The Impact of the Blue Drop certification programme on drinking water quality management in three South African municipalities.

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Declaration

I, AUGUST RODNEY MASHELE, declare that the thesis; **The Impact of the Blue Drop certification programme on drinking water quality management in three South African municipalities** which I hereby submit for the degree: MSc: Water Resource Management at University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE…………………………………………………………………

DATE…………………………………………………………………………

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Abbreviations and Acronyms

- ANOVA: Analysis of Variance
- BDS: Blue Drop System
- CoT: City of Tshwane
- DWA: Department of Water Affairs
- DWAF: Department of Water Affairs and Forestry
- DWI: Drinking Water Inspectorate
- DWS: Department of Water and Sanitation
- *E.coli:* *Escherichia coli*
- HPC: Heterotrophic Plate Count
- mg/l: Milligram per Litre
- MS: Microsoft
- NTU: Nephelometric Turbidity Unit
- RSA: Republic of South Africa
- SALGA: South African Local Government Association
- SABS: South African Bureau of the Standards
- SANS: South African National Standards
- TDS: Total Dissolved Solids
- TLM: Tzaneen Local Municipality
- TON: Threshold Odour Number
- WHO: World Health Organisation
- WRC: Water Research Commission
- WSA: Water Services Authority
- WSI: Water Services Institutions

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Glossary

Borehole: An excavation which is used for the purpose of collecting and storing water that is obtained from the underground aquifer.

Capacity: This term is used in relation to municipalities. It relates to financial, administrative and human resources that a municipality may require in order to fulfil the management responsibilities.

Consumer: The user of water provided for by the appointed water service authority.

Response monitoring: incident management and monitoring of drinking water quality when the numerical limits specified in SANS 241 – 1 are exceeded.

Determinand: micro-organism, physical or aesthetic property or chemical substance.

Drinking Water: water that is intended for human consumption

Water Board: operate water services infrastructure, bulk water drinking water supply systems schemes (selling to municipalities and industries) some retail water infrastructure systems.

Water quality monitoring: establishment and implementation of operational and compliance water quality monitoring programmes, including the location of sampling points, sampling frequency and determinands.

Water Safety Plan: a comprehensive water quality management system based on the principles of preventative of preventative risk management.

Water Services Authority: Metropolitan municipalities, some District municipality, and authorised local municipalities are responsible for ensuring provision of water services within their area of jurisdiction.

Water Services Institution: Water Services Authority or Water Services Provider (or both).

Abstract

The aim of the study was to determine the impact of drinking water quality performance following the introduction of the Blue Drop Certification Programme as a mainstream regulation means to ensure that formal drinking water supplies comply with the South African National Standards. The Blue Drop Certification Programme is an innovative means to regulation which was designed and implemented with the core objective of safeguarding the tap water quality management. The study has focused on the drinking water quality performance with regard to microbiological, chemical, physical and operational compliance in the distribution system. Every effort should be made to achieve drinking water that is safe for human consumption by Water Suppliers. Safe drinking water, as defined by the World Health Organization (WHO) Guidelines and SABS (SANS 241) does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Control of the microbial, chemical, physical and operational quality of drinking water requires the development of management plans. These plans should be implemented to provide the basis for system protection and process control to ensure that the number of pathogens and concentrations of chemicals present a negligible risk to public health and that water is acceptable to consumers.

The study has reviewed drinking water quality performance following an introduction of the Blue Drop certification programme in the following municipalities; Tzaneen municipality within the Mopani District municipality, the Sekhukhune District municipality and the Tshwane Metropolitan municipality. The study has used the water quality determinands data available on the Blue Drop System (BDS). Chemical determinands analysis considered for the study is iron, sulfate, manganese, magnesium, arsenic, nitrate, sodium and calcium. Water quality determinands analyses considered for the study are conductivity, pH, turbidity, colour and odour, free chlorine. One-way ANOVA (analysis of variance) had been used to determine significant differences by comparing the water quality determinands data to determine the p-value in the period between 2010 and 2014 only of the selected determinands. If p-value is < 0.05 reject H_0, there is a significant difference and if $p > 0.05$ the study fails to reject H_0– there is not enough evidence of significant difference.

The study has noted significant improvement in terms of microbiological compliance from 2010 until 2014 within City of Tshwane. Some of the supply systems have maintained consistent microbiological, chemical, operational and physical compliance in the distribution system. The study also noted some decline in water quality on other water supply systems due to non-availability of the water quality data. The Department as a Regulator may have had an influence on strengthening of the drinking water compliance with the municipality to enable the water supply system to achieve the Blue Drop status.

1. Introduction

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking water can result in tangible benefits to health (WHO, 2011). Every effort should be made to achieve drinking water that is safe for human consumption by Water Suppliers (WHO, 2011).Safe drinking water, as defined by the World Health Organization (WHO) Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (WHO, 2011). WHO (2011) further states that those at greatest risk of waterborne disease are infants and young children, people who are debilitated and the elderly, especially when living under unsanitary conditions.

Watson and Lawrence (2003) states that safe drinking water has been taken for granted in the developed world. Diseases related to contamination of drinking water constitute a major burden on human health and interventions to improve drinking water provide significant benefits to health (WHO, 2011).According to the European Community directives, drinking water fulfil the quality requirements at the consumers tap (Lehtola *et al*., 2004). Therefore drinking water of high quality has to be maintained throughout the distribution, including through household plumbing. It is known that microbial growth in drinking water and biofilms cause aesthetic and health problems (WHO, 2011).

WHO (2011) states that overall control of the microbial and chemical quality of drinking water requires the development of management plans. Those plans should be implemented to provide the basis for system protection and process control to ensure that numbers of pathogens and concentrations of chemicals present a negligible risk to public health and that water is acceptable to consumers (DWAF, 2009b and WHO, 2011). In South Africa, the Blue Drop Certification programme was introduced as a mainstream regulation means to ensure that formal water supplies comply with the South African National Standards (SANS 241) (DWA, 2011a). Meeting this goal could be faced with many challenges that are confronting the Water Services Authorities due to limited capacity and resources within the municipalities (DWAF, 2009b).

There is increasing recognition that simple local approaches to ensure drinking water safety should be incorporated into country strategies to reduce waterborne diseases (WHO, 2013). In recognition of the importance of safe drinking water to public health, the Department of Water Affairs and Forestry in 2009 drafted a Drinking Water Quality Framework for South Africa to enable effective management of drinking water quality and protection of health (DWAF, 2009b). The Department has noted that access to safe drinking water is a basic human right and essential to people’s health. Safe water that complies with the South African National Standard (SANS 241) drinking water specifications does not pose a significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages (SABS, 2006 and DWAF, 2009a).

The Department followed a process of conducting consultative audits at all water services authorities (municipalities) and water boards to assess drinking water quality operations and management performance in line with the set Blue Drop Requirements (DWA, 2013). This study looked at the drinking water quality performance following an introduction of this incentive based regulation (Called Blue Drop Certification Programme) in the water sector. The first ever Blue Drop report released in 2009 indicated that the national microbiological compliance for South African tap water was measured at 93.3% against the National Standard (DWAF, 2009a). The Department of Water Affairs (2012) reported that drinking water quality increased to 97.3% in the 2012 Blue Drop reporting cycle in spite of a significant increase in data sets being available of analyses done on tap water by various laboratories.

1.1 Research Problem

The quality of the source water is deteriorating rapidly due to water pollution and human activities throughout the world (Chang *et al*., 1999). Providing safe, reliable tap water to every household is an essential goal (WHO, 2013). WHO (2013) continues to suggests that both rural and urban population have access to sufficient quantities of water but that water is unsafe for human consumption as result of microbial or chemical contamination. The microbial quality of surface is of great concern in a number of areas in South Africa (Venter et al., 1998). Diarrhoea continues to be a public health challenge in South Africa rural and peri-urban areas due to lack of access to safe water (Momba *et al.*, 2010). Primary objective of Drinking Water Regulation is the protection of public health through improving general drinking water quality management in South Africa (DWAF, 2009b).

The South African Bureau of Standards (SABS) sets out the basic water quality determinand limits that every WSI should strive to achieve in order to provide the cleanest, safest and most reliable drinking water possible (SABS, 2006, SABS, 2011). Safe drinking water is defined by the World Health Organisation as water that has acceptable quality in terms of its physical, chemical and bacteriological parameters (WHO, 2011). Drinking water contaminated with *Escherichia coli* (*E. coli)* is known to cause stomach and intestinal illnesses including diarrhoea and nausea, and can even lead to death (Gwimbi, 2011). It is known that microbial growth in drinking water and biofilms that cause aesthetic and health problems, therefore high quality drinking water has to be maintained throughout the distribution, including passage through household plumbing (Lehtola *et al*. 2004).

1.2 Research Statement

The Blue Drop Certification Programme is an innovative means to regulation which was designed and implemented with the core objective of safeguarding the tap water quality management.

1.3 Research Question

- Does the incentive based regulation improve the drinking water quality within the municipalities?
- What is the microbiological compliance of drinking water in the distribution system?
- What is the chemical compliance of drinking water in the distribution system?
- What is the physical compliance of drinking water in the distribution system?
- What is the operational compliance in the distribution system?

1.4 The aim and objectives of the Study

The aim of the study was to assess whether the introduction of the Blue Drop certification programme in the Tzaneen municipality within the Mopani District municipality, the Sekhukhune District municipality and the Tshwane Metropolitan municipality following its inception as an Incentive Based Regulation since 2008 contributed towards the improvement of drinking water quality. The following were the objectives of the study:

- To determine an improvement of microbiological quality compliance in drinking water.
- To determine an improvement of chemical determinands compliance in drinking water.
- To determine an improvement of physical determinands compliance in drinking water.
- To determine an improvement of operational determinands in drinking water.

1.5 Study areas

One of the study areas is the City of Tshwane, Pretoria Central and South supply system. City of Tshwane is one of the Metropolitan Municipalities situated in the Northern part of the Gauteng province in South Africa. Pretoria covers 687.54 km^2 and has a population of approximately2 921488(Stats SA, 2011). Pretoria as a capital city hosts Government institutions such as National Government Departments. City of Tshwane receives bulk treated water from the Rand Water Board and also provides water treated by their own water treatment plants to consumers within their municipal area.

City of Tshwane owns water treatment facilities such as Rietvlei, Temba, Pretoria Fountains and other water treatment works outside of Pretoria. The study has chosen the biggest supply system, Pretoria Central and South water supply system which receives bulk treated water from the Rand Water Board as well as municipal treated water from the Rietvlei and Fountain water treatment facilities.

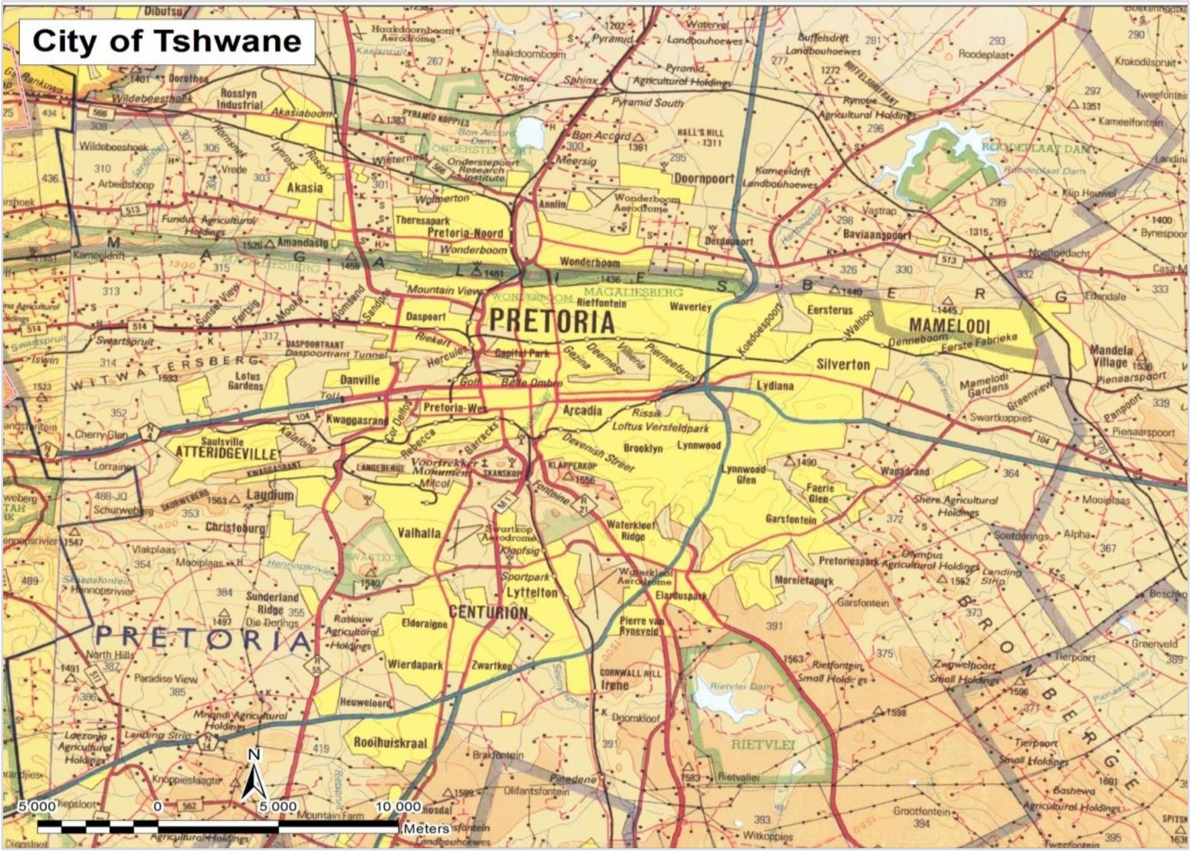

Figure 1: City of Tshwane

Greater Sekhukhune District Municipality

The Greater Sekhukhune District Municipality is a Category C municipality and is located in the Limpopo province, the most northern part of South Africa. The district is located in the south-eastern part of the province and has five local municipalities: Makhuduthamaga, Greater Tubatse, Elias Motsoaledi, Ephraim Mogaleand Fetakgomo. The Greater Sekhukhune District Municipality covers an area of 13527.7 km^2 and is home to a population of approximately 1 076 840 (STATS SA, 2011). The Greater Sekhukhune District Municipality has its own water treatment facilities which treats and supplies the majority of its consumers while some areas receives bulk water supply from Lepelle Northern Water Board and Dr J.S Moroka Local Municipality (DWA, 2012) as water service providers.

The study at the Greater Sekhukhune District municipality has considered three main water supply systems namely Burgersfort, Flag Boshielo and Groblersdal water supply systems and they are within the jurisdiction of the municipality as shown in Figure 2.

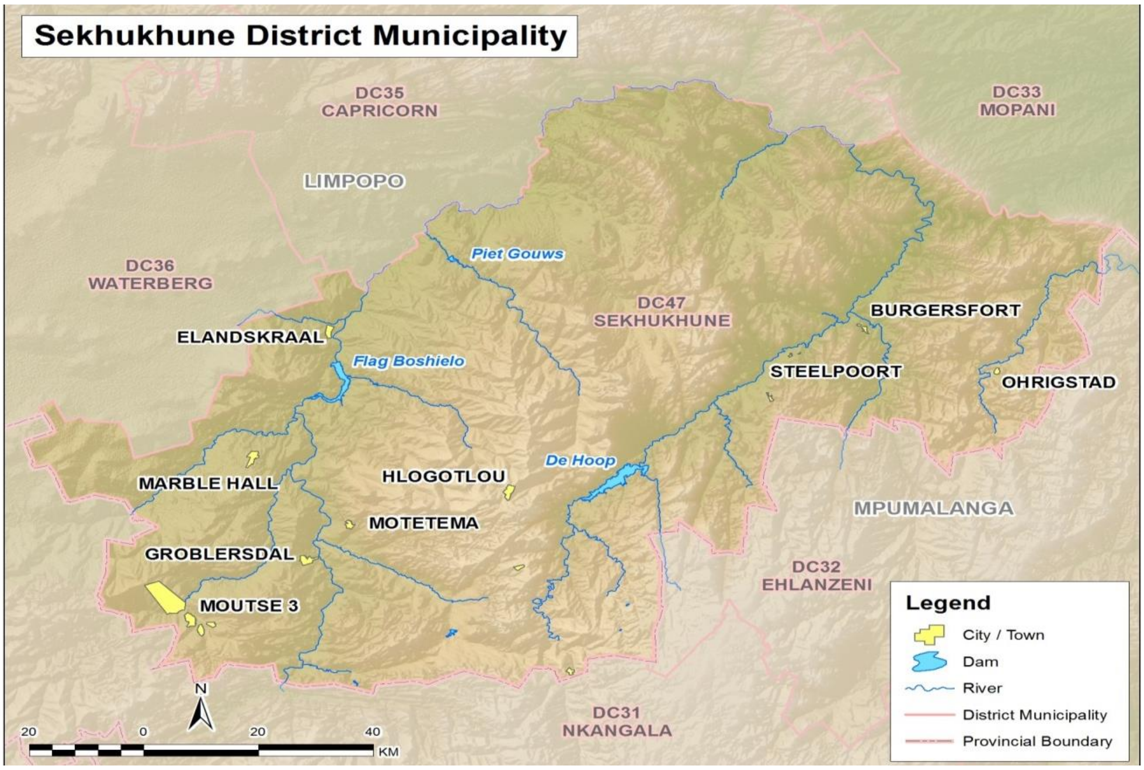

Figure 2: Sekhukhune district municipality

Flag Boshielo Dam was built in 1987 for irrigation of agriculture downstream of the dam, to supply municipal water to Polokwane, and to ensure dry-season water storage for mines in the area (Van Koppen, 2008 and Dabrowski *et al*., 2014). Flag Boshielo dam as shown in the Figure below also supply raw water to most of the villages within the local municipalities under Greater Sekhukhune District Municipality. The study continues to indicate that through long-term monitoring of the water during the drought seasons, the quality of the water deteriorated, with high levels of dissolved salts, especially potassium (K), sodium (Na), chloride (Cl), fluoride (F), and total alkalinity. Following the drought, dissolved salt concentrations dropped, and there was a brief flush of inorganic N and P (Dabrowski *et al*., 2014).

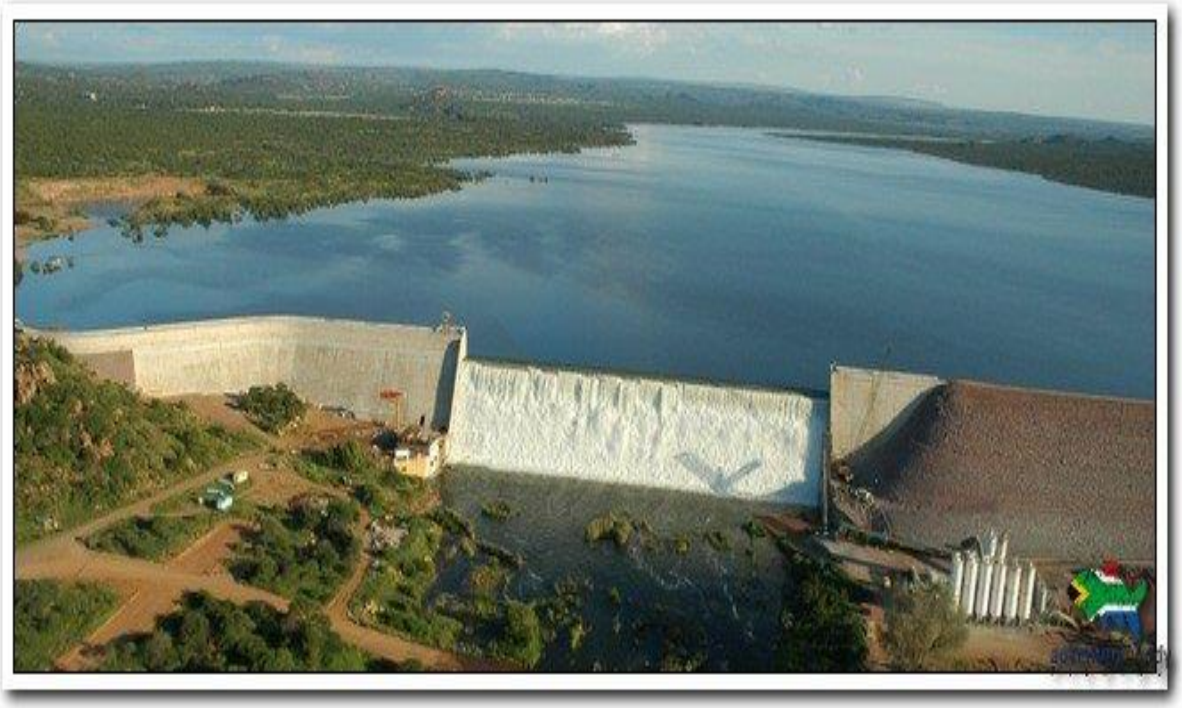

Figure 3: Flag Boshielo Dam in Greater Sekhukhune District Municipality

Tzaneen Local Municipality

Tzaneen is one of the five local municipalities within the Mopani District Municipality within the Eastern part of the Limpopo Province. It is characterised by extensive and intensive farming activities and considerable untapped tourism potential. Tzaneen local municipality covers a population of approximately 390 095 (STATS SA, 2011).

The Tzaneen Local Municipality operates the supply of water for two water supply systems on behalf of the Mopani District Municipality namely Tzaneen town and Letsitele water supply systems as shown in Figure 4. The study has chosen this local municipality in Limpopo and operates its own water treatment works. Tzaneen Municipality area encompasses the proclaimed towns of Tzaneen, Nkowankowa, Lenyenye, Letsitele and Haenertsburg. In addition, there are 125 rural villages, concentrated mainly in the south-east, and north-west of the study area. Tzaneen source its raw water from the Letaba River and Fanie Botha Dam as shown in Figures 4 and 5 below.

