (2019/11/13). Understanding water benchmarks do what. American Productivity and Quality Center (APQC). Retrieved from https://www.apqc.org/blog/what-are-four-types-benchmarking

https://rockcontent.com/blog/competitive-benchmarking/ [Accessed 19/07/2022]

https://www.ib-net.org/benchmarking-methodologies/other-benchmarking-methodologies/process-benchmarking/ [Accessed 19/07/2022]

Kayaga, S. M., Kingdom, W., Jalakam, A. (2018). Organizational design for improved performance of urban water utilities in developing countries. *Utilities Policy,* Vol. 50*,* 49–50. http://dx.doi.org/10.1016/j.jup.2017.10.001.

Mwiinga, G., Gumbo, T., Mkoka, I. (2008). Water conservation and demand management in practice. Wisa Conference, Sun City, South Africa.

OECD, 2021. Water governance in Cape Town, South Africa. OECD Studies on Water, Paris. https://doi.org/10.1787/a804bd7b-en.

Rietveld, L. C., Siri, J. G., Chakravarty, I., Asernio, A. M., Biswas, R., Chatterjee. (2016). Improving Health in cities through systems approach for urban water management. *Environmental Health*, Vol. 15 (1), 151–160. DOI 10.1186/s12940-016-0107-2.

Rodrigue, M. (2021/10/18). The beginner's guide to competitive benchmarking. Hubspot. https://blog.hubspot.com/sales/competitive-benchmarking

SALGA, 2015. Municipal Benchmarking Initiative: Supporting Water Services Performance Measurement and Improvement. Annual report on water services.

Sattarov, M., Valkova, T. (2017). A PERFORMANCE MANAGEMENT FRAMEWORK FOR WATER UTILITIES IN DEVELOPING COUNTRIES. *Journal of Business Management,* Vol. 13*,* 91-109. ISSN 1691-5348

Shersen, Rodda, N., Strenstrom, T. A., Schmidt, S., Dent, M., Fux, B., Hanke, N., Buckely, C. A., Fennemore, C. (2016). Water security in South Africa: Perceptions on public expectation and municipal obligations, governance and water re-use. *Water SA*, Vol. 42 *(*3), 456–464. http://dx.doi.org/10.4314/wsa.v42i3.11.

Soppe, G., Janson , N., Piantini, S. (2017). Water utility Turnaround Framework: A guide for improving performance. World Bank, Washington DC.

STATSSA (2017), The state of basic service delivery in South Africa: In-depth analysis of the community survey 2016 data. Statistics South Africa, Report No. 03-01-22 2016.

Stephenson, D., Barta, B., Manson, N. (2001). Asset management for the water service sector in South Africa. Water Research Commission, Project No. 897/1/01.

Tutusaus, M., Schwartz, K. (2018). Water Services in small towns in developing countries: at the tail and of development. *Water Policy,* Vol. 20*,* 1–11. http://iwaponline.com/wp/article-pdf/20/S1/1/237231/020000001.

USEPA (2022/06/21). Effective water utility management practices. https://www.epa.gov/sustainable-water-infrastructure/effective-water-utility-management-practices [Accessed 21/09/2021]

Wegelin, W. A., Jacobs, H. E. (2013). The development of a municipal water conservation and demand management strategy and business plan as required by the Water Services Act, South Africa. *Water SA*, Vol. 39 (3), 415-421. http://dx.doi.org/10.4314/wsa.v39i3.11.

https://www.valuemetrics.co.uk/internal-benchmarking [Accessed 14/07/2022]