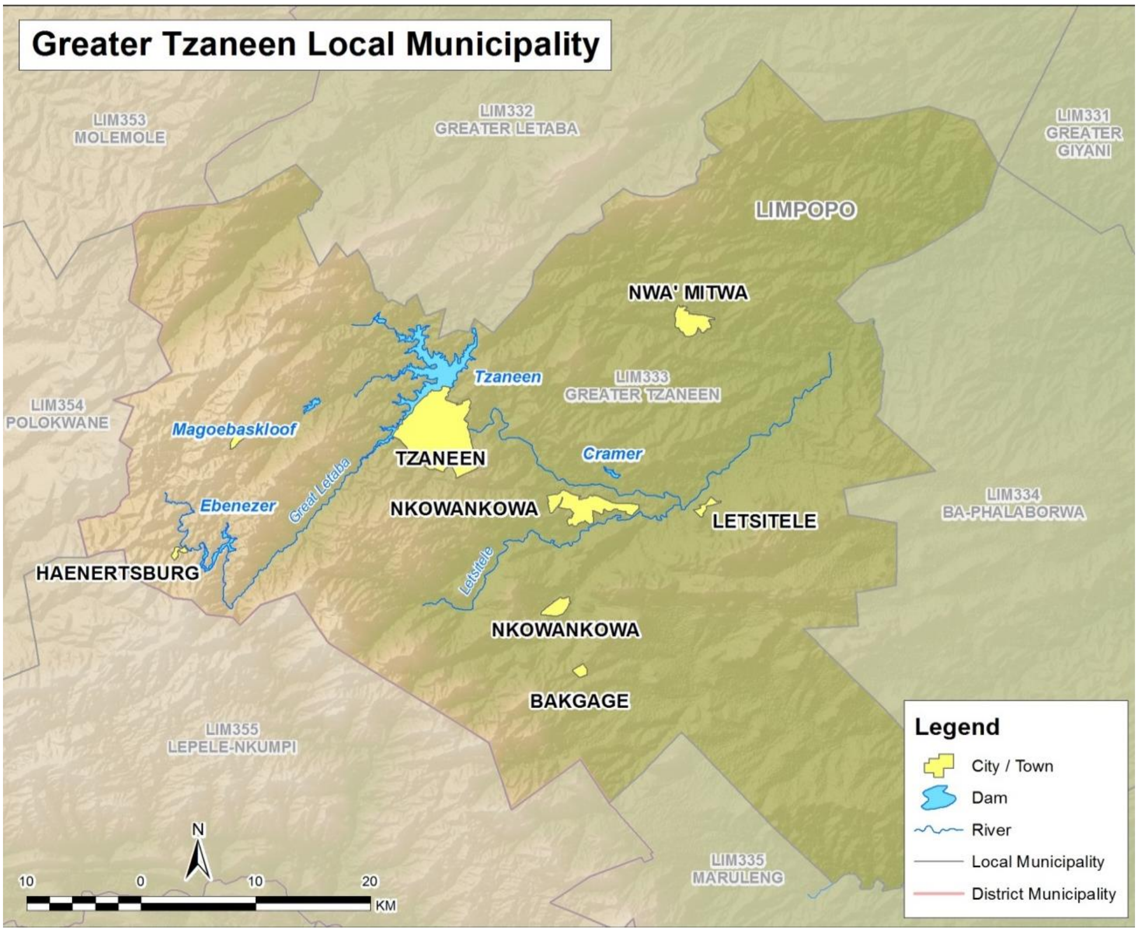

Figure 4: Greater Tzaneen local municipality

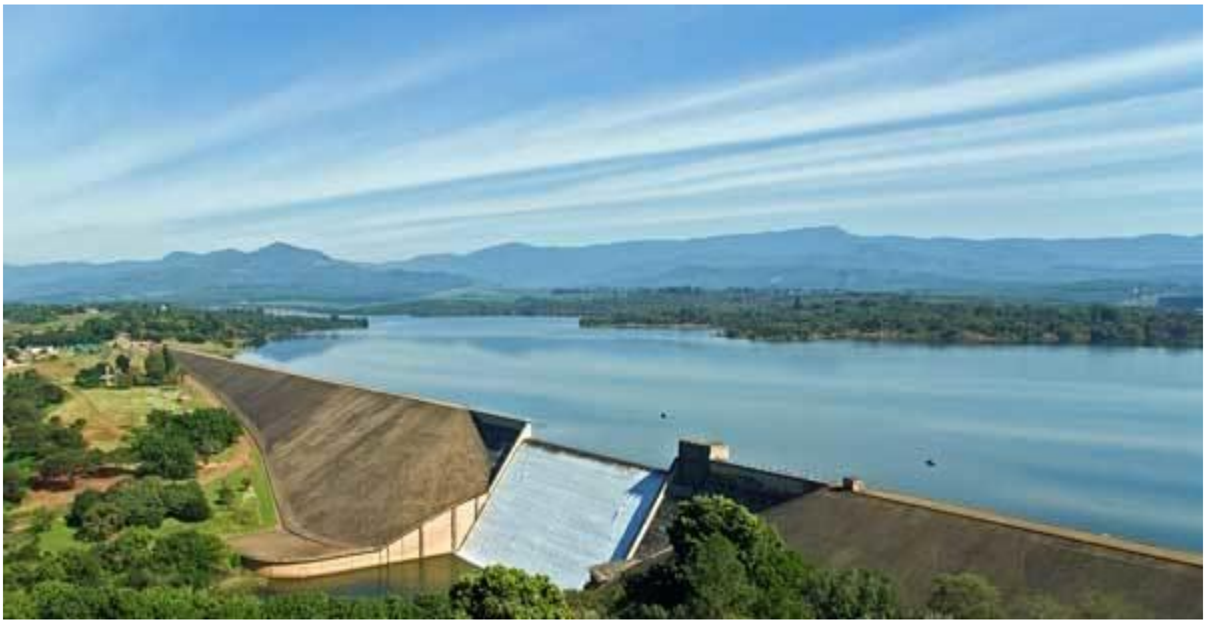

Figure 5: Fanie Botha Dam

2. Literature Review

2.1 International Drinking Water Quality Management

The quality of the source water is fast deteriorating due to different factors including pollution and human activities throughout the world (Chang *et al*., 1999). Over thirty-five countries worldwide have water monitoring and reporting systems that have well documented cases of either voluntarily or mandatorily implemented Water Safety Plans (WSPs), or their equivalent under other names, that serve as a preventive risk management approach in an effort to ensure the safety of drinking water (Baum *et al*., 2015). The proactive management such as managing drinking water from catchment to consumer becomes international best practice (DWA, 2011a). Although WSPs have been implemented in more countries including South Africa, a lack of documented cases in these areas suggests more research needs to be done in order to successfully advertise the benefits of the WSP approach throughout different regions of the world (Baum *et al*., 2015). Kayser *et al*., (2015)state that the provision of safe drinking water rests with the municipalities or government entities of countries and examples such as Ecuador, Brazil and Malawi can be looked at which is similar to the practice in South Africa. This scientific paper reveals that the municipalities or government entities of the mentioned countries are facing common challenges such as lack of technical skills, lack of financial resources, and poor operation and maintenance of the treatment plants (Kayser *et al*., 2015). This scientific paper reveals that, in Ecuador, Brazil and Malawi, there are significant gaps in the management of drinking water quality due to inadequate resources or scarce financial resources.

Marlow *et al*., (2014) refers to the studies done in the USA where a widespread deterioration of water infrastructure is highlighted. This paper further suggests even after adequate treatment, water quality can be compromised within the pipes network, especially if non-potable water enters into the water supply system (Marlow *et al*., 2014). Similar to South Africa, according to Baum *et al*., (2015) the United States of America (USA) implemented voluntary management program practices to improve drinking water quality. These management programs have been reported to be successful in improving drinking water quality (Baum *et al*., 2015). The WHO (Drinking Water Quality Guidelines) has recommended implementation of a Water Safety Plan (WSP) to ensure safety of drinking water and protection of the public's health (WHO, 2011). In South Africa, the Department of Water and Sanitation (DWS) has adopted a WSP approach to manage the quality of drinking water from source to tap (DWA, 2011a). The most effective means of consistently ensuring the safety of a drinking water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer (WHO, 2011).

Baum *et al*., (2015) emphasise that the water systems which have implemented WSPs have seen an increase in regulatory compliance, improvements in microbiological water quality, decreases in the incidence of clinical cases of diarrhoea, greater customer satisfaction and better asset management that lead to potential financial benefit. Sobsey (2006) reveals that despite the developed world's preoccupation with addressing a growing list of chemicals and their purported but mostly unproven health risks, the greatest risks of waterborne disease globally and in the United States are still from microbes. WHO (2011) revealed that the greatest risk to the public health is associated with consumption of contaminated drinking water with animal and human excrete. Microbes cause illness and kill people and contaminated drinking water contributes substantially to the global burden of waterborne infectious diseases (Sobsey, 2006). Managing faecal pollution can be challenging for many less economic developed countries due to inadequate public resources and reliable information about the extent, sources, risks and severity of faecal pollution (Nnane *et al*., 2011).

2.2 Drinking Water Quality Management in South Africa

The South African Bill of Rights gives everyone the right to an environment that is not harmful to their health or wellbeing (Constitution, 1996). It further states that everyone has the right to access of sufficient food and water (Constitution, 1996). This includes constant provision of clean and safe water (Momba *et al*., 2010). The Constitution gives the responsibility for provision of water services to Local Government i.e. Water Services Authorities (The Constitution of SA, 1996 and Water Services Act, 1997). In the South African context, the Minister of the Department of Water and Sanitation (DWS) has a role to ensure that water services are provided to the consumers through regulating and supporting the WSAs (Water Services Act, 1997).

The strategic framework for water services states that the drinking water provided to the public by Water Services Institutions (WSIs) should comply with the South African National Standard for Drinking Water (SANS) 241 (DWAF *et al*., 2003). SANS 241 is the definitive reference on acceptable limits for drinking water quality determinands in South Africa and provides limits for a range of water quality characteristics (DWA, 2011a, SABS, 2015). The SANS 241 (SABS, 2006) states that drinking water must meet the determinands' numerical limits set in the standards as confirmation that the drinking water is safe for human consumption. Both the drinking water standard and the Department of Water Affairs and Forestry (DWAF) state that the WSIs should develop and implement adequate water quality monitoring programmes to ensure the delivery of safe drinking water to the consumers (RSA, Government Gazette, 2001, SABS, 2006). The National Regulator has a responsibility of safeguarding drinking water quality by ensuring that the potable or drinking water provided to the public meet the minimum requirements of SANS 241 (DWA, 2010a).

There has been public perception generally in and outside South Africa that municipal tap water is not fit for human consumption and poses human health risks to consumers (Slabbert, 2011). The Department of Water Affairs and Forestry in 2009, introduced the incentive based programme for drinking water quality (Blue Drop certification programme) to stimulate performance of the drinking water quality management in the country and provide accurate information to the public on drinking water quality performance (DWAF, 2009a, DWA, 2010).

South Africa benchmark itself against the WHO guidelines by managing water from catchment to tap (DWAF, 2009b). It is therefore expected of the country to adopt some of the drinking water guidelines such as the WHO drinking water guidelines principles to better improve the drinking water quality by following the Water Safety Planning process (DWAF, 2009b). South Africa commenced implementing the WSP approach in 2009 on specific water supply systems within the country (DWA, 2012). It was further extended to all water supply systems in the country during the 2012 Blue Drop audit cycle (DWA, 2012).

2.3 Blue Drop Certification Programme

The Blue Drop certification programme is an innovative means to regulate compliance of drinking water services provision by the WSAs (DWA, 2011a). It was designed and implemented with the core objective of managing and safeguarding the quality of tap water in the country (DWA, 2012). Though the participation in the programme is not clearly stated in the legislations, the Department uses section 82 (1e) of the Water Services Act (108 of 1997) which states that failure or refuse to give information, give false information or misleading information when required by the Minister of Water Affairs is an offence and liable on conviction of a fine or imprisonment or to both.

The Department combines both the regulatory standards and international best practices as part of the Blue Drop certification programme which allows proactive management and regulation of drinking water quality (DWA, 2013). The DWS uses both incentive based regulation, compliance monitoring in terms of Norms and Standards and punitive regulations i.e. enforcement to monitor performance of the WSAs (DWA, 2013). The Certification is obtained as an acknowledgement of Excellent Drinking Water Quality Management, this surpasses the requirements of the national norms therefore where the water complies very well with expected standards but there might be some shortcomings identified with the overall risk management (DWA, 2012). DWS further states it is important to note that none of these regulatory approaches takes preference over the other but are being used to improve drinking water quality (DWA, 2013). The Blue Drop requirements against which the WSIs are assessed to achieve Blue Drop Certification are: Water Safety planning process, drinking water quality process management and control, drinking water quality compliance, management accountability and local regulation and Asset management. Each of the Key Performance Areas (KPA) has key performance indicators (DWA, 2011b).

- Water safety planning process - This key performance area focuses on whether the WSIs has a team of technical experts such as technical, financial and management staff of the WSI participating in the process (DWA, 2011b). The water safety planning process focuses on the risk assessment from source to tap as well as the development and implementation of water quality monitoring programmes.
- Drinking Water Quality process management and control – This key performance area only focuses on the classifications of the water services treatment works and Process Controllers by applying the

requirements stipulated in the Regulation 2834 and draft Regulation 813 (RSA,1985 and RSA Government Notice, 2013) respectively.

- Drinking water quality verification – this KPA focuses on drinking water quality compliance. It should be noted that the drinking water quality compliance contributes a significant percentage to the total KPAs of the Blue Drop requirements (i.e. 30%) (DWA, 2013).
- Management Accountability and Local Regulation – this KPA focuses on the management commitment through Service Level Agreements of supplying safe drinking water to consumers and proof of publication of water quality performance to the consumers using different media. This could be demonstrated through approval of water safety plans, signed water quality monitoring programmes, water services development plans and operations and maintenance plans.
- Asset Management – this KPA focuses on management of assets to ensure that international best practice is adhered to by the WSIs by requiring operational and maintenance budgets, conduct process audits to ensure continual provisioning of safe drinking water and maintenance of assets.

These Blue Drop requirements are communicated to the water sector through the Department of Water and Sanitation’s published Blue Drop handbook that specifies requirements for each Blue Drop Assessment cycle (DWA, 2013). All the water supply systems scoring 95% and above receives regulatory acknowledgment and is awarded the Blue Drop status for excellent performance (DWA, 2010). Blue Drop status is awarded as a sign of acknowledging excellence in the manner that the WSI is managing drinking water (DWA, 2013).

2.4 Drinking water compliance with the regulatory requirements in South Africa

Unsafe drinking water poses health threats to consumers (DWA, 2010). The quality of drinking water should comply with the microbiological, physical, aesthetic and chemical determinands numeric limits as stated in SANS 241 (SABS, 2006). The majority of small water treatment systems fail to produce drinking water quality that conforms to the SANS 241 standard (Momba *et al*., 2010). There was a scientific study conducted by Luyt *et al*., (2012) which also revealed that infectious diseases rose to 61% in the country and some of the infectious diseases could be pointed to waterborne diseases from domestic water supplies. The key to ensure clean and safe drinking water is to implement multiple barriers such as coagulation/flocculation, sedimentation and filtration which remain the most effective means to reduce pathogen during water treatment (Momba *et al*., 2010). The WSI has to develop a drinking water monitoring programme which should include determinands to be tested, number of sample sites and frequency of samples to be tested, and location to take samples (DWA, 2010).

2.5 Microbiological water quality compliance

The evaluation of drinking water supplies for coliform bacteria is important in determining the quality of drinking water (Zamxaka *et al*., 2004). SANS 241 standards require the WSI to take a specific number of samples for microbiological analysis to determine microbiological water quality compliance of the drinking water in the distribution network (SABS, 2006). The *E.coli* can be used as an indicator to represent different faecal coliforms species such as *shigella* species, vibrio cholera, *Salmonella typhy* and other species associated with faecal coliforms (WHO, 2011). High faecal pollution in water becomes challenging to developing nations (Lin, 2004). Lin (2004) further states waterborne bacterial pathogens such as *E.coli 0157, Salmonella, Shigellaspp*, and *Vibrio cholerae* can lead to diarrhoea outbreaks and have implications on the economy of both developed and developing countries. This argument is emphasised by Momba *et al*., (2010) by stating that microorganisms' presence in drinking water remains a challenge especially in the era of HIV/AIDS in developing countries. This scientific paper reveals the importance to recognise that, what could be harmless to the healthy individual, could be potentially fatal to children, immune-compromised individuals and the elder population.

2.6 Drinking water meeting microbiological health standards

The SANS 241: microbial statistic compliance requirement in South Africa is 99% on an annual basis (SABS, 2006). All WSIs are expected to achieve this target to ensure that the drinking water provision to the public is safe for human consumption. The first Blue Drop report published in 2009 by the Department of Water Affairs and Forestry revealed that the average microbial compliance between 2008 and 2009 was 74.94% and 93% respectively (DWAF, 2009a). The drinking water quality microbial performance reveals poor performance against the SANS 241 requirements. It must also be noted that the regulatory approach of the Department does not necessarily criminalise a drinking water quality failures incident, but such incidents require sufficient proof (justification) that the authority (and provider) acted according to their incident management protocol (DWA, 2012). The Department requires protocol to guide towards rectification as result immediate action should be taken and follow up samples to proof correction of results to safe guide the public health (SABS, 2006, DWA, 2012). The drinking water quality compliance KPA contributed 35% of total Blue Drop certification score in 2009 and was revised to contribute 30% in the 2012 Blue Drop assessment cycle (DWAF, 2009a and DWA, 2012).

In the latest Blue Drop report published by DWA in 2012, microbiological compliance had increased to 97.3% (DWA, 2012). The Department states that this improvement could be attributed to the implementation of risk management that requires WSI to implement risk informed monitoring programmes as part of the Blue Drop requirements. A study conducted by Gunnarsdottir *et al*., (2012) states that the WSPs provide systematic evidence of the positive impacts on drinking water quality through reducing non-compliance with respect to Heterotrophic Plate Count (HPC) in both source and distribution system. Gunnarsdottir *et al*., (2012) concluded by revealing that there are significant benefits in risk management such as regulatory compliance with the drinking water standards and a reduction of waterborne diseases which resulted in improved public health. Momba *et al*., (2010) suggest that drinking water compliance could be achieved through implementing approaches that protect water sources from contamination, properly managing water treatment plants and integrity of distribution systems (Momba *et al*., 2010). Momba *et al*., (2010) continues to suggest that there must be strategies in place such as collection of appropriate information about the water sources, vulnerability and aspects that are required for water treatment to ensure sustainable production of safe drinking water.

2.7 Chemical drinking water quality compliance

There are chemicals in drinking water which are associated with health effects and there is a need for controlling chemical safety in drinking water through the development of numerical limits (Bartram and Howard, 2003). Bartram and Howard (2003) further suggest that in order to direct resources to best effect, the identification of those chemicals that may be of public health concern is important. A good knowledge of chemical qualities of raw water is necessary to guide its suitability for usage (Okonko *et al*., 2008). In South Africa, SABS have identified some chemical determinands that must be monitored at prescribed frequencies by the WSIs as stipulated in the South African National Standards 241 (SABS, 2006). This Standard necessitates drinking water to comply with the requirements of class I water for lifetime consumption in relation to the chemical requirements. Chemical compliance requires 95% and above per annum for lifetime consumption and this excludes class II water (SABS, 2006). The SANS 241 (SABS, 2006) specifies two categories of drinking water which is Class I and Class II, for all the listed determinands with different numerical limits. Class I is defined as drinking water with a quality that can be consumed for a lifetime with no health risks, while Class II drinking water is defined as water that can be consumed for a limited period of time with no health risks (SABS, 2006). This was first suggested by Kempster *et al*., (1997) that class II water may be used for short periods of time or emergency use but without intending to consume that water for a lifetime.

It is important to note that some of the chemical determinands have nutritional benefits if consumed at lower levels while on maximum levels it may pose health risks to public health hence each country has to develop its own determinand limits while considering the local environment (WHO, 2011). Bartram and Howard (2003) further suggested that by identifying chemical health determinands that are associated with large health effects to the public, such as arsenic (As) and fluoride (F), in order to direct resources to best effect for example. Schoeman and Steyn (2003) states that high levels of nitrates (N) which is (>6 mg/l) concentration in drinking water can cause an illness in infants called blue baby syndrome. The drinking water standard (SABS, 2006) requires WSI to conduct water quality risk assessments to prioritise all risks from catchment to tap (SABS, 2006). Patrick (2011) explains that investment in expensive water treatment facilities has been less successful in Canada and a more holistic approach to safe drinking water has been supported which endorses a multi-barrier approach to deliver safe water. Patrick (2011) further suggests that source water protection is a safe, logical, and affordable means of protecting human health (Patrick, 2011). As stated before, WHO (2011) guidelines suggests that WSIs should develop and implement water safety planning processes in order to be able to identify water quality hazards and prioritized high risks based on the risks that are posed to water supply systems and finally to consumers (DWA, 2013, WHO, 2011). The water quality risk management must cover a full spectrum analysis of all determinands prescribed in the drinking water quality standard (SABS, 2006).

Okonko and Mothiba (2005) revealed that there is inadequate knowledge and data specifying concentrations of heavy metals in South African surface waters. This is due to the fact that relatively few studies have been undertaken in South Africa dealing with high levels of metals, particularly their concentration in surface waters (Okonko and Mothiba, 2005). Durand (2012) points out that mines release waste into the environment that contains high concentrations of sulfate (SO_4^{2-}) and lead. Consumption of (SO_4^{2-}) in excess of 200 mg/l by humans may lead to vomiting and diarrhoea and lead can be fatal to organisms including humans (Durand, 2012). Mora *et al*., (2008) further reveal that high levels of metals in drinking water threaten human health when consumed through tap water at high concentrations. Mora *et al*., (2008) further suggests that high concentrations of heavy metals such as manganese (Mn), copper(Cu), zinc (Zn) and aluminium (Al) in drinking water may pose a risk of the development of different diseases in consumers. This emphasises Durand's (2012) scientific paper that high levels of aluminium (Al), cobalt (Co), nickel (Ni), calcium (C) and magnesium (M) may have an endocrine-disrupting effect on organisms. Durand (2012) has reported the presence of heavy metals in the river systems caused by the run off from mining activities as a result of rain water decanting into the rivers, dams and other water sources. In addition high levels of salinity (>1000 mg/l) of Total Dissolved Solids (TDS) concentration in drinking water can cause diarrhoea, high blood pressure and other health problems in people consuming such water (Schoeman and Steyn, 2003).

2.8 Meeting Chemical Health Standards in tap water

The Blue Drop programme requires chemical determinands listed in SANS 241to be monitored at least once per year (SABS, 2006). The water safety planning process serves as a drinking water quality framework that will enable a WSI to provide acceptable drinking water to consumers by identifying determinands which poses a threat to the consumers (SABS, 2015). It is noted that analysing all the chemical determinands at the point of consumption may not be cost effective or could be costly prohibitive (SABS, 2006, WHO, 2011). Implementation of WSPs could assist in prioritising a list of chemical determinands based on risks identified during the Water Safety Planning process (DWA, 2013). The Department of Water and Sanitation uses the Blue Drop Certification strategy to encourage the WSIs to implement the monitoring of all required chemical determinands from catchment to tap (DWA, 2013).

The SANS 241:2015 (SABS, 2015) further states that if a determinand exceeds the numerical limit specified in the standard, the WSI has to increase the frequency of the monitoring and remedial action have to be taken to improve the quality of tap water. The first 2009 National Blue Drop report stated that the average chemical water quality compliance exceeded the 95% target (DWA, 2009a).

2.9 Aesthetic Determinands in the tap water

Drinking water has to be palatable (SABS, 2006). This means that the water should not have unpleasant taste and odour and the appearance should be appealing for the consumers to deem it safe to drink (SABS, 2006). Consumers tend to apply taste, odour and appearance of drinking water to determine whether the water is safe to drink and can use alternative water sources that might not be safe to drink (Srinivasan and Sorial, 2011). It is worth noting that aesthetic determinands in water do not necessarily have direct impact on the safeness of the drinking water, but if aesthetic quality fails to comply with the drinking water standard, consumers will reject the water (WHO, 2011). WHO further states that the provision of drinking water that is safe and aesthetic acceptable should be of high priority with the WSI (WHO, 2011). Scientific studies show that cyanobacteria are often responsible for the taste and odour introduced into the water sources such as rivers and dams (Stander, 1980, Hu *et al*., 2003). The 2-methylisoborneol (2-MIB) and Geosmin metabolites of microbial origin are introduced through municipal discharges and non-point sources (Hu *et al*., 2003). Excessive turbidity might also result in clouding appearance and affect taste of water that also lead to rejection of the drinking water by the public (WRC,1998).

The SABS (2006) states that water shall comply with the requirements for class I for lifetime consumption in relation to the physical, organoleptic and chemical but not aesthetic requirements (SABS, 2006). The SABS (2006) has noted the cost implications of conducting aesthetic analysis. The drinking water should meet acceptable standard limits for both health and aesthetic water quality (SABS, 2015). Monitoring of electrical conductivity determinand should be part of aesthetic risks that must be monitored as part of compliance (WRC, 1998, SABS, 2015). Conductivity levels at 370 mS/m or higher has adverse effects on infants and may also have disturbance of salt and water balances on heart patients and individuals with high blood pressure or individuals with renal disease and laxative effects (WRC, 1998). The SANS 241 limit is much stricter where the conductivity levels shall not exceed 170 mS/m (SABS, 2006).

2.10 Operational determinands

Operational determinands are those determinands used to determine the efficiency of the treatment processes (SABS, 2015). This includes turbidity, standard plate count, total coliforms, pH, turbidity and other determinands (SABS, 2006). Turbidity contributes significantly in drinking water for both operational and aesthetic risks as stated by the WHO guidelines (2011) and SANS 241:2015. Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water. This parameter does not have an impact on the risk of infectious diseases (WRC, 2000). High levels of turbidity can protect microorganisms from disinfection, stimulate the growth of bacteria and give rise to a significant chlorine demand (WHO, 2011). The guideline further illustrates that microorganisms are attached to suspended solids therefore when the turbidity is removed the process also removes microorganisms in water. Turbidity as a determinand does not have a direct health impact on the consumers (WRC 2000, WRC 2001).

The WSI has to manage pH levels of the drinking water. Low pH values result in a sour taste and high pH levels result in a soapy taste (WRC, 2000). The pH level does not have direct impact on the health of consumers, but could result in the irritation of mucous and contributes toward corrosion of the infrastructure (WRC, 2000 and Kempster *et al*., 1997). The Blue Drop Certification programme requires WSIs to monitor the pH levels during every 8 hour shift at the treatment plant. Corrective measures should be taken through process controlling to adjust the pH level when it exceeds the operational numerical limits (DWA, 2013).

2.11 Developing Drinking Water Quality Monitoring Programmes

In recognition of the limitations of a compliance monitoring approach, the Drinking Water Quality Framework for South Africa is based on a preventative risk management approach, which is comprehensive from catchment to consumer (DWAF, 2009b). The guideline further reveals that this approach promotes an understanding of the entire water supply system, the events that can compromise drinking water quality in the system and the operational control necessary for optimising drinking water quality and protecting public health. RSA, Gazette No 7079 (2001) states that within two years of the promulgation of these Regulations, a water services authority must include a suitable programme for sampling the quality of potable water provided to consumers in its water services development plan. Storey *et al*., (2010) states that there is a need to rapidly detect and respond to contamination on time. The study further reiterates that water utilities worldwide should implement on-line monitoring tools and early warning systems at all stages of the urban water cycle, from intake protection and treatment operations through to the distribution systems. Hrudey *et al*., (2006) suggests that implementation of risk management processes from catchment to tap may prevent catastrophic consequences that the drinking water may pose to consumers. Monitoring of water sources assist the WSIs to understand the quality of water that may enter into the treatment plants and distribution system (WRC, 2000). Roig *et al*., (2011) points out that heavy rainfall and floods can flush sewage, microorganisms, organic wastes and chemicals into water sources and lead to contamination of drinking water supply. Freshwater supplies are influenced by temporal and geographical variation in natural and anthropogenic factors (Watson and Lawrence, 2003). Watson and Lawrence (2003) continues to states major ions, nutrients, dissolved organic compounds and metals such iron, arsenic levels in raw water vary with seasons.

The Department of Water Affairs states that implementation of monitoring programmes should assist the WSI to establish whether the water treatment operation processes needs to be optimised or not based on the quality of raw water (DWA, 2013). When raw water or source water is less polluted, less chemicals may be used to treat the water (WHO, 2011). Chang *et al*., (1999) further states that monitoring of water quality from catchment to tap will enable the WSIs to identify the risks in the water source and then upgrade or optimise the water treatment processes based on the quality of water sources. Control measures must be put in place to address all identified risks (Chang *et al*., 1999). The Department of Water Affairs encourages the WSI to understand risks from the catchment to the point of use (DWA, 2013).

2.12 Drinking Water Quality Framework

A Drinking Water Quality Framework for South Africa states that effective drinking water quality management requires an integrated approach with collaboration and commitment from all relevant stakeholders (DWAF, 2009b). The DWAF (2009b) continues to emphasise that catchments and its source water (such as groundwater, riverine source waters, storage dams and abstractions) should be assessed as these areas can compromise drinking water quality. Nnane *et al*., (2011) reveal that implementation of effective low cost microbial source tracking techniques within river catchments may significantly improve water quality by enhancing public health protection in a proactive and preventative manner. The study further suggests that water safety planning have been proven to be an important tool to be used as risk assessment and risk management which, through its implementation, identify potential spatio-temporal faecal hotspots within the catchment. The WSIs are expected to take adequate water samples at locations prescribed by the SANS 241 that would be a true representation of water supplied to the consumers and furnish to DWS with the sample results as required by the Water Services Act (SABS, 2015, RSA, Government Gazette 2001). WSIs have to identify sample points, determinands to be monitored and the frequencies of sampling in the water supply system (SABS 241, 2011). Samples collected should be analysed at an accredited laboratory or laboratory that participate in the proficiency testing scheme or a laboratory that is recognised by the Department of Water Affairs (DWA, 2013). The results obtained should be credible i.e. accurate and reliable (WRC, 2000). The identified sample points, determinands to be monitored and the frequency should be included in the water quality monitoring programme for the entire water supply system (WRC, 2000 and SABS, 2011).

2.13 Risk Based Monitoring versus Risk management

Hrudey *et al*., (2006) described on essential characteristics of risk management as being preventative rather than reactive to ensure safe drinking water. Nnane *et al*., (2011) further state that multiple barriers of protecting and evaluating source water should be supported by the well-designed monitoring programme. When managing drinking water, the water suppliers should not focus only to meet the legislative requirements but attention should be given to assets, chemicals and other areas that contribute to drinking water quality management (Hrudey *et al*., 2006). Prevention of contaminants entering the raw water sources should be given priority in terms of ranking risks and as a result this will assist the WSI to reduce the amount of treatment chemicals that will be required to purify water (WHO, 2011). The Water Treatment Works (WTWs) is one of the locations that should be monitored for water quality (WRC, 2000). The WRC report states that water should be monitored at final water of the treatment works to determine fitness for domestic use (WRC, 2000). The final water at the water treatment works is expected to be fit for human consumption as required by the SANS 241 (SABS, 2015).

Chang *et al*., (1990) state that when optimising the water treatment processes to remove pollutants, the quality of raw water (abstracted water) should be considered. Chang *et al*., (1999) further argue that based on the monitoring of raw water, if the results prove that current water treatment processes cannot remove the specific pollutants, the WSIs have to upgrade the water treatment works or find alternative water sources that would be suitable for the applied water treatment processes. Monitoring results from the raw water and treated final water have to be compared to determine the performance of the water treatment works (SABS, 2015). DWAF (2000) reveals that water samples should be taken at the outlet of the treatment works to check the effectiveness of treatment processes and the quality of water supplied to the consumers. SANS 241, 2011 indicates that if the determinand of both raw water and final water exceed numerical limits stipulated in the standard, it implies that the existing infrastructure cannot remove the determinand therefore corrective measures should be taken to comply with the standard (SABS, 2011).

Final water has to be monitored rigorously with appropriate frequency prescribed in the SANS 241 (SABS, 2015).

2.14 Distribution system and point of use water quality monitoring

The main purpose of monitoring of water quality in the distribution system is to determine whether drinking water is fit for human consumption with respect to microbiological, chemical and physical quality (WRC, 2001). The SABS (2015) SANS 241 prescribed the number of samples to be taken per month from the final water and distribution system of the water supply system to confirm compliance with the water quality standards. The WSIs have to further comply with a certain number of *E.coli* samples taken per month based on the population served in the water supply system (SABS, 2011). The water sample results contribute towards determining routine monitoring compliance with the standard that the DWAF requires on a monthly basis to determine the performance of water supply systems (DWA, 2010 and DWA, 2013).

2.15 Reducing impact of non-compliance of drinking water quality

Distribution system infrastructure consists of water treatment works, storage reservoirs, network pipes and the quality of drinking water may change or deteriorate between treatment and consumers (Clark, 2013). Clark (2013) further reveals that potable water traveling between all these stages may deteriorate due to loss of residual disinfectant, bacterial growth and formation of biofilms. Some risks of water may be introduced during repair and replacement of infrastructure and water companies must follow specific procedure to reduce the risks (Dawson and Sartory, 2000). In South Africa all WSIs should develop monitoring programmes to monitor drinking water and compare the results with the SABS SANS 241 standards and water must be tested throughout the different stages to determine its fitness to consumers (RSA, Government Gazette, 2001, SABS , 2006). The WSI has to inform the public of drinking water failures to conform to the standards (RSA, Government Gazette, 2001). SANS 241 (SABS, 2011) states that the non-conformance with the drinking water quality standard must trigger corrective action to ensure that tap water meet the prescribed standards. Similar to UK and Wales, the Drinking Water Inspectorate (DWI) and Health Authorities should be kept informed of abnormal water quality that may affect public health (Dawson and Sartory, 2000). This is similar to South Africa where the Government Gazette No 7079 Section 5 also requires WSI to inform the public, Department of Water Affairs and Forestry and Provincial Department of Health if potable water fails to meet the drinking water quality limits (RSA, Gazette No 7079, 2001). There is a realisation that when the constituents' concentrations are exceeding the prescribed limits it may not necessarily lead to detrimental health effects but long time exposure has an effect on consumers (Kempster *et al*., 1997).

2.16 Water Quality Determinands of Interest

The study looked at the water quality determinands that should be regularly monitored by the municipalities such as pH, conductivity, turbidity, free chlorine, colour, odour and *E.coli* and chemical determinands such as iron, nitrate, arsenic, sodium, manganese.

Turbidity

Turbidity is an expression of the optical property of water that causes light to be scattered and is measured by determining the degree of light scattering by particulates present in the samples (Lechavallier *et al*., 1981). High levels of turbidity can shell or protect micro-organisms and reduce the effects of disinfection, stimulate the growth of bacteria and give rise to a significant chlorine demand (WHO, 2011). Turbidity can carry nutrients to support microbial growth in the distribution system (Lechavallier *et al*., 1981).

pH

pH has a marked effect on the taste of the water and also indicates possible corrosion problems and potential copper, zinc and cadmium presence (WRC, 1998). Low pH values can result in structural problems in the distribution system (SABS, 2015).

Electrical conductivity (EC)

The EC of the water indicates what the total dissolved salt (TDS) content of the water is. Irrigation return flows and other effluents and discharges in the source waters may raise the EC to as much as 300 mS/m or even higher (WRC, 1998). EC results above 150 mS/m impart a salty taste to the water, and water with conductivity above 300 mS/m does not slake thirst (WRC, 1998).

Free chlorine (Cl^-)

Free chlorine is an indication of the effectiveness of the disinfectant in the water. Cl^- is the chlorine concentration remaining at least 30 minutes after disinfection. There should be Cl^- in the water, but if concentrations are too high it may impart an unpleasant taste and smell to the water (WRC, 1998).

Faecal coliforms and/or E.coli

Faecal coliform is an indicator of the possible presence of disease-causing organisms and establish whether water is polluted with faecal matter (WRC, 1998).The *E.coli* presence in water therefore indicates recent faecal pollution (SABS, 2006).

Nitrate (N)

High concentration of nitrate in drinking water can cause stomach and bladder cancer in humans and may result cyanosis and difficulty to breath in bottle fed bottle infants (Morales-Suarez-Varela *et al*.,1994 and WRC, 1998).

Sulfate (SO_4^{2-})

Sulfate is a determinand that is particularly common in mining areas and can cause diarrhoea, particularly in users not accustomed to drinking water with high sulfate concentrations (WRC, 1998).

Arsenic (As)

WHO (2011) describes arsenic to be present in natural waters at concentrations of less than 1–2 µg/l. In waters, particularly groundwater, where there are sulfide mineral and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated. This can lead to arsenic poisoning.

Manganese (Mn)

The presence of manganese is a common reason for brown or black discolouration of fixtures and stains in laundry. The presence of manganese can be common in bottom waters of dams, or in mining areas (WRC, 1998). High concentrations found in drinking water have been associated with aesthetic problems such as discolouration and unpleasant metallic taste (WRC, 2013).

Iron (Fe)

Iron affects the taste of the water and may also cause a reddish brown discolouration. Its presence can be common in bottom waters of dams or in mining areas. Iron and manganese are significant due to its aesthetic effect on water acceptability (WHO, 2011). If corroded from water distribution systems is the most common cause of water contamination but not harmful to human health (WRC, 2013). Iron can turn water a red-orange colour, and it may cause people to avoid piped water and choose another, possibly contaminated, water source (WHO, 2013).

Sodium (Na)

Sodium affects the taste of the water. Concentration is often elevated in hot, arid areas and in the Western Cape, particularly in groundwater (WRC, 1998).

Calcium (C)

This can cause scaling and can reduce the lathering of soap (WRC, 1998).

Magnesium (M)

This affects the taste and aesthetic of the water and tastes bitter at high concentrations(WRC, 1998, Barnard *et al*., (2013). It also caused brownish-black precipitates and stains on clothes or households features (Barnard *et al*., 2013).

3. Research Methodology

3.1 Study data Collection

Data used for the study was collected from the Department of Water and Sanitation's Blue Drop System (BDS). The twelve months drinking water quality data had been collected from the BDS each year for the period of 5 years. The selected three municipalities analysed collected samples in their retail network using an accredited laboratory or a laboratory that participates in the proficiency testing scheme. The study considered other supporting information including water related management documentation and plans. Credibility of the results had been determined using information available on the regulatory system. Compliance for each year and the trends including authorised results were sourced from the BDS. The WSIs also submitted the supporting documentation such as water quality monitoring programmes, proof of accreditation certificates and z-scores results attached as Annexure C. The study used municipal drinking water quality data of between 2010 and 2014. The data was then uploaded on the BDS by the municipalities after analyses. Minimum *E.coli* water samples were 12 analysis and maximum samples were1120 for each water supply systems. Chemical water samples were from 1 to200 samples per year. Physical and operational determinands have considered between 1 analysis of each determinand and maximum samples of 1120 per annum depending on the population supplied with water. Where the municipality have failed to provide analytical laboratory results, the study has noted the non-availability of the data. Water quality results were communicated with the municipalities to determine the name of the laboratory and the procedures of addressing non-compliance with the standard. All three municipalities were requested to submit incident management protocols.

The study reviews drinking water quality performance following an introduction of the Blue Drop certification programme. The municipalities are selected according to their categories such Metropolitan, District and Local Municipality. These municipalities represent those categories and determine performance accordingly. The data of all three municipalities (City of Tshwane Metropolitan, Greater Sekhukhune District and Tzaneen Local Municipalities) were analysed against the South African National Standards (SANS) 241: 2006 limits of the South African Bureau of Standards (SABS, 2006). The supply systems selected for this study for City of Tshwane Metropolitan municipality were; Pretoria Central and Pretoria South supply systems, for Greater Sekhukhune District municipality the Burgersfort, Flag Boshielo and Groblersdal water supply systems were selected and for Tzaneen local municipality the Tzaneen Town and Letsitele supply systems were selected.

3.2 Data Analysis

The microbiological determinand analysis selected for the study was *E.coli* only. The aim of the study was to consider 100 samples for *E.coli* per water supply system but the study had to consider the total number of samples submitted due to the unavailability of the required number. Chemical determinands analysis considered for the study is iron, sulfate, manganese, magnesium, arsenic, nitrate, sodium and calcium. Physical determinands analyses considered for the study are conductivity, pH, turbidity, colour and odour. Free chlorine concentrations are considered as the Operational determinand for the study since this is required to be monitored within the distribution system.

It should be noted that all the selected municipalities do analysis for more determinands than the ones selected for this study. The study considered water quality determinands that have acute, chronic, aesthetic and operational risk in drinking water. The study also considered determinands that were frequently analysed by the municipalities to determine trend performance. The study has considered common determinands that may or are likely to exceed limits where water treatment works fail to remove them. The study considered drinking water quality data that is available within the municipality's jurisdiction therefore the study did not use data or information from their bulk water suppliers. The municipalities may have limited authority and/or access to the data of the bulk water suppliers therefore the study considered the data that is within the municipality's control.

Table 1: Micro, chemical, physical and operational determinands to determine drinking water quality compliance

Microbiological compliance			
Determinand	**Risk**	**Unit**	**Standard limit (SANS 241)**
E.coli	Acute health	count/100 ml	Not detected
Chemical compliance			
Iron	Aesthetic/operation	mg/l	<200
Manganese	Aesthetic	mg/l	<100
Magnesium	Aesthetic/health	mg/l	<70
Arsenic	Health	µg/l	<10
Nitrate	Health	mg/l	<10
Sodium	Aesthetic/health	mg/l	<200
Calcium	Aesthetic/operational	mg/l	<150
Sulfate	Aesthetic/health	mg/l	<400
Physical compliance			
Conductivity	Aesthetic	mS/m	<150
pH	Aesthetic/operational	pH	5.0-9.5
Turbidity	Aesthetic/operational	NTU	<1
Colour	Aesthetic	mg/l Pt-Co	<15
Odour	Aesthetic	TON	<5
Operational compliance			
Free chlorine	Chronic health	mg/l	0.2 – 0.5

The study used a statistical tool in Microsoft Excel (MS, 2010) to calculate the water quality compliance levels of all selected determinands for each municipality. Water quality data was extracted from the DWS BDS using the Comma Separated Value (CSV) file format which was then converted into a readable Microsoft Excel spreadsheet. Compliance for each determinand was calculated using the formula: Total number of compliant data ÷ Total number of data multiply by 100. A compliance graph was then plotted to indicate compliance for all the years.

The study used the box plot diagrams to present the values for physical and operational determinands against the SANS 241 standard limits. The box plot diagrams present results for determinands which would show significant variance results against the numerical limits of the standard. Chemical and microbiological determinands may not reflect significant variance results, hence these determinands were not considered to be presented in the box plot diagrams.

One-way ANOVA (analysis of variance) was also used to determine significant differences by comparing the water quality determinands data of p-values in the period between2010 and 2014 only of the selected determinands. The null hypothesis states that there is no difference among the population of determinands of the groups being compared. The null hypothesis is that the sets of data have the same mean (Dytham, 2011).The alternative hypothesis would state there is a difference among the population of water quality determinands. If p-value is < 0.05 reject H_0, there is a significant difference and if $p > 0.05$ the study fails to reject H0– there is not enough evidence of significant difference.

In science one usually takes a value of 0.05 or 5% as the critical level for the rejection of a null hypothesis (Dytham, 2011). Dytham (2011) continues to explain that small P-value ($p < 0.05$) indicates significant varied as result the study rejected the null hypothesis and where the p-value is>0.05,the study had rejected null hypothesis of drinking water quality as result may determinands results may reflect water quality’s improvement or deterioration.

Data for microbial, chemical, physical and operational determinands in drinking water samples were entered and analysed using the Microsoft Excel 2010 version (MS, 2010). The microbial, chemical, physical and operational determinands entered are *E. coli*, arsenic, iron, manganese, magnesium, calcium, sodium, colour, pH, turbidity, odour, conductivity, free chlorine, total dissolved solids, chloride, sulfate, phosphate, hardness, nitrate, and iron respectively. One way ANOVA was used to test for statistical differences in concentrations of the analysed determinands. The null hypothesis (H_0) of the study, there was not a significant difference.

4. Results and discussion

Water quality data assessed for all selected supply systems varied every year depending on the capability of the municipality to analyse for a particular determinand. The results below represent the chemical, microbiological, operational and physical quality of water samples collected in the municipalities' reticulation network from the year 2010 to 2014 as uploaded on the BDS. The required compliance limits for microbiological determinands is 99% and for chemical and physical determinands are 97% as per SANS 241.Determinands that do not comply with limits set in SANS 241 could pose risks such as chronic, acute and/or aesthetic risks.

4.1 City of Tshwane drinking water quality performance

Pretoria Central and South water supply systems have a population of approximately 1 193 194 (DWA, 2012). SANS 241 requires the Water Services Institutions (WSIs) to monitor for *E.coli* in the network based on the number of population supplied. City of Tshwane analysed for 102 *E.coli* samples on a monthly basis. Figure 6 presents the drinking water quality performance in percentages for the Pretoria Central and South supply systems for the period 2010 to 2014.

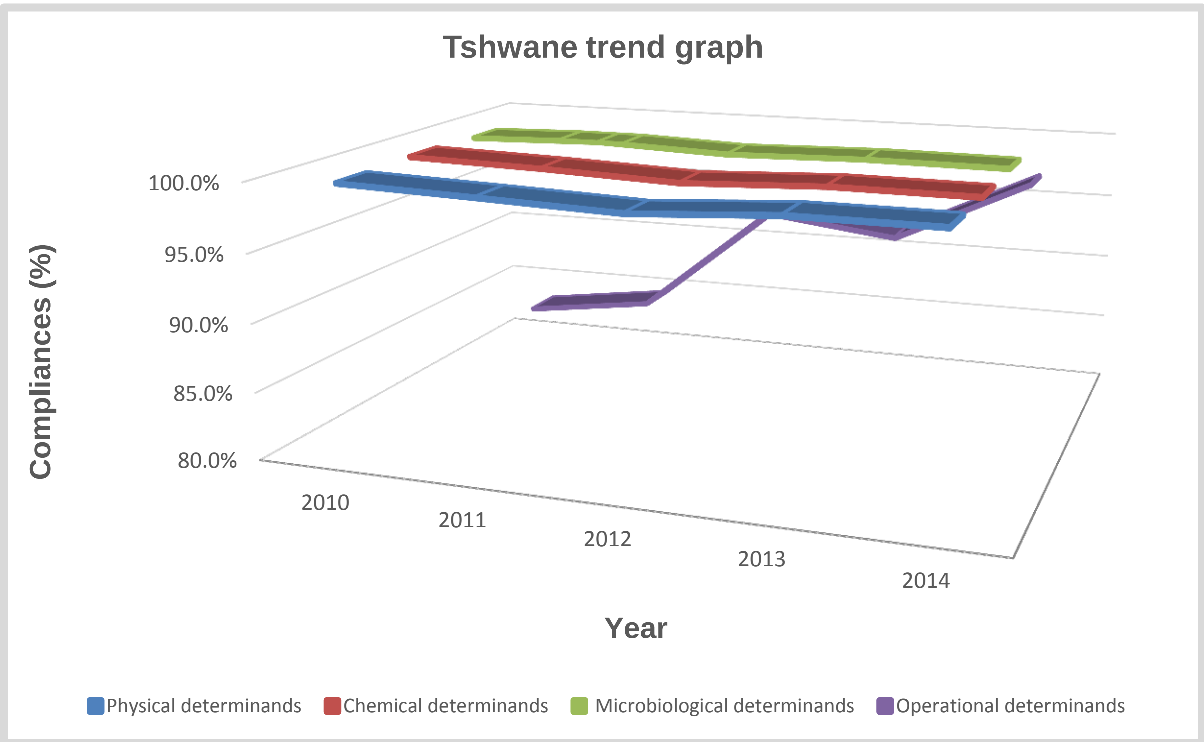

Figure 6: City of Tshwane drinking water quality performance percentages

Odour was not analysed in 2010. Odour results analyses were less between 2011 and 2014 as compared to other physical determinands and were compliant to the numerical limit of the SANS 241. As shown in Figure 6, City of Tshwane's drinking water quality compliance had been compliant with the standard (SANS 241) except for the operational determinand between the years 2010 and 2013. Microbiological, chemical and physical determinands complied with the standard and is classified as excellent water quality according to the SANS 241 requirements. *E.coli* did comply with the standard however there were few failures detected in the year 2010 and 2012. There were few *E.coli* results which did not comply with the standard limit. The results had improved significantly in the following year and the number of *E.coli* failures decreased. This improvement could be attributed to the increasing concentration levels of free chlorine between 2010 and 2014.

The water supply system's chemical compliance performance was classified as excellent as it complied with SANS 241 in the reticulation network. The chemical water quality sample analyses have been used to determine chemical compliance percentages. Chemical water quality was classified as excellent with an achievement of 97% compliance (SABS, 2006). Pretoria Central and South had incidents of iron and manganese analysis results not complying with the numerical value as prescribed in the SANS 241: 2006. These determinands may not have immediate health implications but have an impact on the aesthetic risk of the water quality.

Point of consumption water samples were used to determine drinking water quality compliance percentages for the operational determinand and Figure 7 below shows compliance in this supply system with an improvement of maintenance of chlorine in the distribution system. Figure 7 shows an improvement for free chlorine as the operational determinand in the drinking water noting that still not compliant with the standard. However compliance with the standard was noted in 2014. Maintenance of free chlorine in the distribution system could be a tedious exercise due to long water supply systems such as Pretoria. But the municipality appeared to be managing residual disinfectant in the distribution.

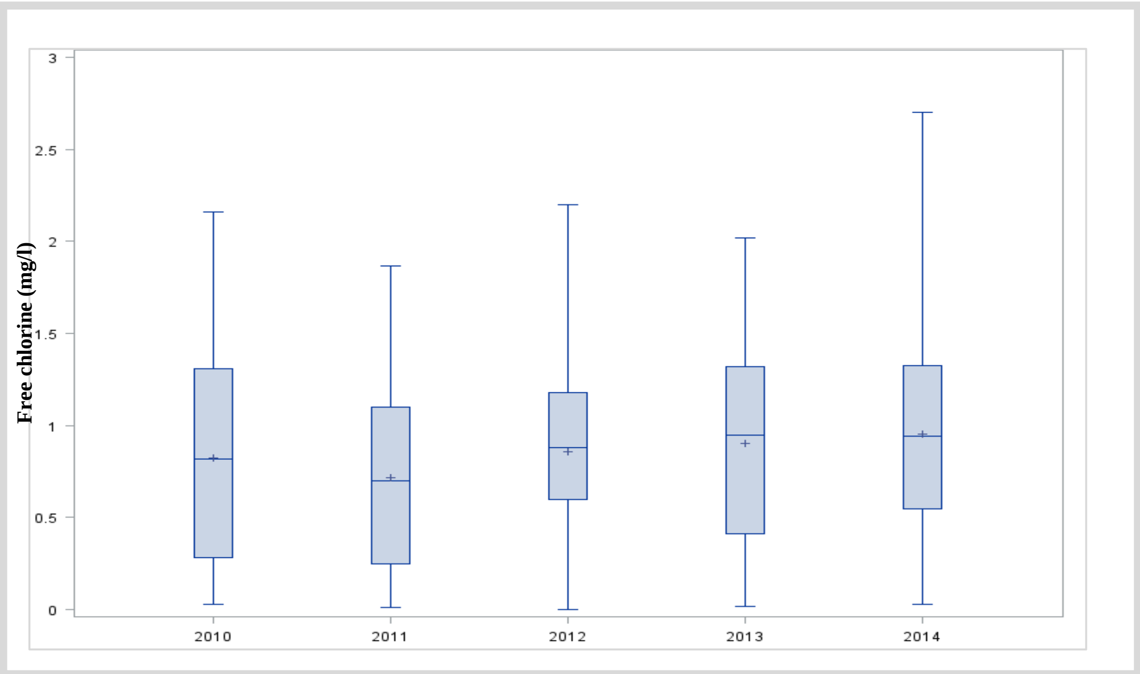

Figure 7: Box Plot for free chlorine at Pretoria Central and South

Figure 8 below shows the levels of turbidity results of treated water in the Pretoria Central and South water supply system between 2010 and 2014. Extreme values of 40 and 29 NTU respectively are noted for 2011 and 2012 exceeding the numerical limits of the standard. While turbidity results were regularly meeting the SANS 241 numerical limit of between 1 and <5 NTU, overall compliance could not exceed 98% in the City of Tshwane's distribution. Figure 8 below continues to show tap water turbidity results in 2010, 2013 and 2014 to be consistent with the standard particularly aesthetic water quality requirement of the standard of below 5 NTU in the distribution. The presence of turbidity in water results in a cloudy or muddy appearance, and may also affect the taste and colour of the water (WRC, 1998).