APPENDICES

1. Data collection tools

1.1. Water utility management questionnaire

Water Utility Management Questionnaire	
Water Service Delivery	
1. Coverage (% of households with piped water services)	
2. Daily Water Supplied	
3. Do customers experience acceptable service interruptions (i.e. <48 hours per event, cumulative <15 days per year)?	
Don't know	0
None (i.e. 0%)	1
<50% of Households	2
>50 of Households	3
>75% of Households	4
>90% of Households	5
Yes, all (i.e. 100%	6
4. Do customers experience water pressure problems (i.e. no flow/ partial flow <10l/min)?	
Don't know	0
All (i.e. 100%)	1
>50% of Households	2
<50% of Households	3
<25% of Households	4
<10% of Households	5
No, None (i.e. 0%)	6
5. How many water complaints/ callouts are responded to within 24 hrs?	
Don't know	0
<50%	1
Some (i.e. >50%)	2
Most (i.e. >75%	3
All (i.e. 100%)	4
Operation and maintenance	
6. Do you have persistent capital under spending (2018 - 2020)?	
No	1
Yes	2
7.Do you have an appropriate infrastructure Asset Management Plan?	
Don't know	0
No, disagree	1
In place, but not ideal	2
Yes, strongly agree	3
8. What are your infrastructure maintenance cost/ total operating cost (%)?	
Don't know	
10% or more	
8% - <10%	
5% - <8%	
<5%	
Product Quality	
9. Is the Water Treatment Plant operated by staff with correct skills/ qualification and experience (as per Blue Drop	
Don't know	0
None (i.e. 0%)	1
<50%	2
Some (i.e. >50%)	3
Most (i.e. >75%)	4
Yes, All (i.e. 100%)	5
10. How many water quality complaints are logged monthly?	
Don't know	0
<25%	1
<50%	2
Some (i.e. >50%)	3
Most (i.e. >75%	4
All (i.e. 100%)	5
Human Resources	
11. How many water treatment staff have the following qualifications?	
No formal schooling	
Some primary school	
Primary school completed	
Some secondary school	
Secondary school completed	
Some tertiary education	
Undergraduate completed	
Post graduate	
12. How many registered engineers are responsible for water services?	
13. How many water service technicians are responsible for water services?	
14. How many technical staff members are responsible for water services?	

1.2. Interview schedule for water service beneficiaries.

Interview Schedule for water services beneficiaries	
1. Do you get notifications for water interruptions?	
2. Do you know the municipality emergency water and sanitation contact numbers?	
3. What is the longest period you have experienced without water on your tap due to water interruption	
4. How is the water pressure in your house?	
5. Do you have another source of water on your premises except tap water? If yes, what is source:	
6. What do you think of the quality of tap water? Please explain	
7. Do you buy bottled or commercially sold water? Please explain why	
8. What is your perception of water services in the municipality?	
9. What do you think municipality can do to improve water services?	
10. Do you use tap water for: (if not, why)	
10.1. Drinking	
10.2. Cooking	
10.3. Washing Children	
10.4. Washing Adults	
10.5. Washing Clothes	
10.6. Cleaning the House	
10.7. Flushing the Toilet	
10.8. Garden	

2. Water quality for Steve Tshwete Local Municipality.

2.1. Vaalbank (Middelburg) Water Treatment Plant raw water quality.

STEVE TSHWETE LOCAL MUNICIPALITY

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	9-Nov-2021
Date Reported	17-Nov-2021
Dates Analysed:	09-Nov-2021 to 17-Nov-2021
Quantity Analyzed :	11
Our Ref :	STL / 219 - 229/ B / 11/21
Lab No :	B219

	LPM METHOD	Analysis Results mg/l	VAALBANK RAW	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	12	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	124	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	1064	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	6,86	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	2,62	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	93		
	LPM 84	Free Chlorine as Cl_2 *	<0.1	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76A	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15E	Calcium as Ca	99,7		
	LPM 76A	Chlorides as Cl	24,7	Aesthetic	≤300
	LPM 76A	Fluoride as F	0,54	Chronic Health	≤1.5
	LPM 15E	Magnesium as Mg	95,8		
	LPM 76A	Nitrate NO_3 as N	<0.1	Acute Health	≤ 11
	LPM 76A	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15E	Sodium as Na	44,3	Aesthetic	≤ 200
	LPM 76A	Sulphate as SO_4	558	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15E	Potassium as K	14,0		
	LPM 15	Zinc as Zn	0,01	Aesthetic	≤5

	LPM METHOD	Analysis Results µg/l	VAALBANK RAW	SANS Standards -241 : (2015) Domestic Water	
				Risk	Standard Limits
Micro Determinants					
	LPM 15	Aluminium as Al	51,0	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	5,02	Chronic Health	≤ 10
	LPM 67	Barium as Ba	76,3	Chronic Health	≤ 700
	LPM 15	Boron as B	67,4	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	<1	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	4,61		
	LPM 67	Copper as Cu	1,55	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	32,5	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	499	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	<1	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	12,2	Chronic Health	≤ 70
	LPM 67	Selenium as Se	1,32	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 67	Vanadium as V	1,60		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	8,08	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

QUALITY CONTROL CHECKS	
Cation Balance	15,15
Anion Balance	14,20
% Difference	3,2
Measured TDS	1064
Calculated TDS	894
Limits	1,2
Calcul TDS / E.C.	0,7