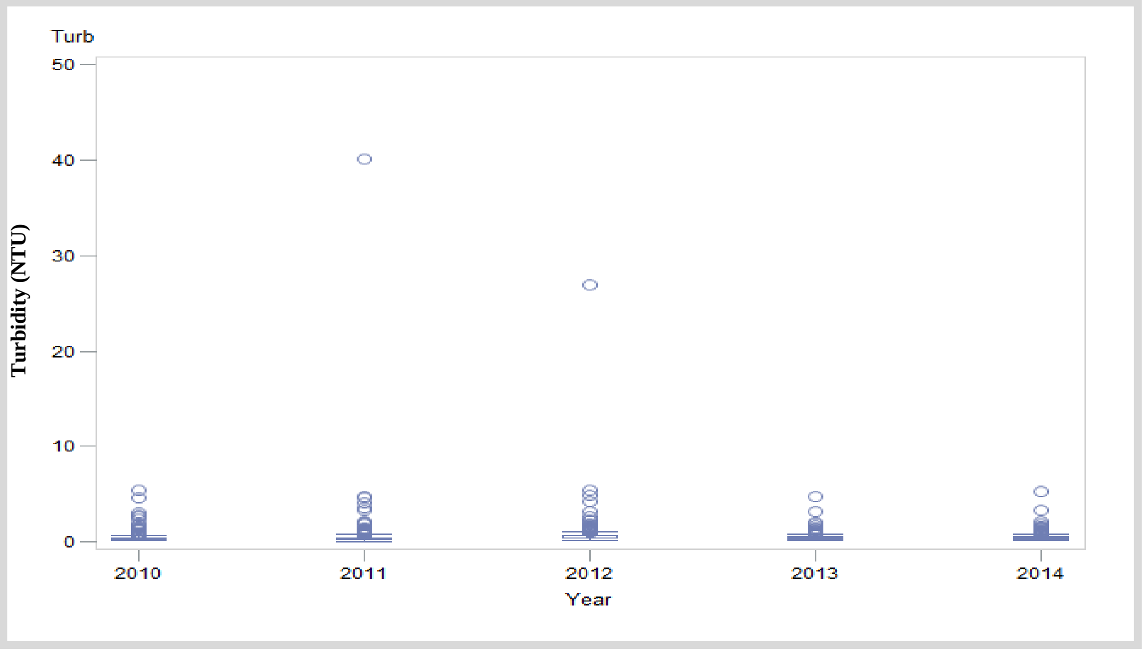

Figure 8: Box plot for the turbidity results of Pretoria Central and South

Figure 9 shows results for electrical conductivity below the maximum limit of 150 mS/m as prescribed in the SANS 241 standard. Conductivity analysis results have been fluctuating but remains within the numerical limit of the standard. The Box plot diagram shows that while the results were within the numerical limit of the standard, there were highly inconsistent conductivity concentrations entering into the distribution system. Conductivity is an indicator of the presence of total dissolved salts (TDS), and also establishes whether the water is drinkable and capable of slaking thirst (WRC, 1998).

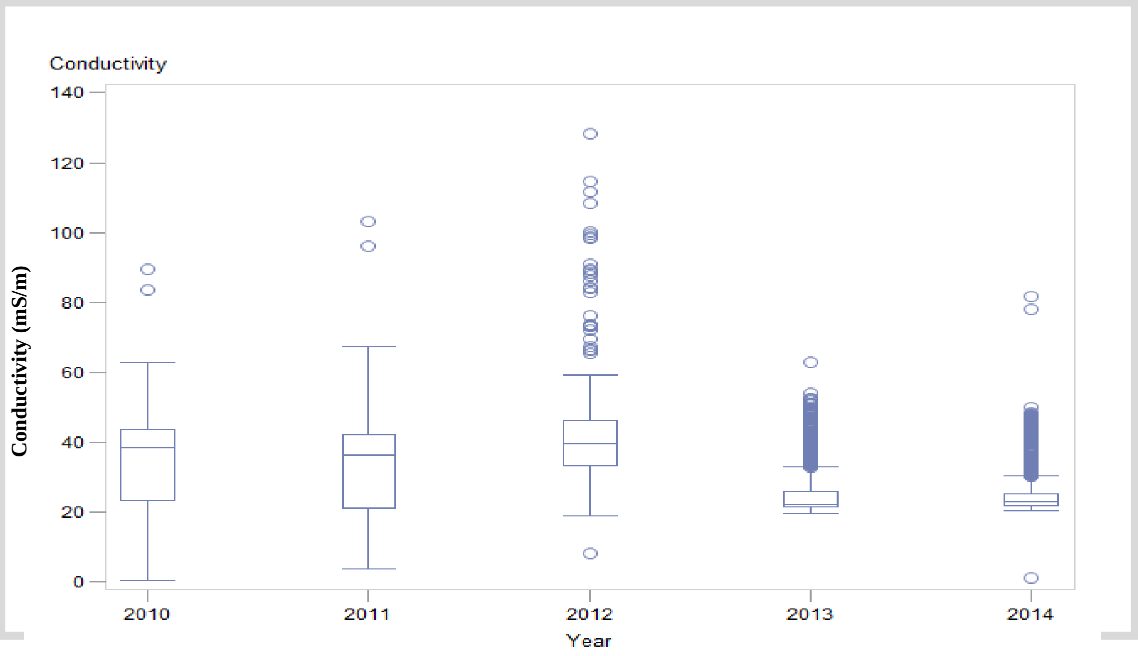

Figure 9: Box plot diagram of city of Tshwane conductivity laboratory results

City of Tshwane Pretoria Central and South water supply system p-value results for drinking water quality from 2010 until 2014 are presented in the table 2 below. These results should determine whether there is significant difference between 2010 and 2014. The Table presents only determinands considered for this study.

4.2 Pretoria Central and South water supply system p-value results

This subsection presents p-value results for determinands that constituted compliance shown in Figure 6. The p-values are for microbiological, chemical, physical and operational determinands used to determine drinking water quality compliance. The p-values calculated assisted to determine whether there is a significant or not significant difference of the water quality determinands selected between the years 2010 and 2014. Tables below show p-value results Pretoria Central and South. Table 2 shows p-values for *E.coli* results between 2010 and 2014 to determine whether to reject or not to reject the null hypothesis.

Table 2: Pretoria Central and South P-value results for *E.coli* in the distribution system

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
0	1200	4	0.004499	0.006736	1824%	
0	1200	0	0	0	#DIV/0!	
0	1120	15	0.013135	0.058548	1842%	
0	1092	2	0.001832	0.00183	2336%	
0	1200	7	0.005973	0.024729	2633%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.115011	4	0.028753	1.492244	0.2016432	2.373582
Within Groups	103.7395	5384	0.019268			
Total	103.8545	5388				

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	890	4	0.004494	0.006729	1825%	
_2011	1095	0	0	0	#DIV/0!	
_2012	1120	15	0.013123	0.058497	1843%	
_2013	1093	2	0.00183	0.001828	2337%	
_2014	1120	7	0.005968	0.024708	2634%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.114914	4	0.028729	1.49237	0.201605	2.373581
Within Groups	103.7397	5389	0.01925			
Total	103.8547	5393				

#DIV/0!: Note E.coli results were zero hence formula shows an error results.

Note: coefficient is a coefficient of variation

Table 2 above shows p-value expression for *E.coli* from 2010 to 2014. It also shows p-value expression for 2010 and 2014. Both p-value expressions are >0.05which suggest that there is no significant difference of *E.coli* results in 2010 and 2014. The p-value expression above implies that the null hypothesis of the study cannot be rejected. Table 2 also reflects non-compliant with the drinking water standard from 2010 until 2014 except for the year 2011 where compliance was above 99.9% as shown on Annexure A, Table 1 – 5.

Table 3 below shows p-values for iron concentrations for the years from 2010 until 2014. It also shows p-value for the years 2010 and 2014. Both p-value expressions from 2010 and 2014 are <0.05which suggests that there is significant difference between 2010 and 2014. This implies that the null hypothesis can be rejected.

Table 3: Pretoria Central and South p-value for iron concentration in the distribution system

Anova: Single Factor						
Iron						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	13999.11	69.99554	1992.248	64%	
_2011	200	13231.84	66.1592	3053.938	84%	
_2012	200	20200.03	101.0001	52938.43	228%	
_2013	200	9672.121	48.36061	1638.249	84%	
_2014	200	6403.714	32.01857	4629.549	213%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	535161.1434	4	133790.3	10.4113	2.9035E-08	2.380876
Within Groups	12786230.1	995	12850.48			
Total	13321391.24	999				

Anova: Single Factor						
Iron						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	13875.01	70.07503	2011.427	64%	
_2014	200	6351.627	32.07893	4676.075	213%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	145937.7	1	145937.7	44.01545	1.06071E-10	3.864811341
Within Groups	1326241	400	3315.602			
Total	1472179	401				

The average values confirm that there is significant difference in the results. The study noted that the iron concentrations complied with the numerical limit for the period under review. Actual data is presented in Annexure A in Tables 1 – 5 and Annexure B City of Tshwane (Presented on the CD).Iron concentration average results increased in the year 2012 but significantly decreased in 2013 and 2014.

Table 4 shows p-value expression for magnesium concentrations of <0.05 from 2010 until 2014.It further suggests that there is significant difference of magnesium concentration results in2010 and 2014.

Table 4: Pretoria Central and South magnesium concentration in the distribution system

Anova: Single Factor						
Magnesium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	1677.309	8.262605911	4.092656	24%	
_2011	200	1603.521	7.899118227	14.08131	48%	
_2012	200	1869.651	9.210103448	10.81493	36%	
_2013	200	1877.389	9.248221675	9.213534	33%	
_2014	200	1920.891	9.462517241	9.94545	33%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	387.1278	4	96.78195185	10.05049	5.5936E-08	2.380743
Within Groups	9725.873	1010	9.629576915			
Total	10113	1014				

Anova: Single Factor						
Magnesium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	1677.309	8.262606	4.09266	24%	
_2014	200	1920.891	9.462517	9.94545	33%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	137.6889	1	137.6889	19.4735	1.30883E-05	3.864465
Within Groups	2870.652	406	7.070571			
Total	3008.341	407				

Both p-value expressions suggest that there is a significant difference and as a result, the null hypothesis is rejected. The study noted that magnesium concentration fluctuated in 2010 and 2012.Magnesium average results show concentration increased between 2012 and 2014 except in the year 2011.But magnesium concentration results remained within the numerical limits of the standard.

Table 5 shows p-values for manganese concentration results from 2010 until 2014 as well as separate p-values for 2010 and 2014. The p-value for 2010 and 2014 is <0.05 and the expression implies that there is a significant difference therefore the study rejects the null hypothesis. There is an increase of manganese concentration between 2012 and 2013 compared to other years.

Table 5: Pretoria Central and South manganese concentration in the distribution system

Anova: Single Factor						
Manganese						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	1244.702	6.22351	222.7753	240%	
_2011	200	1110.71	5.55355	205.4763	258%	
_2012	200	2864.181	14.32091	1669.988	285%	
_2013	200	2409.387	12.04694	550.5705	195%	
_2014	200	1068.089	5.340445	194.8207	261%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14023.25	4	3505.813	6.164325	6.6983E-05	2.380876
Within Groups	565882.6	995	568.7262			
Total	579905.8	999				

Anova: Single Factor						
Manganese						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	1244.702	6.22351	222.7753	240%	
_2014	200	1068.089	5.34045	194.8207	261%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	91.05563192	1	91.0556	0.446436	0.50441	3.8643514
Within Groups	83216.17166	408	203.961			
Total	83307.2273	409				

The 2010 and 2014 p-value expression is >0.05 and as a result implies that there was not a significant difference therefore the null hypothesis cannot be rejected. The 2010 and 2014 manganese average results are close to one another compared to overall manganese average results for other years as shown in Table 5.

Table 6 shows nitrate concentration p-values from the years 2010 until 2014as well as p-value expressions in 2010 and 2014. The p-value expression from 2010 until 2014 is <0.05 and implies that there is a significant difference of nitrate concentration.

Table 6: Pretoria Central and Central p-value for nitrate in the distribution system

Anova: Single Factor						
Nitrate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	152.907	0.760731	0.293023	115%	
_2011	200	196.078	0.975512	1.351353	101%	
_2012	200	107.524	0.534945	0.261574	137%	
_2013	200	132.006	0.656746	0.379637	123%	
_2014	200	146.845	0.730572	0.139636	117%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21.02843507	4	5.257109	10.83841	1.325E-08	2.380831
Within Groups	485.0444154	1000	0.485044			
Total	506.0728504	1004				

Anova: Single Factor						
Nitrate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	152.907	0.76073	0.293023	115%	
_2014	200	146.845	0.73057	0.139636	117%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.091112	1	0.09111	0.429786	0.51247364	3.864989
Within Groups	84.16184	397	0.21199			
Total	84.25295	398				

Nitrate concentration results fluctuated between 2010 and 2014. P-value for 2010 and 2014 is >0.05 and suggests that there is not a significant difference in2010 and 2014.Nitrate results remained within the numerical limit of the drinking water quality standard.

Table 7 shows sodium p-value results from 2010 until 2014 as <0.05 and this p-value expression suggests that there is a significant difference.

Table 7: Pretoria Central and South p-value of sodium concentration in the distribution system

Anova: Single Factor						
Sodium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	65.87	*Coefficient*	
_2010	200	4891.659	13.70213	47.43828	50%	
_2011	200	3428.843	12.42334	41.9475	52%	
_2012	200	4035.649	14.06149	50.5967	51%	
_2013	200	3107.344	14.86767	51.5669	48%	
_2014	200	2968.287	14.33955	53.47491	51%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	844.6017	4	211.1504	4.348061	0.001696	2.378615
Within Groups	64635.99	1331	48.56198			
Total	65480.59	1335				

Anova: Single Factor						
Sodium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	4891.659	13.70213	47.43828	50%	
_2014	200	2968.287	14.33955	53.47491	51%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	228.9859	1	228.9859	5.453091	0.02002258	3.864579
Within Groups	16964.75	404	41.99194			
Total	17193.73	405				

The p-value for years 2010 and 2014is <0.05 and implies that there is a significant difference between 2010 and 2014. Sodium results fluctuated between 2010 and 2013 but the results were still within the numerical limit of the standard.

Table 8 presents p-value expressions for sulfate concentrations from2010 until2014. It also presents the 2010 and 2014 p-value expressions separately. Expression results for both these p-values are <0.05 and imply that there is a significant difference on the overall p-value results. The p-value expression for 2010 and 2014 also suggests a significant difference.

Table 8: Pretoria Central and South sulfate p-value results

Anova: Single Factor						
Sulfate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	3496.783	17.57177	29.89057217	31%	
_2011	200	3426.151	17.21684	51.88858885	42%	
_2012	200	3691.194	18.54871	40.8836163	34%	
_2013	200	3790.552	19.048	69.8959067	44%	
_2014	200	4489.358	22.55959	40.09337053	28%	
ANOVA						
Source of Variatior	SS	df	MS	F	P-value	F crit
Between Groups	3601.008	4	900.2519	19.34760221	2.43385E-15	2.380921
Within Groups	46065.11	990	46.53041			
Total	49666.11	994				

Anova: Single Factor						
Sulfate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	200	3496.783	17.57177	29.89057217	31%	
_2014	200	4489.358	22.55959	40.09337053	28%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	228.9859	1	228.9859	5.453091296	0.020022578	3.864579
Within Groups	16964.75	404	41.99194			
Total	17193.73	405				

Sulfate results show that concentrations had been consistently increasing between 2010 and 2014. The results were within the numerical limit of the drinking water quality standard.

Table 9 below shows overall p-value expression from 2010 until 2014 for arsenic concentrations. It also presents p-value expressions for 2010 and 2014 separately. Both these p-value expression results are <0.05and this implies that there is a significant difference for arsenic concentrations. As a result the study rejects the null hypothesis. Arsenic concentration averages are within the numerical limit of the standard even though results increased between 2010 and 2014.

Table 9: Pretoria Central and South arsenic concentration in drinking water

Anova: Single Factor
Arsenic
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	219.319	1.0803892	0.956303	91%
_2011	200	670.953	3.2889853	5.016919	68%
_2012	200	1020	5	4.13246	41%
_2013	200	1020	5	0.743015	17%
_2014	200	1076.964	5.2792353	0.602118	15%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2570.722	4	642.68061	488.5738	1.06E-234	2.380708
Within Groups	1333.838	1014	1.3154217			
Total	3904.56	1018				

Anova: Single Factor
Arsenic
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	219.319	1.080389	0.956303	91%
_2014	200	1076.964	5.279235	0.602118	15%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1787.491831	1	1787.492	2291.231	1.39E-168	3.864579098
Within Groups	315.1784915	404	0.780145			
Total	2102.670323	405				

Table 10 shows calcium p-values as >0.05, therefore there is no significant difference for concentration results from 2010 until 2014. There is not a significant difference for calcium results from 2010 until 2014. Calcium average results fluctuated with slight increases between 2010 and 2014. Calcium average results were within the numerical limit of the SANS 241.

Table 10: Pretoria Central and South calcium concentration in distribution system

Anova: Single Factor
Calcium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	4209.23	20.83777	14.50294	18%
_2011	200	4506.663	22.31021	44.028	30%
_2012	200	4428.537	21.92345	38.71671	28%
_2013	200	4368.79	21.62767	21.10393	21%
_2014	200	4347.026	21.51993	15.84656	18%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	239.8942	4	59.97354	2.234514	0.06345645	2.380787
Within Groups	26973.83	1005	26.83963			
Total	27213.72	1009				

Anova: Single Factor
Calcium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	4209.23	20.83777	14.50294	18%
_2014	200	4347.026	21.51993	15.84656	18%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	46.99935	1	46.99935	3.097207	0.07918725	3.864695
Within Groups	6100.25	402	15.17475			
Total	6147.25	403				

Table 11 presents p-value results for turbidity averages for the yearsfrom2010 until2014 and p-value expressions for 2010 and 2014 separately. The overall turbidity averages from 2010 until 2014have p-values of <0.05and this implies that there is a significant difference of results. The null hypothesis is rejected as a result and an alternative hypothesis is considered. The study also noted fluctuating turbidity results between 2010 and 2012. Turbidity average results remained within the required limit of 1 NTU for each year. It should be mentioned the results show that turbidity level was manageable in water.

Table 11: Pretoria Central and South p-value for turbidity in the distribution

Anova: Single Factor

Turbidity

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	1200	433.838	0.361532	0.099244	87%
_2011	1200	524.323	0.436936	1.410108	272%
_2012	1200	677.01	0.564175	0.182354	76%
_2013	1064	490.64	0.461128	0.123295	76%
_2014	1120	517.12	0.456417	0.107065	72%

ANOVA

ource of Variatio	SS	df	MS	F	P-value	F crit
Between Group	25.21558	4	6.303894	16.00978	4.837E-13	2.373466
Within Groups	2280.616	5792	0.393753			
Total	2305.832	5796				

Anova: Single Factor

Turbidity

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	1200	433.838	0.361532	0.099244	0.871377
_2014	1120	517.12	0.456417	0.107065	0.7169064

ANOVA

ource of Variatio	SS	df	MS	F	P-value	F crit
Between Group	5.246756	1	5.246756	50.91852	1.28E-12	3.845451
Within Groups	240.1914	2331	0.103042			
Total	245.4381	2332				

Table 12 presents conductivity average results of p-value expression of <0.05 between 2010 and 2014.This suggests that the study rejects the null hypothesis and as a result there is significant difference of conductivity levels in the water between 2010 and 2014.The difference is also confirmed between 2010 and 2014. Conductivity average results are within the numerical limit of the drinking water quality standard.

Table 12: Pretoria Central and South conductivity p-value results in the distribution

Conductivity

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	1120	44387.54	36.8361328	105.0694729	28%
_2011	837	29350.27	35.0660335	123.2656122	5%
_2012	1120	47032.91	39.0314606	141.4003377	4%
_2013	953	24700.07	25.9182267	57.18706755	9%
_2014	1120	29505.5	26.0879752	54.51208537	28%

ANOVA

ource of Variatio	SS	df	MS	F	P-value	F crit
Between Grour	166802.5	4	41700.6359	430.5548104	0	2.373600241
Within Groups	515840.4	5326	96.8532573			
Total	682643	5330				

Anova: Single Factor

Conductivity

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	1200	44387.54	36.83613	105.0695	28%
_2014	1200	29505.5	26.08798	54.51209	28%

ANOVA

ource of Variatioi	SS	df	MS	F	P-value	F crit
Between Groups	67397.66646	1	67397.67	836.2798	1.993E-157	3.84544609
Within Groups	188102.3018	2334	80.59225			
Total	255499.9683	2335				

Table 13 presents p-values for pH (expressed as [H+]) results for the years from 2010 until 2014 and p-values in 2010 and 2014 separately. The Table above reveals overall pH (expressed as [H+]) p-values of <0.05 and implies that there is a significant difference between 2010 and 2014. pH average results fluctuated between 2010 and 2014. The average results in 2010, 2011 and 2014 had been higher than the other years. The Table below further reveals p-values of pH (expressed as [H+]) in 2010 and 2014as >0.05 therefore there is not a significant difference. The study noted that pH results between 2010 and 2014 were within the numerical limit of the SANS 241 as shown in Annexure A, Tables 1- 5.

Table 13: Pretoria Central and South for p-value results for pH (expressed as [H+]) in the distribution system

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of Variation
_2010	1120	2.08E-05	1.854E-08	1.48E-16	66%
_2011	1120	2.84E-05	2.53033E-08	8.97E-16	118%
_2012	1120	1.26E-05	1.12201E-08	8.84E-17	84%
_2013	1064	1.45E-05	1.36157E-08	7.37E-17	63%
_2014	1120	1.97E-05	1.75703E-08	1.84E-16	77%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.29489E-13	4	3.23722E-14	115.4607	1.00547E-94	2.373535
Within Groups	1.55412E-12	5543	2.80375E-16			
Total	1.6836E-12	5547				

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of Variation
_2010	1120	2.08E-05	1.854E-08	1.48E-16	66%
_2014	1120	1.97E-05	1.75703E-08	1.84E-16	77%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.2703E-16	1	5.2703E-16	3.176261	0.074850922	3.845614
Within Groups	3.71678E-13	2240	1.65928E-16			
Total	3.72205E-13	2241				

Table 14 presents p-values for colour results for the years from 2010 until2014 as well as the p-values in 2010 and 2014 separately. Colour average results slightly fluctuated from 2010 until 2014 as shown in Table 14 below. The p-value expressions for colour of <0.05 suggests that there is a significant difference of colour between 2010 and 2014. Both p-value expressions suggest that the study rejects the null hypothesis. Average results for colour shown were in compliance with the numerical limit of the standard.

Table 14: Pretoria Central and South p-value for colour in drinking water

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	1234.672	6.112238	2.286911	37%
_2011	200	1659.083	8.213282	7.367734	90%
_2012	200	1176.538	5.824446	7.58617	130%
_2013	200	969.331	4.798668	5.880315	123%
_2014	200	1343.627	6.651619	2.860176	43%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1272.131	4	318.0327	61.20415	2.6346E-46	2.380787
Within Groups	5222.242	1005	5.196261			
Total	6494.373	1009				

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	200	1234.672	6.112238	2.286911	37%
_2014	200	1343.627	6.651619	2.860176	43%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29.38414	1	29.38414	11.41777	0.00079852	3.864695
Within Groups	1034.564	402	2.573543			
Total	1063.949	403				

Table 15 presents free chlorine overall p-value results of <0.05 and suggests there is a significant difference from 2010 until 2014.P-values for the years 2010 and 2014 are presented separately. Free chlorine result averages fluctuated between 2010 and 2014 but according to Figure 6, compliance of free chlorine had significantly improved in the years under review. Free chlorine p-values for 2010 and 2014 shows not a significant difference (p-value is >0.05) and as a result there was not a significant difference if the results are compared for both years.

Table 15: Pretoria Central and South p-value of free chlorine results

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	980	933.59	0.952643	0.414066	68%
_2011	998	761.27	0.762796	0.266417	68%
_2012	1200	982.86	0.837189	0.174069	50%
_2013	1036	1045.64	1.009305	8.982096	297%
_2014	1107	1082.79	0.97813	0.221029	48%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	44.95802	4	11.2395	5.708182	0.0001396	2.373612
Within Groups	10416.1	5290	1.969017			
Total	10461.06	5294				

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	980	933.59	0.952643	0.414066	68%
_2014	1107	1082.79	0.97813	0.221029	48%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.337673	1	0.337673	1.083438	0.2980505	3.845923
Within Groups	649.8281	2085	0.311668			
Total	650.1658	2086				

4.3 Greater Sekhukhune District Municipality

The study selected three (3) water supply systems which included Burgersfort, Flag Boshielo, and Groblersdal supply systems. These three water supply systems were considered due to the number of population served and the selected water supply systems are conventional water treatment works while other supply systems within the municipality are boreholes systems.

Figures 10, 14 and 17 show the results of the Greater Sekhukhune District municipality's water supply systems improved compliance with the standard limits. The microbiological compliance shows an improvement in all three water supply systems with 93.8% in 2010 to 99.9% in 2014 in Burgersfort water supply system, and Groblersdal water supply systems a slight decline from 94.1% in 2010 to 92.9% in 2014.

4.3.1 Burgersfort water supply system water quality compliance

Burgersfort water supply system serves a population of approximately 10 864 (DWA, 2012). Figure 10 presents Burgersfort drinking water quality compliance in percentages. The drinking water compliance performance had been consistent with the SANS 241 standard (SABS, 2006). The study further observed an overall improvement in compliance against the SANS 241 limits for chemical and physical determinands from 2011 until 2012.

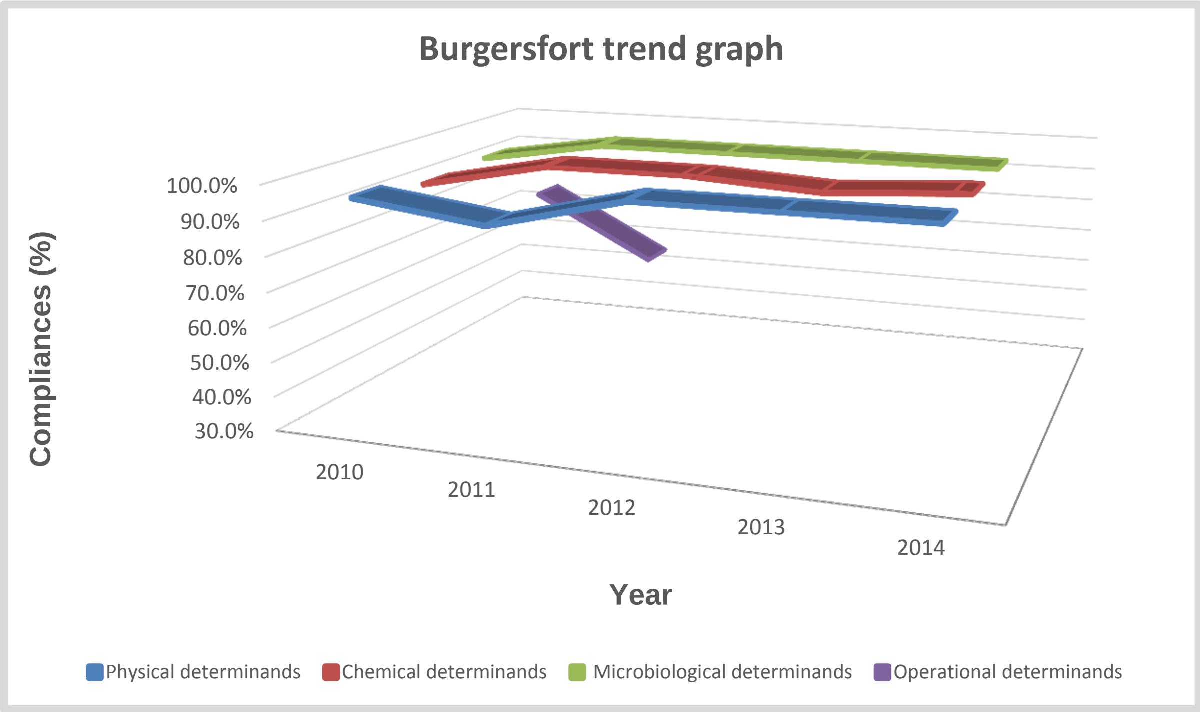

Figure 10: Burgersfort water supply drinking water quality compliance percentages

The municipality had improved overall microbiological compliance from 93.8% to 100% in 2010 and 2014 respectively. The municipality has conducted 16 *E.coli* samples in the first year and the number of analysis gradually increased from 16 to 23 total results per year. This study has considered all *E.coli* laboratory results to determine compliance percentage for microbiological for the past 5 years. The study noted that drinking water quality compliance in 2011 was below 95%.

Figure 10 reveals that microbiological compliance has improved from poor to excellent between 2010 and 2014 (SABS, 2006). There were incidents of microbiological failures in 2010 but improved the following year. According to the World Health Organisation drinking water should be free from any organism that might pose a health risk to the human population (WHO, 2011). The water quality compliance had improved from poor between 2010 and 2013 to excellent in 2014 with compliance above 99.9% (SABS, 2006). The microbiological quality data has been irregularly submitted to the Department between 2010 and 2013.

The municipality submitted a total of 279 chemical analysis results for the 5 year period. The study noted that some determinands were monitored at higher frequencies than others. As shown in Figure 10 chemical compliance has improved from 92.3% in 2010 to 99.9% in 2014. This level of chemical compliance is acceptable according to the SANS 241 numerical limits (SABS, 2006). The study has also noted that chemical determinands such as arsenic, iron, manganese and sodium analysis were not submitted to the Department to determine compliance with the standard. Arsenic is a poisonous semi-metal, which is sometimes used in rat poison and should also be prioritised as required by SANS 241 (WHO, 2011 and SABS, 2006). The detection of even very small quantities is essential because it plays a role in the integrity of the immune system – as well as in skin and hair integrity (WRC, 1998).

Chemical compliance of 99.9% as shown in Figure 10 between 2013 and 2014 had not included analysis results for arsenic, iron, manganese and sodium analysis. Iron and manganese are of widespread significance because of their effects on acceptability in drinking water (WHO, 2011). These constituents should be taken into consideration as part of any priority setting process since the incentive based regulation programme further encourages municipalities to comply with the standard. Sodium may impart a salty taste to the water (WRC, 1998). This means between 2010 and 2014, the determinands considered for chemical compliance were nitrate and sulfate.

Compliance percentages of physical determinands revealed an improvement from 95.6% to 99.9% from the year 2011 to 2014 respectively. The notable incidents of non-compliance for turbidity and conductivity were observed between 2010 and 2011. The results for colour and odour were not available for all the years and were not considered in the compliance calculations for physical determinands. However, the determinands should be part of the water monitoring programme as required by the SANS 241drinking water standard.

The Box plot diagram results in Figure 11 below shows Burgersfort conductivity results to be within the required numerical limit of the standard except for one incident in 2010 in the following years. This non-compliance contributed to low compliance results for the physical determinands as shown on Figure 10 above. It is important to note that the conductivity of water entering the Burgersfort water supply system was inconsistent while maintaining the numerical limit of the standard. The lowest conductivity results achieved within the 5 year period for conductivity results were below 20 mS/m as shown on the Figure 11. The results show that conductivity concentration could be reduced in the distribution network. Conductivity concentration in drinking water should be maintained within the numerical limit of the standard at the distribution system. Conductivity affects taste of the water (WRC, 1998).Figure 11 shows non-compliant conductivity result in 2010 contributed to poor physical compliance as shown on Figure 11.

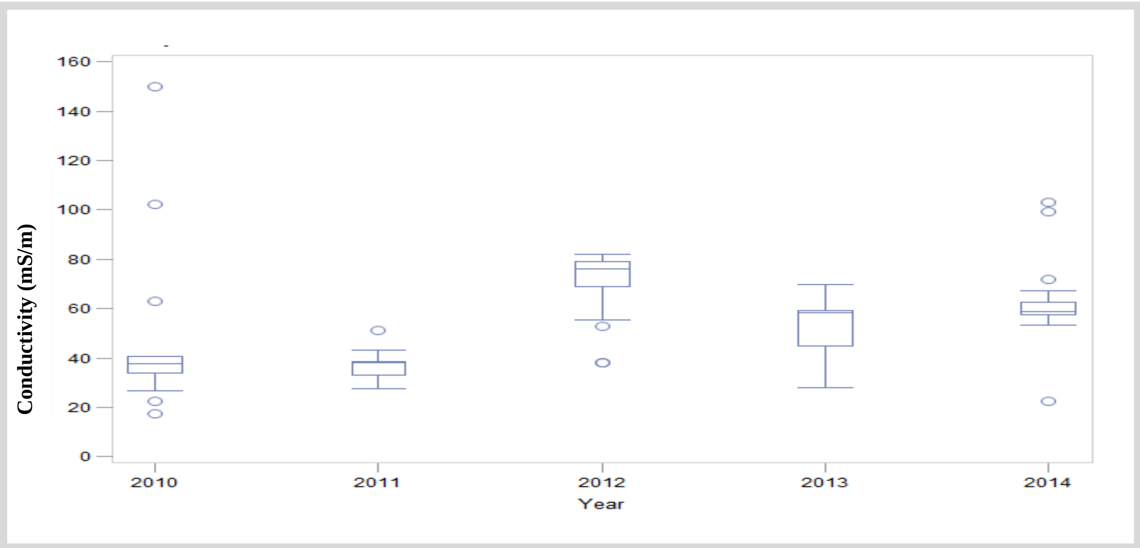

Figure 11: Box plot for conductivity results at Burgersfort water supply system

The results shows in 2010 exceeding 1 NTU and extremes results were further observed in 2011. The municipality has improved turbidity of the water in the distribution between 2012 and 2014. Box plot diagram of Burgersfort water supply system shows turbidity results were below 1 NTU as per the numerical limit of the drinking water standard between 2012 and 2014 as presented on the Figure 12 below.

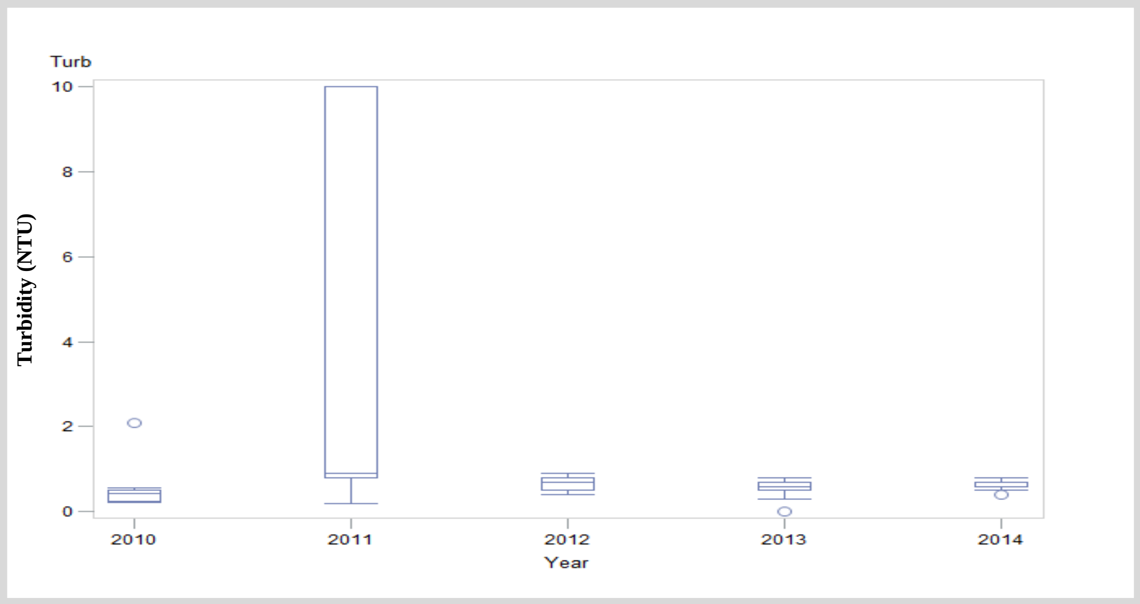

Figure 12: Box plot for turbidity results at Burgersfort water supply system

Figure 13 shows operational compliance with the standard between 2010 and 2011 only. Free chlorine results were not submitted between 2012 and 2014. The box plot diagram at Figure 13 presents performances of concentrations for free chlorine which was acceptable in 2010 and compliance further dropped in 2011.

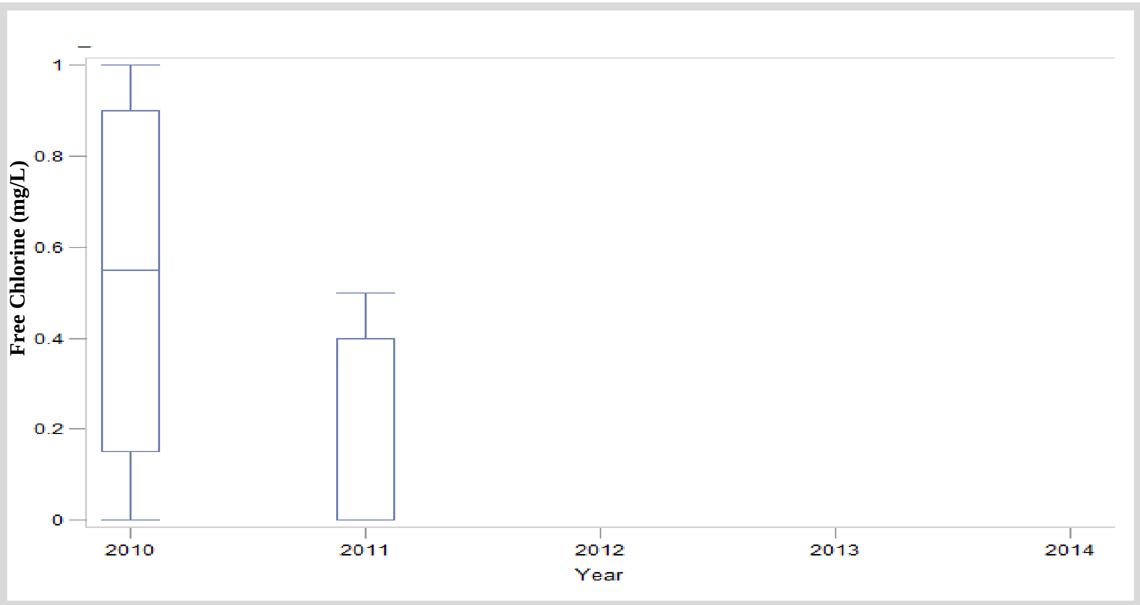

Figure 13: Box plot for Burgersfort water supply system free chlorine results

4.3.2 Flag Boshielo water supply system water quality compliance.

Flag Boshielo water supply system water quality compliance is depicted in Figure 14. The compliance percentages for microbiological, chemical, physical and operational determinands were calculated to determine performance of the supply system against the drinking water standard. This supply system has a population of approximately 100 000.

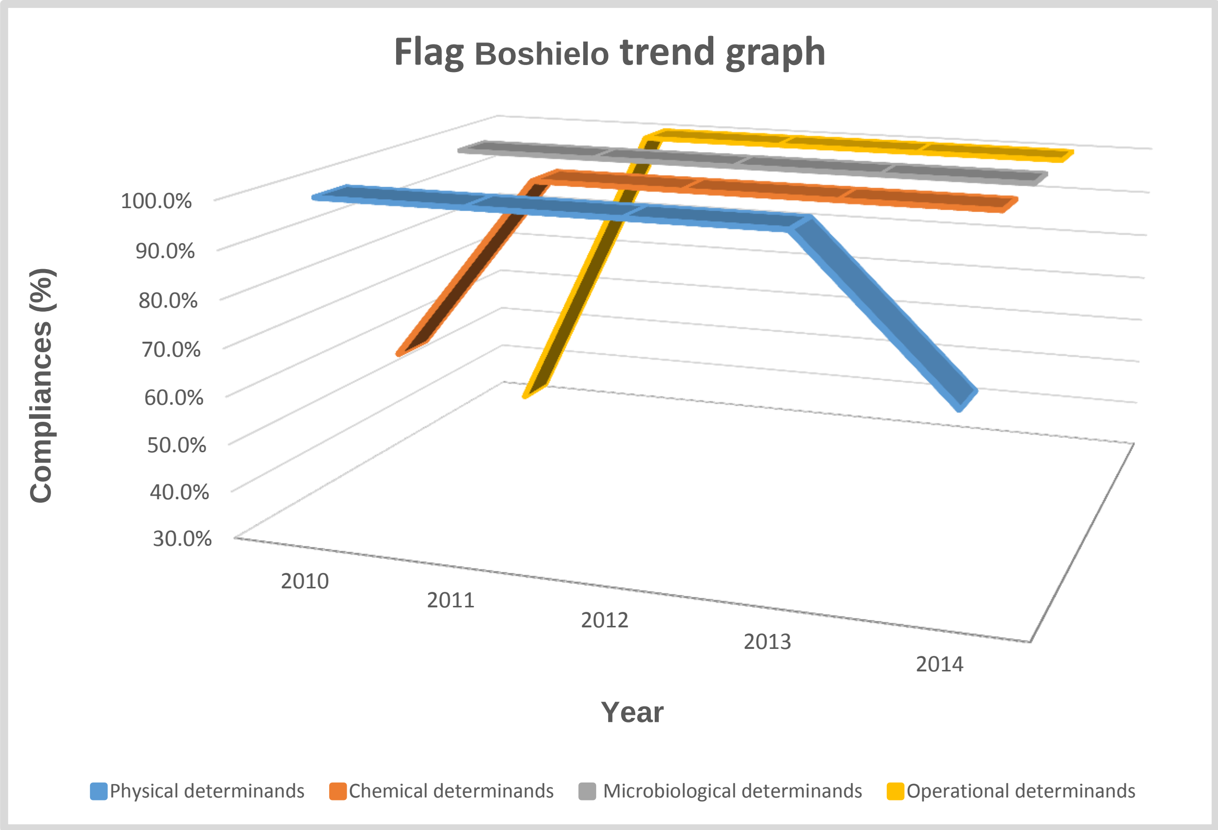

Figure 14: Flag Boshielo drinking water quality performance percentages

Figure 14 shows microbiological determinand compliance as excellent from the year 2010 (< 99%) until 2014 (SABS, 2006). The municipality has been providing water that was microbiological safe as required by the SABS 2006 standard.

Figure 14 further reveal that drinking water chemical compliance performance improved from 60% in 2010 to 99.9% in 2014. The 2014 chemical performance as shown in Figure 14was classified as excellent according to SANS 241. It should be noted that that chemical compliance was calculated using the nitrate and sodium results other results were not available for analysis.

Greater Sekhukhune District Municipality must monitor all chemical determinands with chronic health risks such as nitrate, arsenic and aesthetic chemical determinands required by SABS (2006) and the Blue Drop Certification programme (DWA, 2013). Chemical determinand with chronic risks pose an unacceptable health risks if ingested over an extended period if present at concentration values exceeding the numerical limits specified in SANS 241 (SABS, 2015). Non-monitoring of aesthetic and chemical determinands should be regarded as risk to consumers as the risks associated with water supplied may not be verified. Drinking water may have unknown excessive concentration in water. Durand (2012) states that the consumption of excessive sulfate concentration of 200 mg/l by humans may lead to vomiting and diarrhoea to sensitive individuals. Furthermore high concentration of metals such as manganese and iron may be fatal to organisms and humans (Durand, 2012). All these risks could be prevented through the development of an appropriate monitoring programme to determine the levels of the trace metals in drinking water.

Figure 14 further indicates physical determinands to be in compliance with the standard between 2010 and 2013. The study notes that the municipality submitted insufficient results to the Department between 2013 and 2014. The compliance as shown in Figure 14 had dropped to less than 99.9% in 2014. The results submitted did not meet the numerical limit of the standard. The municipality submitted only 3 turbidity results which were compliant but other determinands such as calcium, odour and colour results were not available to determine compliance. The box plot diagram for turbidity could not be plotted due to insufficient results available on the BDS.

Figure 15 below shows conductivity results complying with the standard for physical determinands compliance. There was a single result of conductivity submitted in 2010, hence conductivity results cannot be plotted properly in the distribution of the results in the box diagram. The Box plot diagram shows inconsistent conductivity results in the distribution between 2010 and 2014 as shown on the Figure 15 below. However, it should be noted that the results remain compliant with the numerical limit of the standard (SABS, 2006) as shown on the Annexure A, Tables 13 – 17 and Annexure B actual drinking water quality results. The results in 2011 show conductivity of below 50 mS/m and concentration increased in the following years.

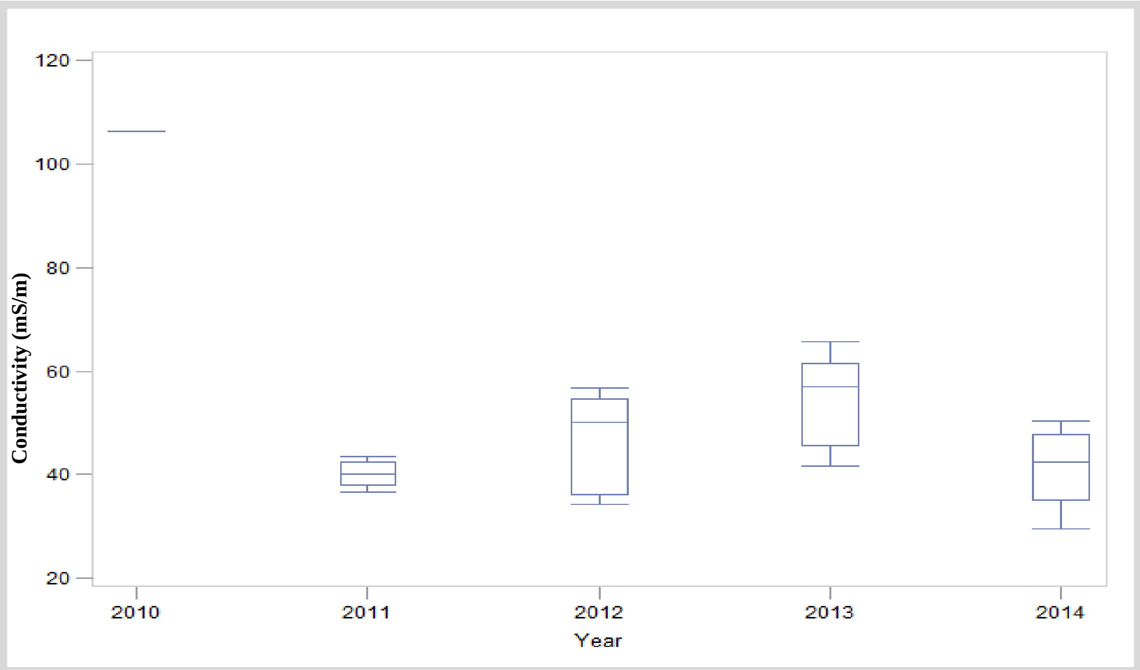

Figure 15: Box plot for conductivity at Flag Boshielo water supply

Figure 16 shows operational determinand had been maintained according to the numerical limit of the drinking water standard in the distribution system. The municipality has taken free chlorine samples in the reticulation network to determine available concentration to safeguard against regrowth of micro-organisms. Free chlorine concentration levels shown in Figure 30 meets the numerical limit of the standard. The study noted that free chlorine was extremely high at 1.5 mg/l and above in the distribution network. The appropriate levels in the distribution system should be at least0.2 mg/l (SABS, 2006). The standard used the 0.2 mg/l as the alert level but not as a compulsory limit. Free residual indicates the adequacy of disinfection of water using chlorine (WRC, 1998).