P.L.G UYS / A. KOHRS
Technical Signatory
Electronic Signature

2.2. Vaalbank (Middelburg) Water Treatment Plant final water quality.

STEVE TSHWETE LOCAL MUNICIPALITY

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	9-Nov-2021
Date Reported	17-Nov-2021
Dates Analysed:	09-Nov-2021 to 17-Nov-2021
Quantity Analyzed :	11
Our Ref :	STL / 219 - 229/ B / 11/21
Lab No :	B220

	LPM METHOD	Analysis Results mg/l	VAALBANK FINAL	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	5	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	124	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	1076	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	7,03	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	0,80	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	96		
	LPM 84	Free Chlorine as Cl_2 *	<0.1	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76A	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15E	Calcium as Ca	98,0		
	LPM 76A	Chlorides as Cl	28,1	Aesthetic	≤300
	LPM 76A	Fluoride as F	0,44	Chronic Health	≤1.5
	LPM 15E	Magnesium as Mg	94,0		
	LPM 76A	Nitrate NO_3 as N	<0.1	Acute Health	≤ 11
	LPM 76A	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15E	Sodium as Na	44,4	Aesthetic	≤ 200
	LPM 76A	Sulphate as SO_4	586	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15E	Potassium as K	13,7		
	LPM 15E	Zinc as Zn	<0.01	Aesthetic	≤5
Micro Determinants µg/l					
	LPM 15	Aluminium as Al	67,9	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	<1	Chronic Health	≤ 10
	LPM 67	Barium as Ba	78,4	Chronic Health	≤ 700
	LPM 15	Boron as B	69,2	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	<1	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	2,62		
	LPM 67	Copper as Cu	1,77	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	19,0	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	363	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	<1	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	12,0	Chronic Health	≤ 70
	LPM 67	Selenium as Se	1,03	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 67	Vanadium as V	1,20		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	7,41	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

QUALITY CONTROL CHECKS	
Cation Balance	14,92
Anion Balance	14,93
% Difference	-0,1
Measured TDS	1076
Calculated TDS	923
Limits	1,2
Calcul TDS / E.C.	0,7



P.L.G UYS / A. KOHRS

Technical Signatory

Electronic Signature

2.3. Hendrina, Arnot and Komati Water Treatment Plants raw water quality.

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	9-Nov-2021
Date Reported	17-Nov-2021
Dates Analysed:	09-Nov-2021 to 17-Nov-2021
Quantity Analyzed :	11
Our Ref :	STL / 219 - 229/ B / 11/21
Lab No :	B229

	LPM METHOD	Analysis Results mg/l	HENDRINA WTP RAW INLET	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	20	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	15,6	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	76	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	7,09	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	6,19	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	57		
	LPM 84	Free Chlorine as Cl_2 *	<0.1	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76A	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15E	Calcium as Ca	11,2		
	LPM 76A	Chlorides as Cl	5,25	Aesthetic	≤300
	LPM 76A	Fluoride as F	<0.20	Chronic Health	≤1.5
	LPM 15E	Magnesium as Mg	6,99		
	LPM 76A	Nitrate NO_3 as N	0,36	Acute Health	≤ 11
	LPM 76A	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15E	Sodium as Na	7,10	Aesthetic	≤ 200
	LPM 76A	Sulphate as SO_4	15,8	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15E	Potassium as K	1,99		
	LPM 15	Zinc as Zn	0,02	Aesthetic	≤5
Micro Determinants µg/l					
	LPM 15	Aluminium as Al	292	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	<1	Chronic Health	≤ 10
	LPM 67	Barium as Ba	38,3	Chronic Health	≤ 700
	LPM 15	Boron as B	<10	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	11,6	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	<1		
	LPM 67	Copper as Cu	1,38	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	250	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	12,1	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	<1	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	1,91	Chronic Health	≤ 70
	LPM 67	Selenium as Se	<1	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 67	Vanadium as V	3,40		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	2,76	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

QUALITY CONTROL CHECKS	
Cation Balance	1,54
Anion Balance	1,64
% Difference	-3,4
Measured TDS	76
Calculated TDS	83
Limits	0,9
Calcul TDS / E.C.	0,5