The box plot for free chlorine in Figure 15 shows inconsistent free chlorine concentration in the distribution between 2010 and 2014. Free chlorine concentration may vary in the distribution depending on the quality of water. Free chlorine dependent on network characteristics and chlorine demand (SABS, 2006). Protector and Hammes (2015) explained that disinfection (chlorine and chloramines) is important to eliminate bacteria and is key component in risk management. Hence free chlorine concentration in the distribution system has a purpose of inhabiting microbial growth in the distribution system.

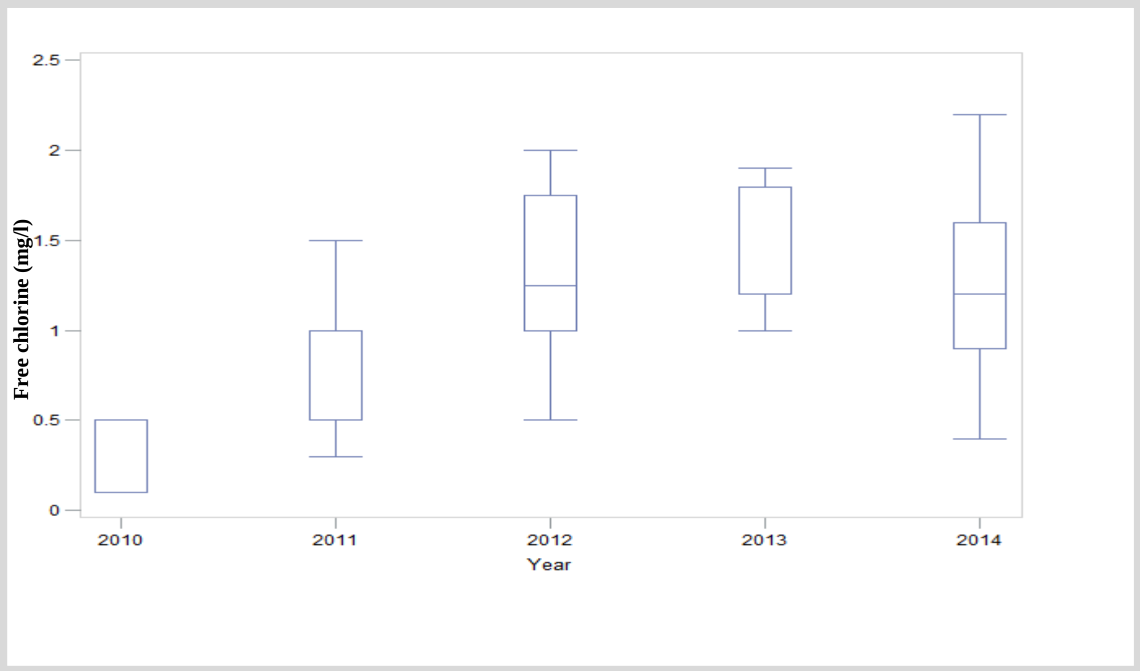

Figure 16: Box plot for free chlorine at Flag Boshielo water supply system

4.3.3 Groblersdal water supply system water quality compliance

Groblersdal water supply system serves a population of approximately 78 552 (DWA, 2012). Figure 31 indicates drinking water performance between 2010 and 2014. Groblersdal water supply system compliance percentages reveal fluctuating performance against the drinking water quality standard.

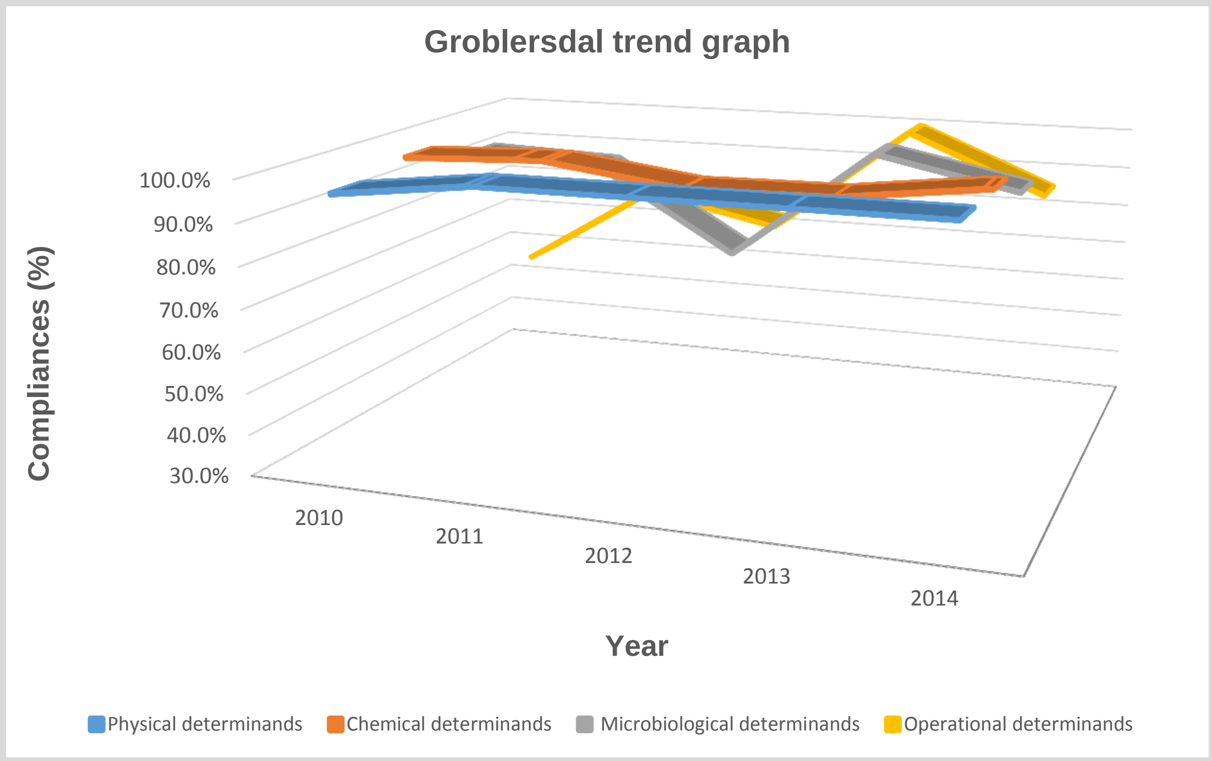

Figure 17: Groblersdal water supply system compliance percentages

Microbial compliance as shown in the Figure 17 shows non-compliance of *E.coli* against the SANS 241 numerical limit. The municipality collected 60 samples for analyses for *E.coli* per year. The *E.coli* results failed to meet SANS 241 numerical limit except for 2014 as shown on the Annexure A, Table 24. The microbiological determinands have been fluctuating significantly over the years. The occurrence of coliform bacteria, therefore, in this system could be related to an inability to maintain an effective disinfectant residual in the distribution system. The Figure 17 further reveals that when operational determinand decreased, microbiological compliance declined. This shows that failure of free chlorine in the distribution, microbiological water quality can be compromised.

Figure 17 shows chemical determinands performance had been fluctuating between 2010 and 2014 while remaining above 90% and classified as good with the SANS 241: 2006 standard. The study noted nitrate concentration in water samples analysed exceeded the SANS 241 numerical limit and affected the chemical determinands compliance to achieve excellent. WRC (1998) report states that nitrates pose severe toxic effects in infants and has the potential to cause tiredness, cyanosis and difficulty to breathe on the kids of less than 1 year. It should be noted that the municipality has consistently submitted nitrate and sulfate while other chemical determinands such as iron, manganese, sodium and magnesium results are available only in 2010 and 2011. The results of arsenic were not available or provided to the regulatory system and did not contribute to the overall chemical compliance.

Box plot Figure 18 shows the distribution of free chlorine over a 5 year period at Groblersdal water supply system. Free chlorine results in 2010 show an average of low level with an improvement from 2011 to 2013. Free chlorine compliance improved from 58.8% to 85.7% in 2010 and 2014 respectively.

There was some non-compliance with the required SANS 241 numerical limit. Compliance percentage for free chlorine gradually improved from 2010 to 2014. The study noted extreme values which were indicative of inconsistent with free chlorine levels in the distribution system. Too high concentration of free chlorine in water may impart unpleasant taste and smell in the water (WRC, 1998). It is advisable to maintain free chlorine in the distribution system ranging between 0.2 mg/l and 0.5 mg/l to maintain disinfection in the distribution system (SABS, 2006). Absence of free chlorine means that either the water was not treated with chlorine, or that insufficient chlorine was used to successfully disinfect the water (WRC, 1998).

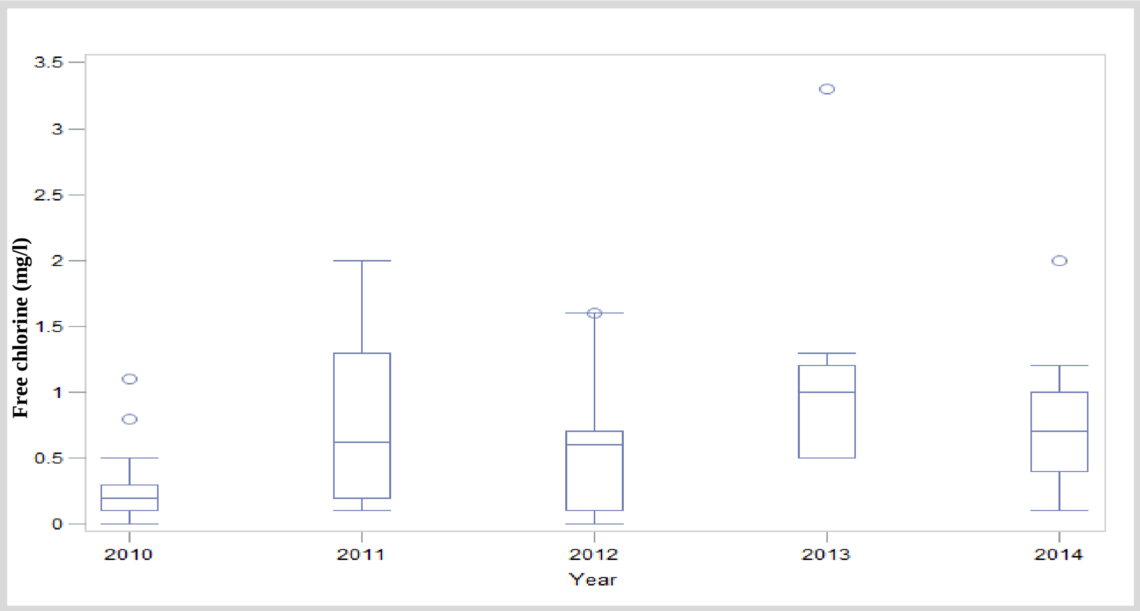

Figure 18: Box plot for free chlorine at Groblersdal water supply system

The municipality has taken a total of 155 physical determinand samples. It should be noted that some of the determinands were monitored on a higher frequency than others. For instance turbidity results were only available in 2010 and the municipality did not submit turbidity results on the BDS beyond 2010, hence the turbidity Box plot could not be plotted. Figure 19 below shows conductivity results meeting the SANS 241 limit. The results as shown in the Box plot is inconsistent but the results are incompliant with the SANS 241 in the distribution network (SABS 2006). Figure 19 shows conductivity results between 2010 and 2014 fell within the numerical limit of the standard.

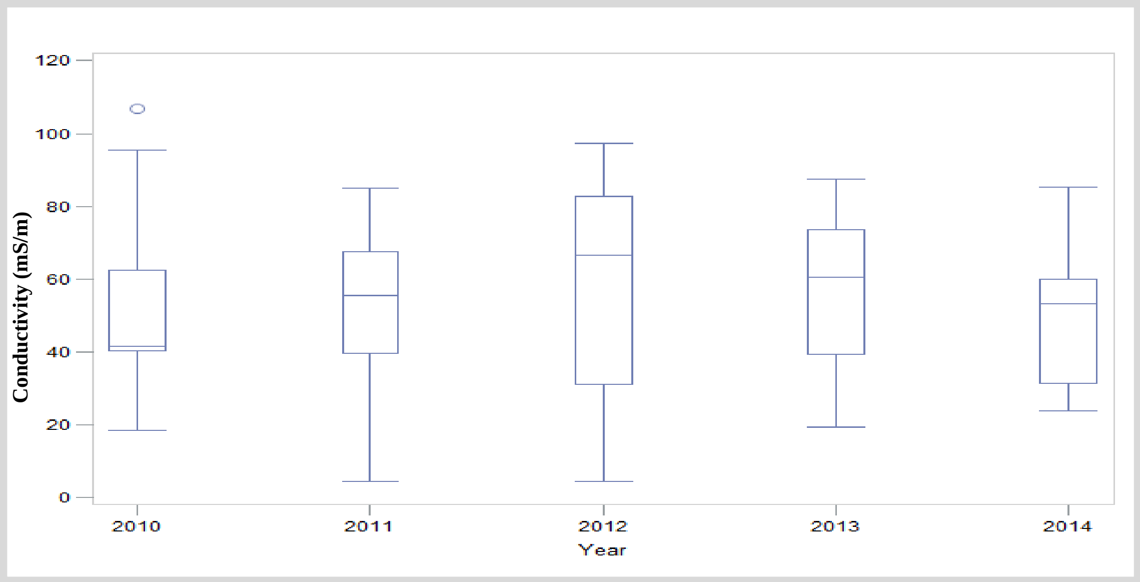

Figure 19: Box plot for conductivity results for Groblersdal water supply system

It should be noted that results of an odour were not available and did not contribute on the compliance results. The municipality should include the analysis of odour in their monitoring programme as this is also a requirement of the SANS 241 and the results may serve as an indication that drinking water is acceptable to consumers.

4.4 Greater Sekhukhune District Municipality p-value results

This section presents p-value results of the water quality determinands of the study period for Greater Sekhukhune District Municipality. This subsection presents p-value results for Burgersfort, Flag Boshielo and Groblersdal water supply systems.

4.4.1 Burgersfort Water Supply System

Burgersfort water supply system p-value results to determine p-value results for this supply system. As the water quality results presented above on the Figure 10 above, the study has used the same water quality determinands for the p-value results.

Table 16 presents *E.coli* p-value results for the years from 2010 until 2014 as well as p-values for the years 2010 and 2014 separately. It also show that results in 2010 and 2014 are not significant varied with p-values of >0.05 and therefore the p-value expression suggests that the null hypothesis cannot be rejected. P-values also show that there is not a significant difference for *E.coli* results in 2010 and 2014. The study has noted *E.coli* failures in 2010 as revealed in Annexure A, Table 7. Table 16 shows that between 2011 and 2014 there was a non-detection of *E.coli* counts in the water analysis.

Table 16: Burgersfort p-value results for *E.coli* in drinking water

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	16	5	0.3125	1.5625	400%	
_2011	24	0	0	0	#DIV/0!	
_2012	22	0	0	0	#DIV/0!	
_2013	21	0	0	0	#DIV/0!	
_2014	23	0	0	0	#DIV/0!	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.326651	4	0.331663	1.429245	0.22975561	2.461698
Within Groups	23.4375	101	0.232054			

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficent*	
_2010	16	5	0.3125	1.5625	400%	
_2014	23	0	0	0	#DIV/0!	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.921474	1	0.921474	1.454701	0.23543114	4.105456
Within Groups	23.4375	37	0.633446			
Total	24.35897	38				

Table 17 illustrates p-value results for calcium for the years from 2010 until 2012. Calcium p-value results presented in the Table below is <0.05 and implies that there is a significant difference between 2010 and 2012. It should be noted that calcium samples were not analysed between 2013 and 2014 hence no results are available. Calcium results gradually increased by more than 100% between 2010 and 2012.Calcium average results remained within the numerical limit of the standard.

Table 17: Burgersfort calcium p-value results in the distribution system

Anova: Single Factor						
Calcium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	7	278.1	39.72857	405.149	51%	
_2011	11	744.1	67.64545	124.7827	17%	
_2012	15	1772	118.1333	384.8381	17%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34123.23	2	17061.62	56.45519	6.77426E-11	3.31583
Within Groups	9066.455	30	302.2152			
Total	43189.69	32				

Table 18 presents p-value results for magnesium for the years from 2010 until 2012. P-values for magnesium of < 0.05 implies that there is a significant difference between 2010 and 2012and thus reject the null hypothesis. Magnesium average results suggest that there was an improvement of magnesium concentration between 2010 and 2012 with results within the numerical limit of the drinking water quality standard. Table 18 further notes analysis results were missing between 2013 and 2014 therefore study cannot determine compliance between that periods.

Table 18: Burgersfort p-value result of magnesium in drinking water

Anova: Single Factor
Magnesium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	7	283.6	40.51429	441.8648	52%
_2011	16	468	29.25	5.562667	8%
_2012	15	380.2	25.34667	6.122667	10%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1105.885	4	276.4712	3.234904	0.024057121	2.658867
Within Groups	2820.346	33	85.46503			
Total	3926.231	37				

Table 19 below shows p-values for nitrate concentrations for the years from 2010 until 2014. It also shows p-value for the years 2010 and 2014 separately. Both p-value results between 2010 and 2014 is <0.05 which implies that there is a significant difference of nitrate in the water quality between this period. The study has also noted that nitrate concentration has improved between 2010 and 2012 but concentration increased between 2013 and 2014. Nitrate average results as presented above remained within the SANS 241 numerical limit

Table 19: Burgersfort p-value of nitrate results in the distribution system

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	18	92.1	5.116667	25.81794	99%
_2011	24	51.5	2.145833	2.571286	75%
_2012	23	12.5	0.543478	0.172569	76%
_2013	21	40.6	1.933333	7.262333	139%
_2014	24	49	2.041667	1.465145	59%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	218.2794	4	54.56986	8.416499	6.26899E-06	2.45821
Within Groups	680.7861	105	6.483677			
Total	899.0655	109				

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coeffiecient
_2010	18	92.1	5.116667	25.81794	99%
_2014	24	49	2.041667	1.465145	59%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	97.25786	1	97.25786	8.231669	0.006544408	4.084746
Within Groups	472.6033	40	11.81508			
Total	569.8612	41				

Table 20 below shows the p-value for sulfate average results concentrations from 2010 until 2014. It also shows p-value for the years 2010 and 2014 separately. The overall p-value result is <0.05 and implies that there is as significant difference between 2010 and 2014 and as a result the study rejects the null hypothesis as the results suggest significantly varied. The municipality has maintained compliance with the numerical limit of the standard and the Table 20 further notes improvement of sulfate concentration as shown below.

Table 20: Burgersfort p-value of sulfate results in the distribution system

Anova: Single Factor
Sulfate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	337.2	25.93846	1958.449	171%
_2011	24	178.1	7.420833	51.51129	97%
_2012	23	88.3	3.83913	43.86794	173%
_2013	21	186	8.857143	101.8286	114%
_2014	24	403	16.79167	49.04167	42%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5275.901	4	1318.975	4.577268	0.001952	2.462615
Within Groups	28815.77	100	288.1577			
Total	34091.68	104				

Anova: Single Factor
Sulfate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
2010	13	337.2	25.93846	1958.449	171%
2014	24	403	16.79167	49.04167	42%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	705.4898	1	705.4898	1.00255	0.3235669	4.121338
Within Groups	24629.35	35	703.6957			
Total	25334.84	36				

The p-value result of sulfate in 2010 and 2014 is >0.05 and implies that the study cannot reject the null hypothesis. Average results for both 2010 and 2014 suggest that sulfate concentration had relatively improved if comparing 2010 and 2014 levels of sulfate concentration. Sulfate results were within the numerical limit as shown on the Annexure A, Table 7 – 11. Sulfate levels in raw water may vary every year or seasons depending on the land use activities in the catchment area.

Table 21 below presents the p-value for the years from 2010 until 2014 and the p-value for the years 2010 and 2014. The overall p-value is <0.05 and implies that there is a significant difference of turbidity results between 2010 and 2014. It also shows a p-value of >0.05 in 2010 and 2014 and suggest that there is no significant difference for turbidity results. Turbidity results had been within the numerical limit of the standard with average results of < 1 NTU except in 2011. But the average results were normalised between 2012 and 2014.

Table 21: Burgersfort p-value for turbidity in drinking water

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	5.18	0.575556	0.342928	102%
_2011	16	66.6	4.1625	21.3745	111%
_2012	23	15.6	0.678261	0.023597	23%
_2013	20	10.9	0.545	0.036289	35%
_2014	21	13.4	0.638095	0.011476	17%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	165.1361	4	41.28404	10.67694	4.815E-07	2.480322
Within Groups	324.7991	84	3.866656			
Total	489.9352	88				

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	5.18	0.575556	0.342928	102%
_2014	21	13.4	0.638095	0.011476	17%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.024641	1	0.024641	0.232072	0.6337357	4.195972
Within Groups	2.972946	28	0.106177			
Total	2.997587	29				

Table 22 shows an overall p-value for pH (expressed as [H+]) of <0.05 and as a result the study show that there is a significant difference between 2010 and 2014.The Table further reveals a p-value of <0.05 at Burgersfort water supply system comparing pH (expressed as [H+]) results in 2010 and 2014. Due to the p-value expression result, the study rejects the null hypothesis with a significant difference in 2010 and 2014. The pH actual results had been consistent with the numerical limits of the SANS 241 between 2010 and 2014 as shown on the Annexure A, table 7 – 11.

Table 22: Burgersfort p-value for pH (expressed as [H+]) in the distribution system

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	18	2.19227E-07	1.21793E-08	8.58005E-17	76%
2011	24	2.87721E-07	1.19884E-08	1.41371E-16	99%
2012	23	4.11E-07	1.78696E-08	1.67871E-16	73%
2013	21	1.6859E-07	8.02808E-09	1.05516E-17	40%
2014	25	1.57458E-07	6.29832E-09	7.83976E-18	44%

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Grou	1.86723E-15	4	4.66806E-16	5.621305145	0.000383513	2.457380022
Within Group	8.80249E-15	106	8.30424E-17			
Total	1.06697E-14	110				

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	18	2.19227E-07	1.21793E-08	8.58005E-17	76%
2014	25	1.57458E-07	6.29832E-09	7.83976E-18	44%

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Grou	3.61942E-16	1	3.61942E-16	9.011401249	0.004553498	4.078545731
Within Group	1.64676E-15	41	4.01649E-17			
Total	2.0087E-15	42				

Table 23 presents p-value results for conductivity results from 2010 until 2014 and p-value results in 2010 and 2014. P-value results for conductivity is <0.05 and implies that there is significant difference.

Table 23: Burgersfort average and p-value for conductivity results in the distribution system

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	18	829.5	46.08333	1003.543	69%
_2011	24	891	37.125	25.48543	14%
_2012	23	1644.1	71.48261	168.7079	18%
_2013	21	1113.4	53.01905	144.1216	23%
_2014	24	1478.1	61.5875	221.0011	24%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	16391.79	4	4097.948	14.67375	1.48862E-09	2.45821
Within Groups	29323.42	105	279.2707			
Total	45715.21	109				

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	18	829.5	46.08333	1003.543	69%
_2014	24	1478.1	61.5875	221.0011	24%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2472.472	1	2472.472	4.466321	0.04085595	4.084746
Within Groups	22143.25	40	553.5813			
Total	24615.72	41				

Conductivity p-value results of 2010 and 2014 is also <0.05 and the results shows significant difference. Conductivity results fluctuated between 2010 and 2014 as shown in the Table above but remained within the numerical limit of the drinking water quality standard.

4.4.2 Flag Boshielo p-value results

This section presents p-values of Flag Boshielo water supply systems of the results presented on the Figure 14 above. The P-value results of this water supply system had to provide whether there is significant difference between the study periods.

Table 24 below shows p-values for *E.coli* for the years from 2010 until 2014 and the p-value for 2010 and 2014. *E.coli's* p-values were zero therefore the p-value cannot be calculated and suggest that the null hypothesis cannot be rejected. The results are not significantly varied between 2010 and 2014. *E.coli* count results were zero during the reviewed period hence the average results are not clearly stated in Table 24. No *E.coli* counts were detected in the distribution system. *E.coli* compliance with the SANS 241 had been maintained between 2010 and 2014.

Table 24: Flag Boshielo p-value *E.coli* results in the distribution system

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	Count	Sum	Average	Variance	Coefficient	
_2010	22	0	0	0	#DIV/0!	
_2011	18	0	0	0	#DIV/0!	
_2012	24	0	0	0	#DIV/0!	
_2013	20	0	0	0	#DIV/0!	
_2014	22	0	0	0	#DIV/0!	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0	4	0	65535	#DIV/0!	2.461698
Within Groups	0	101	0			
Total	0	105				

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	Count	Sum	Average	Variance	Coefficient	
_2010	22	0	0	0	#DIV/0!	
_2014	22	0	0	0	#DIV/0!	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0	1	0	65535	#DIV/0!	4.072654
Within Groups	0	42	0			
Total	0	43				

Table 25 presents p-value results of <0.05 for nitrate average results and as a result the study rejects the null hypothesis. The results for nitrate show significant variance between 2010 and 2014.

Table 25: Flag Boshielo p-value results for nitrate results

Anova: Single Factor						
Nitrate						
SUMMARY						
Groups	Count	Sum	Average	Variance	Coefficient	
_2010	20	109.5	5.475	36.58513	110%	
_2011	18	32.9	1.827778	4.392712	115%	
_2012	24	46	1.916667	0.923188	50%	
_2013	20	27.5	1.375	1.149342	78%	
_2014	22	13.1	0.595455	0.082359	48%	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	289.1856	4	72.29641	8.786395	4.112E-06	2.46355
Within Groups	814.594	99	8.228222			
Total	1103.78	103				

Anova: Single Factor						
Nitrate						
SUMMARY						
Groups	Count	Sum	Average	Variance	Coefficient	
_2010	20	109.5	5.475	36.58513	110%	
_2014	22	13.1	0.595455	0.082359	48%	
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	249.4377	1	249.4377	14.31808	0.0005067	4.084746
Within Groups	696.847	40	17.42118			
Total	946.2848	41				

The study noted nitrate average results had been decreasing between 2010 and 2014. It should be further noted that nitrate average results were within the numerical limit of the standard. The concentration of nitrate levels had significantly reduced in the water. This shows that water treatment works receive less concentration of nitrate between 2010 and 2014.

Table 26 presents p-value results for conductivity from 2010 until 2014. It also presents p-value results for 2010 and 2014 separately. The results show overall p-value conductivity results of >0.05 therefore there was not a significant difference between 2010 and 2014. The p-value of the conductivity results cannot reject the null hypothesis for the overall study period.

Table 26: Flag Boshielo p-value of conductivity results in the distribution system

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	17	844.7	49.68824	525.8711	46%
_2011	18	882.37	49.02056	795.35	58%
_2012	24	1111.2	46.3	72.30435	18%
_2013	20	1063.4	53.17	132.5054	22%
_2014	22	859.7	39.07727	46.82279	18%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2348.365	4	587.0912	2.079827	0.089387	2.466476
Within Groups	27098.77	96	282.2788			
Total	29447.13	100				

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	17	844.7	49.68824	525.8711	46%
_2014	22	859.7	39.07727	46.82279	18%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1079.733	1	1079.733	4.251274	0.046297	4.105456
Within Groups	9397.216	37	253.9788			
Total	10476.95	38				

The study has noted that conductivity averages in 2013 had increased. The study further noted p-value results in 2010 and 2014 of <0.05 and implies that comparing the results of both years, the results show significant difference. Conductivity concentration in water decreased in 2014 as compare to the results in 2013.

Table 27 shows overall p-values for pH (expressed as [H+]) as >0.05 and as a result the null hypothesis cannot be rejected. The overall p-value results are further confirmed through comparing the results in2010 and 2014. The results show non-significant difference of pH (expressed as [H+]) average results. The p-value (expressed as H+) results reveal that there was not a significant difference in 2010 and 2014. Annexure A, Table 13 to 17 reveals that pH results have been within the numerical limit of the SANS 241.

Table 27: Flag Boshielo p-value for pH (expressed as [H+]) results in water

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	22	5.59464E-07	2.54302E-08	4.0419E-16	79%
2011	18	5.00183E-07	2.77879E-08	9.70398E-16	112%
2012	24	5.00737E-07	2.0864E-08	1.4911E-16	59%
2013	20	3.49819E-07	1.74909E-08	2.19191E-16	85%
2014	22	5.29105E-07	2.40502E-08	1.99372E-16	59%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.2833E-15	4	3.20826E-16	0.881348032	0.47798419	2.461698
Within Groups	3.67657E-14	101	3.64017E-16			
Total	3.8049E-14	105				

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	22	5.59464E-07	2.54302E-08	4.0419E-16	79%
2014	22	5.29105E-07	2.40502E-08	1.99372E-16	59%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.09472E-17	1	2.09472E-17	0.069411859	0.793483353	4.072654
Within Groups	1.26748E-14	42	3.01781E-16			
Total	1.26958E-14	43				

Table 28 shows the p-value results for free chlorine from 2010 until 2014 and p-values for 2010 and 2014. P-values are <0.05 and implies free chlorine results are significantly varied. Table 28 below shows p-value results between 2010 and 2014 for free chlorine result the null hypothesis is rejected.

Table 28: Flag Boshielo p-value of free chlorine results in the distribution system

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	14.5	0.763158	0.688012	109%
_2011	13	15.8	1.215385	0.38641	51%
_2012	24	29.3	1.220833	0.214764	38%
_2013	20	29.5	1.475	0.137763	25%
_2014	22	30.44	1.383636	0.228148	35%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.85527	4	1.463817	4.635279	0.0018609	2.469595
Within Groups	29.36933	93	0.315799			
Total	35.2246	97				

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	14.5	0.763158	0.688012	109%
_2014	22	30.44	1.383636	0.228148	35%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.925056	1	3.925056	8.912625	0.0048719	4.091279
Within Groups	17.17532	39	0.440393			
Total	21.10038	40				

The p-value results suggest the study rejects the null hypothesis and alternative is considered. Free chlorine average results had increased between 2010 and 2014 in the distribution system to guard against microbial regrowth as shown in Table Annexure A, Table 13 - 17.

4.4.3 Groblersdal water supply system

This section presents p-value results of the water quality determinands presented on the Figure 17 above to determine whether there was significant difference between 2010 and 2014 or not. P-value results had to reveal whether drinking water quality improved or deteriorated as the study analysed the results between the study periods.

Table 29 presents p-value results for *E.coli* from 2010 until 2014 and p-values in 2010 and 2014. The Table reveals *E.coli* overall p-values of >0.05 and as a result the study cannot reject the null hypothesis. The p-value for *E.coli* results in 2010 and 2014 suggest that null hypothesis cannot be rejected and implies that there is not a significant difference for *E.coli* results between 2010 and 2014. *E.coli* average results show that samples failed to meet the SANS 241 requirements.

Table 29: Groblersdal p-value for *E.coli* results in water

Anova: Single Factor
E.coli
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	8	1	0.125	0.125	283%
_2011	14	3	0.214286	0.642857	374%
_2012	11	410	37.27273	6558.418	217%
_2013	12	0	0	0	#DIV/0!
_2014	14	5	0.357143	1.17033	303%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12308.76	4	3077.19	2.53272	0.050726576	2.542918
Within Groups	65608.63	54	1214.975			
Total	77917.39	58				

Anova: Single Factor
E.coli
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	8	1	0.125	0.125	283%
_2014	14	5	0.357143	1.17033	303%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.131494	1	0.131494	0.167165	0.686988326	4.351244
Within Groups	15.73214	20	0.786607			
Total	15.86364	21				

Table 30 presents overall nitrate p-value results of >0.05 and as a result the study cannot reject the null hypothesis between 2010 and 2014. P-value expressions suggest nitrate concentrations results were not significantly varied.

Table 30: Groblersdal water supply p-value for nitrate in the distribution

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	89.9	4.731579	68.18006	175%
_2011	14	12.3	0.878571	0.412582	73%
_2012	11	30.8	2.8	9.064	108%
_2013	12	26.9	2.241667	6.64447	115%
_2014	14	24.5	1.75	0.965769	56%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	139.8289	4	34.95723	1.612775	0.18166226	2.51304
Within Groups	1408.889	65	21.67521			
Total	1548.718	69				

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	89.9	4.731579	68.18006	175%
_2014	14	24.5	1.75	0.965769	56%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	71.65728	1	71.65728	1.791727	0.19045073	4.159615
Within Groups	1239.796	31	39.99342			
Total	1311.453	32				

Table above further confirms p-value as >0.05 in 2010 and 2014. The study noted some nitrated results exceeding the numerical limit of the standard in 2010 as shown in Annexure A, Table 30 and thus the nitrate average results in 2010 is higher compared to the other years.

Table 31 indicates conductivity p-value results as >0.05 and as a result the null hypothesis cannot be rejected. The p-values between 2010 and 2014 reveal that there is no significant difference for conductivity average results. Table 31 notes high average results in 2012 and 2013 compared to other years. The averages results are within the numerical limit of the standard.

Table 31: Groblersdal water supply system p-value for conductivity results in water

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	959.29	50.48895	523.5175	45%
_2011	15	791.18	52.74533	385.3423	37%
_2012	11	635.28	57.75273	882.4682	51%
_2013	12	681.7	56.80833	519.4008	40%
_2014	14	703.2	50.22857	403.8191	40%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	649.9957	4	162.4989	0.309917	0.87036671	2.510833
Within Groups	34605.85	66	524.331			
Total	35255.84	70				

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	959.29	50.48895	523.5175	45%
_2014	14	703.2	50.22857	403.8191	40%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.546474	1	0.546474	0.001155	0.97311199	4.159615
Within Groups	14672.96	31	473.3214			
Total	14673.51	32				

The overall p-value as presented in Table 32 shows results of <0.05 therefore the study rejects the null hypothesis for the period from 2010 until 2014.The pH (expressed as [H+]) average results fluctuated between 2010 and 2014. The results reveal pH (expressed as [H+]) p-values of >0.05 in 2010 and 2014. The p-value for pH (expressed as [H+]) showed that there was no significant difference in 2010 and 2014. The pH results between 2010 and 2014 have been within the numerical limit of the SANS 241 as shown in Annexure A, Tables 19-23.

Table 32: Groblersdal water supply system p-value for pH (expressed as (H+]) results in the distribution

Anova: Single Factor						
pH (Expressed as [H+])						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient of variation*	
2010	24	8.3E-07	3.44798E-08	1.3E-15	104%	
2011	15	1.7E-07	1.13447E-08	9.8E-17	87%	
2012	11	8.7E-08	7.8751E-09	1.5E-17	50%	
2013	12	1.3E-07	1.05069E-08	8.2E-17	86%	
2014	14	3E-07	2.14626E-08	5.4E-16	108%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.88309E-15	4	2.22077E-15	4.02042	0.005377189	2.500760421
Within Groups	3.92185E-14	71	5.52373E-16			
Total	4.81016E-14	75				

Anova: Single Factor						
pH (Expressed as [H+])						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient of variation*	
2010	24	8.3E-07	3.44798E-08	1.3E-15	104%	
2014	14	3E-07	2.14626E-08	5.4E-16	108%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.49827E-15	1	1.49827E-15	1.46557	0.233934123	4.113165277
Within Groups	3.68031E-14	36	1.02231E-15			
Total	3.83014E-14	37				

Table 33 reveals overall results of <0.05 and as a result the study rejects the null hypothesis of the study. There is a significant difference of free chlorine average results between 2010 and 2014. There had been fluctuating results between 2010 and 2014 as shown in Table 33. It further shows that 2010 had the lowest average compared to the other years. In 2013 there was the highest average of above 1 mg/l of free chlorine in the distribution system. The study has also noted the p-value of <0.05 in 2010 and 2014 which further rejects the null hypothesis of the study. P-value further confirms that free chlorine results in 2010 were low compared to 2014.

Table 33: Groblersdal water supply system p-value for free chlorine in the distribution system

Anova: Single Factor						
Free chlorine						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	17	4.8	0.282353	0.084044	103%	
_2011	15	12.3	0.82	0.4404	81%	
_2012	11	6.07	0.551818	0.204336	82%	
_2013	12	13	1.083333	0.579697	70%	
_2014	14	10.8	0.771429	0.260659	66%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.231956	4	1.307989	4.333128	0.003652	2.515318
Within Groups	19.31891	64	0.301858			
Total	24.55086	68				

Anova: Single Factor						
Free chlorine						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	17	4.8	0.282353	0.084044	103%	
_2014	14	10.8	0.771429	0.260659	66%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.8364	1	1.8364	11.25132	0.00223041	4.182964
Within Groups	4.733277	29	0.163216			
Total	6.569677	30				

4.5 Tzaneen local municipality

Tzaneen local municipality collected samples to determine drinking water quality compliance percentages for both Tzaneen town and Letsitele water supply systems. Tzaneen town has a population of approximately 13 000 and Letsitele serves approximately 3000 consumers (DWA, 2012). Figures 20 and 24 present drinking water compliance percentages for water supply systems within the municipal jurisdiction.

4.5.1 Tzaneen water supply system

The municipality has collected *E.coli* samples and submitted results on the regulatory system to confirm compliance against SANS 241 standard. All sample analyses submitted conformed to the numerical limit of non-detection between 2011 and 2014 as shown in Figure 20 below. In 2010 the microbiological quality had been classified as excellent at 99.9% and water quality remained excellent in 2014 for the Tzaneen town supply system. Microbiological quality compliance was 98.7% in 2010 and improved to above 99.9% between 2011 and 2014.

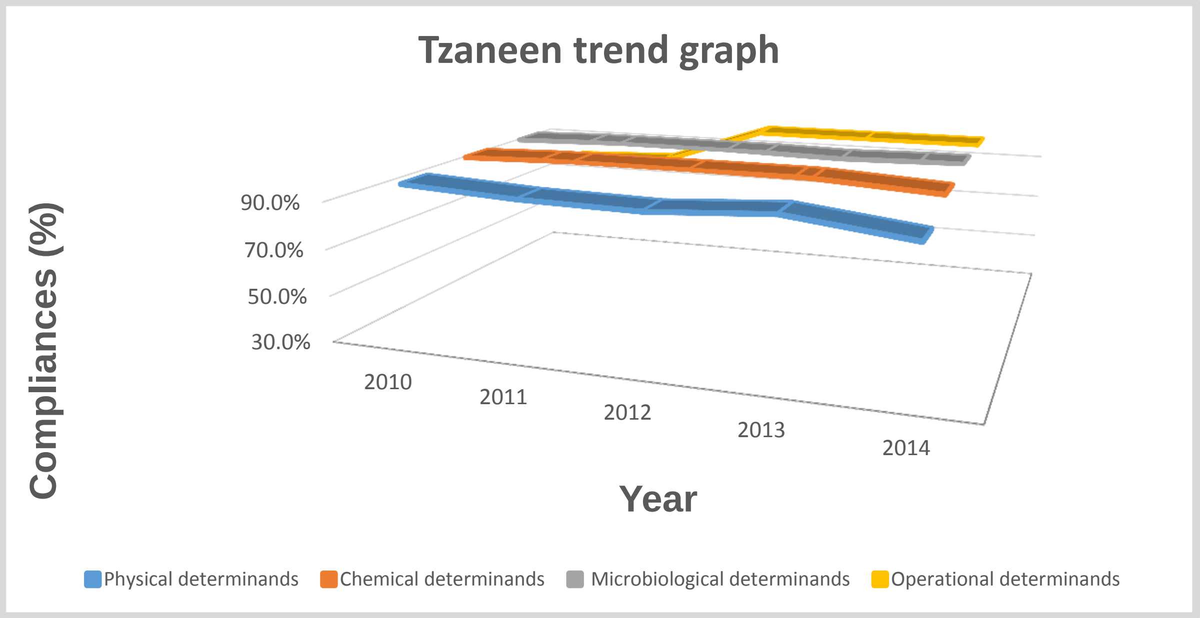

Figure 20: Tzaneen town water supply system drinking water compliance percentages

As shown on Figure 20 chemical determinands compliance was also excellent (SABS, 2006), exceeding 97% between 2010 and 2014. There were incidents of non-compliance for calcium in 2010 but results improved to meet the numerical limit of the standard in the following years. Calcium has aesthetic and operational risks with the numerical limit of < 150 mg/l (SABS, 2006). The study also noted declining compliance in 2013 from >99.9% to 96.6% in 2014. The decline was due to magnesium results exceeding the numerical limit of the standard. The magnesium has aesthetic and health risks and should not exceed <70 mg/l (SABS, 2006).

Figure 20 shows physical determinand compliance percentages fluctuating between 2010 and 2014, but was kept above 80% compliance. There were number of failures contributing to poor physical compliance. The results exceeding numerical limits of the standard include turbidity, colour, odour and pH. Figure 21 below shows the distribution of turbidity results between 2010 and 2014. The results are within the required numerical limit of the standard but there are extreme results exceeding the 1 NTU limit but other results was kept < 5 NTU. The turbidity results in 2010 and 2013 are low which comply with the standard. Turbidity results in 2011, 2013 and 2014 exceeded 1 NTU but were within 5 NTU. Turbidity results above 1 NTU can indicate process inefficiency and risks associated with pathogens (SABS, 2006). The presence of turbidity in water results in a cloudy or muddy appearance, and may also affect the taste and colour of the water (WRC, 1998).

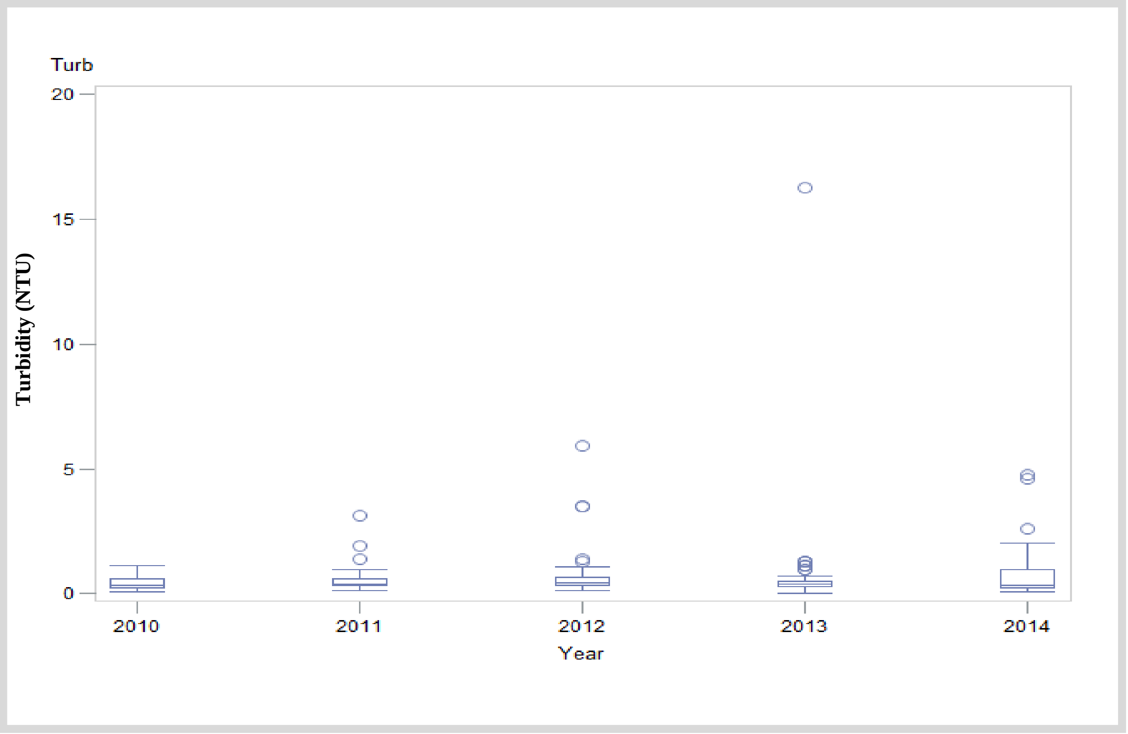

Figure 21: Box plot of Tzaneen water supply system turbidity results

The study has noted that colour, turbidity, odour and pH have contributed repeatedly to non-compliance of the numerical limit of the standard. Turbidity results as depicted in Figure 21 reveals instances where turbidity exceeded the numerical limit of 1 NTU.

Figure 22 reveals that conductivity results are compliant with the standard for all the years except in 2010. Overall conductivity results are below 100 mS/m and average compliance with the standard limit is relatively consistent in all the years except in 2010. The conductivity results for samples taken in 2010 exceeded the numerical limit. This water supply system receives low concentrations of conductivity and continual compliance with the standard limit reduces the risks of heart failures and kidney diseases (WRC, 1998). Figure 22 shows that there were insufficient conductivity analyses in 2014 hence Box plot does not provide clear median for that year.

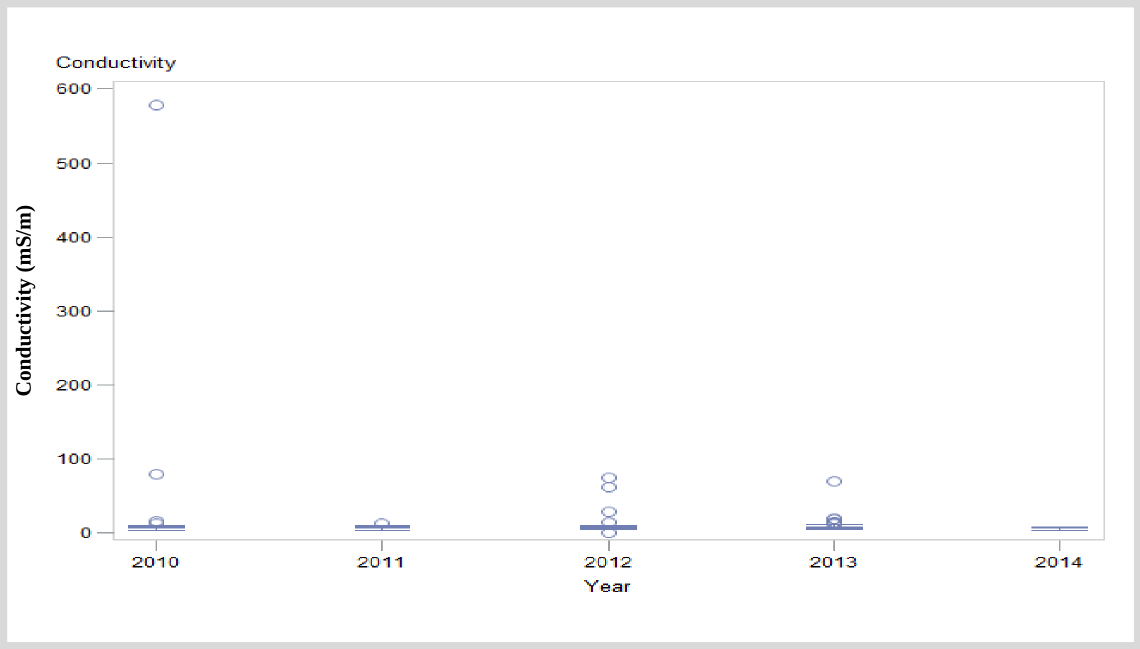

Figure 22: Box plot for Tzaneen water supply system conductivity results

The municipality has taken a total of 885 samples for chemical determinands that contributed to the overall chemical compliance calculation. Figure 20 shows chemical determinands complied with the SANS 241 limits from 2010 to 2014 Tzaneen water supply system chemicals determinands were within the numerical limits of the standard and classified as excellent (>99.9%).

There were free chlorine sample results used to determine compliance for operational determinands compliance. Figure 20 above shows operational determinand compliance has improved from 2010 to 2014. It is also important to note that in 2014 only one analysis of free chlorine was available to determine the compliance hence the box plot shows low data. Figure 23 indicates the level of free chlorine in the distribution network. Figure 23 shows free chlorine inconsistency in the distribution network between 2010 and 2014. Low free chlorine in the distribution may lead to compromise microbiological quality of water in the distribution system.

When free chlorine level is sufficient and turbidity (suspended solids) is low, this may also indicate the absence of pathogens (WHO, 2013). Maintaining acceptable free chlorine levels should be prioritised by the municipality to avoid regrowth of microbes and growth of biofilm in the distribution network. If the concentration of free chlorine is too high then irritation of mucous membranes, nausea and vomiting may occur (WRC, 1998).