P.L.G UYS / A. KOHRS
Technical Signatory
Electronic Signature

2.4. Hendrina (Pullensehope) Water Treatment Plant final water quality.

STEVE TSHWETE LOCAL MUNICIPALITY

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	9-Nov-2021
Date Reported	17-Nov-2021
Dates Analysed:	09-Nov-2021 to 17-Nov-2021
Quantity Analyzed :	11
Our Ref :	STL / 219 - 229/ B / 11/21
Lab No :	B228

	LPM METHOD	Analysis Results mg/l	HENDRINA WTP POTABLE FINAL	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	4	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	15,5	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	102	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	7,33	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	0,71	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	53		
	LPM 84	Free Chlorine as Cl_2 *	<0.1	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76A	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15E	Calcium as Ca	11,4		
	LPM 76A	Chlorides as Cl	5,50	Aesthetic	≤300
	LPM 76A	Fluoride as F	<0.20	Chronic Health	≤1.5
	LPM 15E	Magnesium as Mg	7,20		
	LPM 76A	Nitrate NO_3 as N	0,36	Acute Health	≤ 11
	LPM 76A	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15E	Sodium as Na	6,97	Aesthetic	≤ 200
	LPM 76A	Sulphate as SO_4	16,6	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15E	Potassium as K	1,91		
	LPM 15	Zinc as Zn	<0.01	Aesthetic	≤5
Micro Determinants µg/l					
	LPM 15	Aluminium as Al	27,5	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	<1	Chronic Health	≤ 10
	LPM 67	Barium as Ba	36,3	Chronic Health	≤ 700
	LPM 15	Boron as B	<10	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	<1	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	<1		
	LPM 67	Copper as Cu	1,17	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	21,1	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	<10	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	<1	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	1,56	Chronic Health	≤ 70
	LPM 67	Selenium as Se	<1	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 67	Vanadium as V	1,40		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	2,26	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

QUALITY CONTROL CHECKS	
Cation Balance	1,52
Anion Balance	1,59
% Difference	-2,2
Measured TDS	102
Calculated TDS	82
Limits	1,2
Calcul TDS / E.C.	0,5



P.L.G UYS / A. KOHRS

Technical Signatory

Electronic Signature

2.5. Rietkuil (Arnot) Water Treatment Plant final water quality.

STEVE TSHWETE LOCAL MUNICIPALITY

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	8-Nov-2021
Date Reported	17-Nov-2021
Dates Analysed:	08-Nov-2021 to 17-Nov-2021
Quantity Analyzed :	4
Our Ref :	STL / 34 - 37 / B /11/21
Lab No :	B34

	LPM METHOD	Analysis Results mg/l	RIETKUIL	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	4	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	18,7	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	84	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	8,42	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	0,52	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	59		
	LPM 84	Free Chlorine as Cl_2 *	2.6 ##	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76A	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15	Calcium as Ca	11,1		
	LPM 76A	Chlorides as Cl	12,2	Aesthetic	≤300
	LPM 76A	Fluoride as F	<0.20	Chronic Health	≤1.5
	LPM 15	Magnesium as Mg	7,14		
	LPM 76A	Nitrate NO_3 as N	0,39	Acute Health	≤ 11
	LPM 76A	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15	Sodium as Na	12,2	Aesthetic	≤ 200
	LPM 76A	Sulphate as SO_4	16,2	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15	Potassium as K	1,94		
	LPM 15	Zinc as Zn	0,02	Aesthetic	≤5
Micro Determinants µg/l					
	LPM 15	Aluminium as Al	94,2	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	<1	Chronic Health	≤ 10
	LPM 67	Barium as Ba	31,6	Chronic Health	≤ 700
	LPM 15	Boron as B	13,8	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	<1	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	<1		
	LPM 67	Copper as Cu	1,97	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	40,8	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	<10	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	1,17	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	1,77	Chronic Health	≤ 70
	LPM 67	Selenium as Se	<1	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 15	Vanadium as V	<1		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	1,59	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory. ## Chlorine reading supplied by client

QUALITY CONTROL CHECKS	
Cation Balance	1,73
Anion Balance	1,89
% Difference	-4,3
Measured TDS	84
Calculated TDS	97
Limits	0,9
Calcul TDS / E.C.	0,5

P.L.G UYS / A. KOHRS

Technical Signatory

Electronic Signature

2.6. Komati Water Treatment Plant final water quality.

STEVE TSHWETE LOCAL MUNICIPALITY

P. O Box 14 MIDDELBURG 1050

CERTIFICATE OF ANALYSIS

Date Received:	12-Nov-2021
Date Reported	23-Nov-2021
Dates Analysed:	12-Nov-2021 to 23-Nov-2021
Quantity Analyzed :	3
Our Ref :	STL / 692 - 694 /B / 11/21
Lab No :	B694

	LPM METHOD	Analysis Results mg/l	KOMATI	SANS Standards -241 : (2015) Drinking Water	
				Risk	Standard Limits
Physical requirements					
	LPM 92	Colour as Pt-Co *	5	Aesthetic	≤ 15
	LPM 51	Conductivity at 25° C (mS/m)	25,7	Aesthetic	≤ 170
	LPM 2	Total Dissolved Solids	144	Aesthetic	≤ 1 200
	LPM 51	pH Value at 25 ° C (pH units)	8,34	Operational	≥ 5.0 to ≤ 9.7
	LPM 23	Turbidity (NTU)	0,50	Operational Aesthetic	≤ 1.0 ≤ 5.0
	LPM 11	Total Alkalinity as $CaCO_3$	65		
	LPM 84	Free Chlorine as Cl_2 *	0.6##	Chronic Health	≤ 5
	LPM 84	Monochloramine *	<1.0	Chronic Health	≤ 3
Macro Determinants					
	LPM 76K	Free & Saline Ammonia as N	<0.20	Aesthetic	≤ 1.5
	LPM 15	Calcium as Ca	15,9		
	LPM 76K	Chlorides as Cl	21,0	Aesthetic	≤300
	LPM 76K	Fluoride as F	<0.20	Chronic Health	≤1.5
	LPM 15	Magnesium as Mg	8,46		
	LPM 76K	Nitrate NO_3 as N	0,34	Acute Health	≤ 11
	LPM 76K	Nitrite NO_2 as N	<0.1	Acute Health	≤ 0.9
	-	Nitrite - Nitrate Ratio	<1.0		≤ 1
	LPM 15	Sodium as Na	22,9	Aesthetic	≤ 200
	LPM 76K	Sulphate as SO_4	30,6	Acute Health Aesthetic	≤ 500 ≤ 250
	LPM 15	Potassium as K	3,30		
	LPM 15E	Zinc as Zn	0,01	Aesthetic	≤5
Micro Determinants µg/l					
	LPM 67	Aluminium as Al	41,6	Operational	≤ 300
	LPM 67	Antimony as Sb	<1	Chronic Health	≤ 20
	LPM 67	Arsenic as As	<1	Chronic Health	≤ 10
	LPM 67	Barium as Ba	42,4	Chronic Health	≤ 700
	LPM 15E	Boron as B	20,2	Chronic Health	≤ 2 400
	LPM 67	Cadmium as Cd	<1	Chronic Health	≤ 3
	LPM 15	Total Chromium as Cr	<1	Chronic Health	≤ 50
	LPM 67	Cobalt as Co	<1		
	LPM 67	Copper as Cu	1,47	Chronic Health	≤ 2000
	LPM 80K	Cyanide as CN *	<70	Acute Health	≤ 200
	LPM 15	Iron as Fe	152	Chronic Health Aesthetic	≤ 2000 ≤ 300
	LPM 67	Lead as Pb	<1	Chronic Health	≤10
	LPM 67	Manganese as Mn	23,4	Chronic Health Aesthetic	≤ 400 ≤ 100
	LPM 67	Mercury as Hg	<1	Chronic Health	≤ 6
	LPM 67	Nickel as Ni	2,23	Chronic Health	≤ 70
	LPM 67	Selenium as Se	1,57	Chronic Health	≤ 40
	LPM 67	Uranium as U (238)	<1	Chronic Health	≤ 30
	LPM 15	Vanadium as V	2,10		
Organics Determinand					
	LPM 68I	Total Organic Carbon mg/l	2,74	Chronic Health	≤ 10
	LPM 73	Total Trihalomethanes µg/l *	Attached	Chronic Health	
	LPM 95	Mycrosystin as LR µg/l *	<1	Chronic Health	≤1
	LPM 73	Phenolic Compounds µg/l*	Attached	Aesthetic	≤ 10

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested.These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory. ## Chlorine reading supplied by client

QUALITY CONTROL CHECKS	
Cation Balance	2,58
Anion Balance	2,55
% Difference	0,5
Measured TDS	144
Calculated TDS	142
Limits	1,0
Calcul TDS / E.C.	0,6



P.L.G UYS / A. KOHRS

Technical Signatory

Electronic Signature