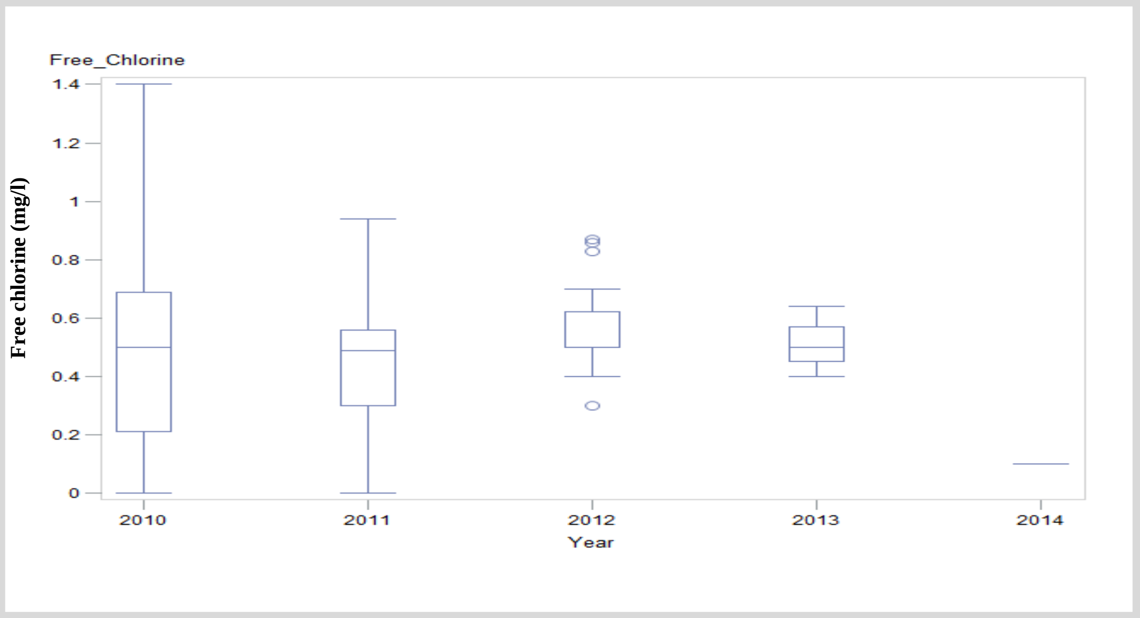

Figure 23: Box plot for Tzaneen water supply systems free chlorine results

WRC (1998) stresses that absence of free chlorine means that either the water was not treated with chlorine, or that insufficient chlorine was used to successfully disinfect the water.

4.5.2 Letsitele water supply system

Figure 24 below presents drinking water quality compliance for microbiological, chemical, physical and operational determinands compliance between the years 2010 and 2014. This performance shows compliance of the drinking water quality at Letsitele water supply system.

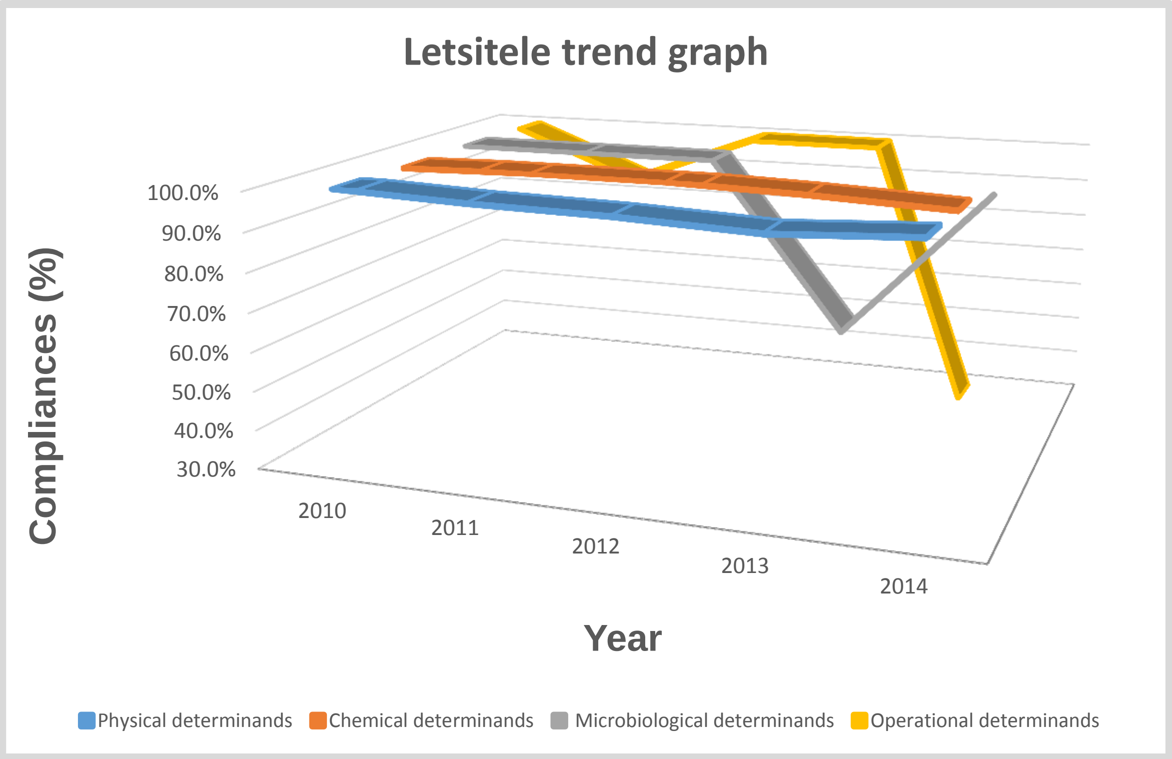

Figure 24: Letsitele water supply system compliance percentages

Figure 24 shows microbiological compliance in 2010 above 99.9% until 2012 but the compliance dropped to below 60% in 2013. The study also noted that compliance improved to 99.9% in 2014. The microbiological compliance was very poor in 2013 and this is an indicator of the possible presence of disease-causing organisms (WRC, 1998). Figure 24 also show microbiological compliance was within the standard limit in 2010 following the implementation of the Blue Drop certification programme.

Approximately 150 chemical determinand samples were submitted to the Department every year. However, it should be noted that other determinands were monitored at high frequencies and this could be attributed to those determinands that could be regarded as risks within the supply system. Figure 24 shows chemical compliance between the year 2010 and 2014 as excellent by the standard (SABS, 2006). Compliance was above 99.9% and there were few chemical results exceeded the numerical limits of the standard. This is noted in the year 2014 where compliance dropped to less than 99%. The non-compliant results of iron were observed in 2013 hence the compliance dropped from 99.9%. Other chemical determinands results were within the numerical limits.

There were a total of 455 physical determinands samples used to determine compliance percentage for physical determinands. Figure 24 shows fluctuating physical compliance between 2010 and 2014. The physical compliance was >99.9% in 2010, 98.7% in 2011 and declined even sharply to below 96% in 2013.The determinands exceeding the numeric limit of the standard was colour, odour and turbidity results. These determinands have aesthetic and operational risks rather than health risks to consumers (SABS, 2006).

Figure 25 shows that average turbidity results are within the numerical limit of 1 NTU but extreme results were also observed between the year 2011 and 2013 exceeding 1 NTU in the distribution system. The study has noted that overall turbidity average results are within the required numeric limits particularly in the years 2010 and 2014. The outliers of results exceeding numerical limit of the standard are observed between the years 2011and 2013.

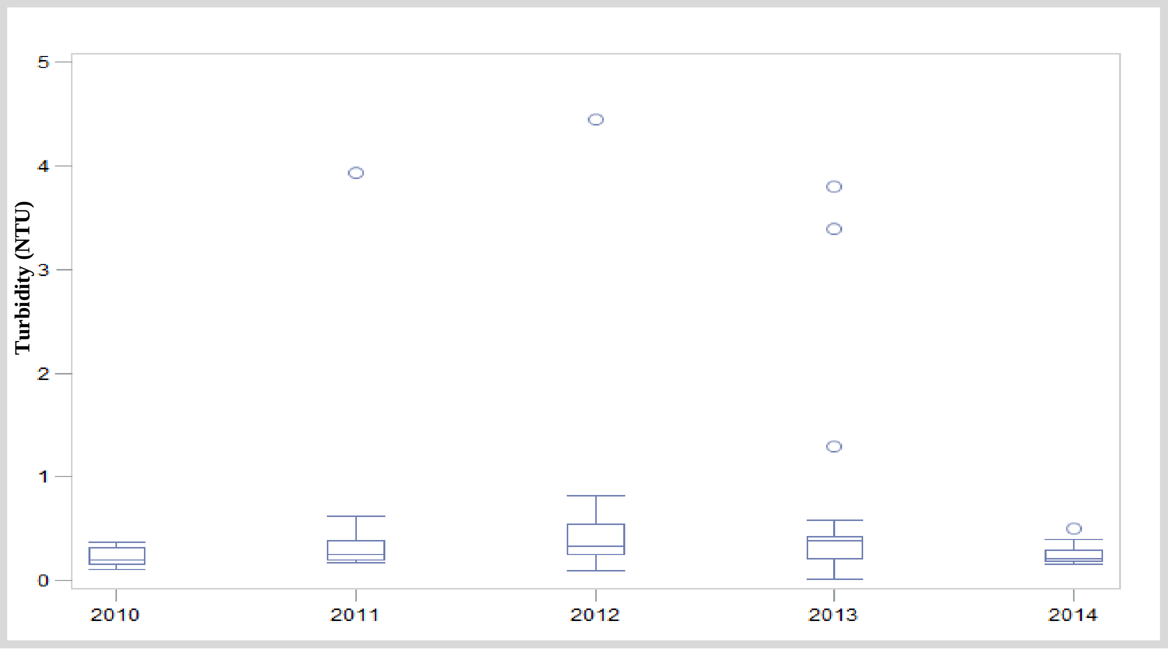

Figure 25: Box plot for Letsitele water supply system turbidity results

Figure 26 shows conductivity results to be within the numerical limit as required by the standard. The results had fluctuated but below 80 mS/m which is excellent. The municipality has to maintain consistency of conductivity concentration in water in the distribution system.

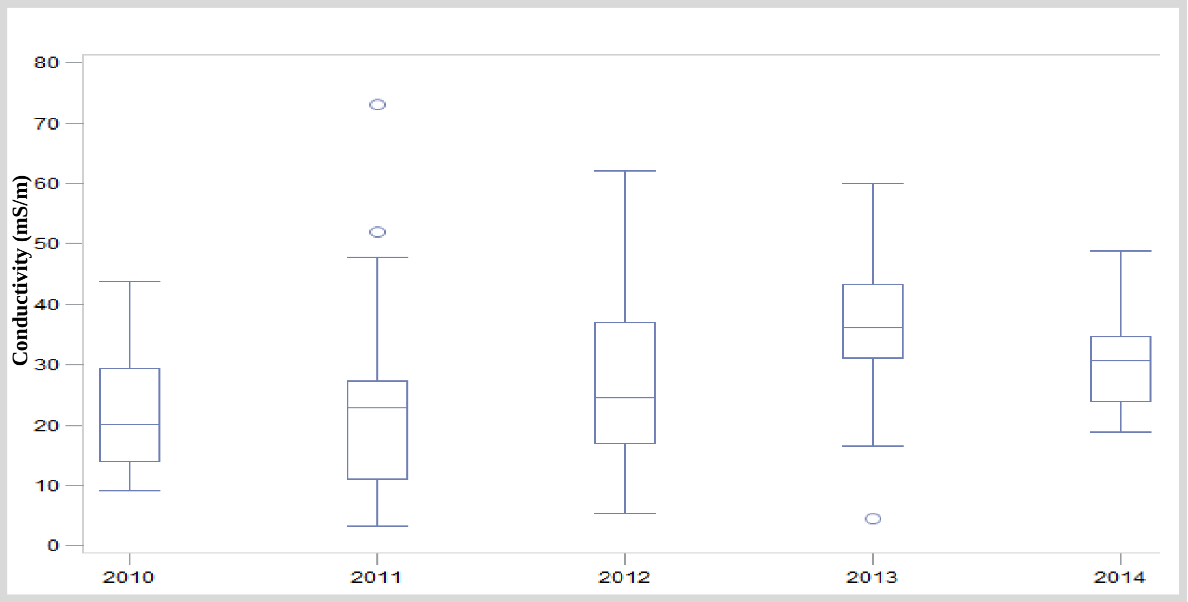

Figure 26: Letsitele water supply conductivity results Box plot diagram

Free chlorine sample results had been submitted by the municipality and used to determine operational determinand compliance. As part of the requirements, the municipality has to maintain the level of free chlorine in the reticulation network as prescribed in the standard. The results as shown in Figure 27 for free chlorine indicates that there has been a challenge of maintaining free chlorine levels in the reticulation network. Operational determinands such as residual chlorine has been improved by maintaining required minimum levels within the distribution network. Free chlorine results shown in figures 27 inconsistent in the distribution. The study noted insufficient free chlorine results in the year 2014 hence the plot cannot be properly displayed. The study has noted that the Table 27 and 28 on the Annexure A reveal insufficient analyses in the distribution were insufficient to determine operational compliance in the distribution network.

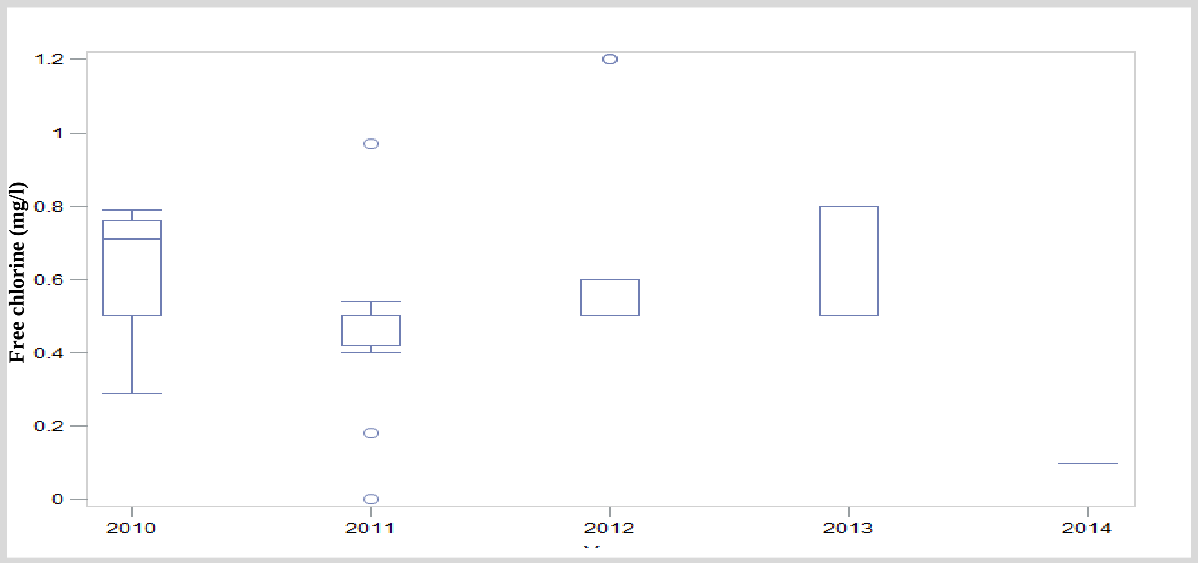

Figure 27: Box plot for Letsitele water supply system free chlorine results

Free chlorine results were inconsistent as shown in Figure 27. Free chlorine has an influence on the quality of drinking water produced at the final point of the treatment works (WRC, 1998). Figure 27 shows that free chlorine maintained the required level between the years 2012 and 2013 ranging between 0.2 and <1.0 mg/l. Free chlorine has to be maintained between 0.2 to 0.5 mg/l in the distribution network but should not exceed concentrations of 0.5 mg/l (SABS, 2015).

4.5.3 Tzaneen and Letsitele p-value results of the drinking water Quality determinands

The statistic p-values of drinking water determinands for Tzaneen municipality have been presented in the Tables below. This section presents drinking water quality determinands p-values for both Tzaneen and Lestitele water supply systems. The numbers of analyses were different from one selected determinand to another due to the number of samples submitted to the water quality system for each determinand.

4.5.3.1 Tzaneen water supply system p-value results

The p-values of the drinking water seek to determine whether to reject the null hypothesis of the study. The null hypothesis of the study was that there is no improvement of the drinking water quality following the introduction of the incentive based regulation i.e. Blue Drop certification programme.

Table 34 below shows p-value results for *E.coli* from 2010 until 2014. It also shows p-value results for 2010 and 2014. Overall p-values between 2010 and 2014 is <0.05 and implies that there is a significant difference. Overall p-value result rejects the null hypothesis. The study has noted *E.coli* counts in 2010, 2013 and 2014 and as a result the p-value results suggest that *E.coli* were significantly varied between 2010 and 2014.

Table 34: Tzaneen p-value for *E.coli* in the distribution system

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	78	0.7	0.008974	0.006282	883%	
_2011	81	0	0	0	#DIV/0!	
_2012	93	0	0	0	#DIV/0!	
_2013	90	31	0.344444	0.22834	139%	
_2014	56	3	0.053571	0.051623	424%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.819422	4	1.954856	32.49105	2.06973E-23	2.394649
Within Groups	23.64523	393	0.060166			
Total	31.46465	397				

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	78	0.7	0.008974	0.006282	883%	
_2014	56	3	0.053571	0.051623	424%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.064832	1	0.064832	2.575334	0.110931082	3.912875
Within Groups	3.323004	132	0.025174			
Total	3.387836	133				

Table 34 further shows *E.coli* p-values of >0.05 in 2010 and 2014 and the results imply that the study cannot reject the null hypothesis. *E.coli* results in 2010 and 2014 show there was not a significant difference for both years due to a number of *E.coli* counts detected in both years.

Table 35 presents p-values for iron concentration for the years from 2010 until 2014. It also shows the p-value results for 2010 and 2014 only. Both p-value expressions are > 0.05 and as a result suggests that the study cannot reject the null hypothesis. Table 35 further shows that the iron concentration in the water improved between 2010 and 2014, the results show variance decreasing between the years. The study has noted iron concentration exceeding the numerical limit of the standard in 2010 as shown in Annexure A, Table 25. But the concentration levels had improved from 2011 to 2014 as shown in Table 26 – 29 in Annexure A.

Table 35: Tzaneen water supply system's p-value for iron in the distribution system

Anova: Single Factor						
Iron						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	23	1960.11	85.22217	11266.33	125%	
_2011	18	1230.08	68.33778	4159.664	94%	
_2012	17	1029.247	60.54394	2059.022	75%	
_2013	50	2062.159	41.24318	10289.22	246%	
_2014	22	1316	59.81818	1044.061	54%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33164.51	4	8291.127	1.180917	0.322474952	2.444174
Within Groups	877615.1	125	7020.921			
Total	910779.6	129				

Anova: Single Factor						
Iron						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	23	1960.11	85.22217	11266.33	125%	
_2014	22	1316	59.81818	1044.061	54%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7256.746	1	7256.746	1.156627	0.288163634	4.067047
Within Groups	269784.4	43	6274.057			
Total	277041.2	44				

Table 36 show overall p-value expressions of <0.05 for magnesium average results from 2010 until 2014. The results were significantly varied and suggest that the study rejects the null hypothesis. Magnesium levels in water had been varied between 2010 and 2014 as shown on Table 36 above. All magnesium levels fell within the numerical limit of the standard. P-value expression of magnesium levels in 2010 and

2014 is >0.05 and this imply that results in both years are not significantly different. Magnesium results in 2010 and 2014 were not varied.

Table 36: Tzaneen water supply's p-value for magnesium in the distribution system

Anova: Single Factor
Magnesium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	24	31.37	1.307083	0.883604	72%
_2011	26	41.52	1.596923	4.684942	136%
_2012	17	12.3	0.723529	0.120137	48%
_2013	50	402.55	8.051	174.1914	164%
_2014	23	53.41	2.322174	19.21503	189%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1389.426	4	347.3566	5.154519	0.000677644	2.438739
Within Groups	9097.48	135	67.38874			
Total	10486.91	139				

Anova: Single Factor
Magnesium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	24	31.37	1.307083	0.883604	72%
_2014	23	53.41	2.322174	19.21503	189%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12.10182	1	12.10182	1.229156	0.273461452	4.056612
Within Groups	443.0535	45	9.845633			
Total	455.1553	46				

Table 37 reveals overall p-values of <0.05 and implies that there is a significant difference for manganese results from 2010 until 2014. Manganese average results had significant difference. P-value expressions in 2010 and 2014 are>0.05 and this suggests that results were not significantly different for both results. But the average results in 2010 and 2014 were varied and fall within the numerical limit of the standard.

Table 37: Tzaneen water supply system's p-value for manganese in water

Anova: Single Factor
Manganese
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	22	497	22.59091	323.0152	80%
_2011	18	139.11	7.728333	255.9949	207%
_2012	9	91.029	10.11433	78.78783	88%
_2013	50	1587.075	31.7415	311.4461	56%
_2014	23	634	27.56522	705.2569	96%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9830.336	4	2457.584	6.758897	6.26417E-05	2.449202
Within Groups	42542.05	117	363.6072			
Total	52372.38	121				

Anova: Single Factor
Manganese
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	22	497	22.59091	323.0152	80%
_2014	23	634	27.56522	705.2569	96%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	278.2296	1	278.2296	0.536521	0.467851999	4.067047
Within Groups	22298.97	43	518.5807			
Total	22577.2	44				

Nitrate concentration results in water reveal p-values of >0.05 as shown in Table 38 below. Nitrate p-values suggest that there is not significant difference between 2010 and 2014. The study noted an increase of concentration levels in 2011 but improved in the following year. P-values for 2010 and 2014 is >0.05 and shows not significant difference. It should be noted that nitrate results meet the numerical limit of the drinking water quality standard.

Table 38: Tzaneen water system’s p-value of nitrate in water

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	20	17.36	0.868	0.985417	114%
_2011	26	32.51	1.250385	3.651756	153%
_2012	17	7.49	0.440588	0.740331	195%
_2013	15	8.38	0.558667	1.035884	182%
_2014	15	8.05	0.536667	0.429267	122%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.472282	4	2.36807	1.463679	0.220085537	2.475277
Within Groups	142.3742	88	1.617889			
Total	151.8465	92				

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	20	17.36	0.868	0.985417	114%
_2014	15	8.05	0.536667	0.429267	122%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.940987	1	0.940987	1.255529	0.270587723	4.139252
Within Groups	24.73265	33	0.749474			
Total	25.67364	34				

Sodium results were significantly varied (P-value <0.05) each year as shown in Table 39 above from 2010 until 2014. The p-values in 2010 and 2014 is >0.05 and suggests that there was no significant difference for both years. Table 39 noted the difference of sodium concentration averages in both 2010 and 2014.

Table 39: Tzaneen water supply system’s p-value for sodium in the distribution system

Anova: Single Factor
Sodium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	43	209.32	4.867907	56.91669	155%
_2011	50	169.31	3.3862	23.35915	143%
_2012	53	191.25	3.608491	37.18283	169%
_2013	54	641.64	11.88222	339.7616	155%
_2014	23	167.04	7.262609	59.25178	106%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2597.55	4	649.3874	5.713045	0.000216587	2.413059
Within Groups	24779.51	218	113.6675			
Total	27377.06	222				

Anova: Single Factor
Sodium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	43	209.32	4.867907	56.91669	155%
_2014	23	167.04	7.262609	59.25178	106%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	85.93206	1	85.93206	1.48879	0.226881239	3.990924
Within Groups	3694.04	64	57.71938			
Total	3779.972	65				

Table 40 shows p-values of <0.05 in 2010 and 2014 which further confirms that the average results are significantly varied between 2010 and 2014. The study has noted that each year the average concentration of sulfate fluctuated. Sulfate average results remained within the numerical limit of the SANS 241. Sulfate concentration in the water shows significant difference between 2010 and 2014 and as a result the null hypothesis is rejected therefore alternative hypothesis is considered.

Table 40: Tzaneen water supply system's p-value for sulfate in water

Anova: Single Factor						
Sulfate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	47	67.3	1.431915	3.516133	131%	
_2011	50	242.4	4.848	67.51683	169%	
_2012	53	275.1	5.190566	84.58549	177%	
_2013	54	627.3	11.61667	986.3607	270%	
_2014	23	94.11	4.091739	23.04266	117%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2855.425	4	713.8562	2.61285	0.036290273	2.412311
Within Groups	60652.57	222	273.2098			
Total	63507.99	226				

Anova: Single Factor						
Sulfate						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	47	67.3	1.431915	3.516133	131%	
_2014	23	94.11	4.091739	23.04266	117%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	109.253	1	109.253	11.11025	0.00139203	3.981896
Within Groups	668.6807	68	9.833539			
Total	777.9337	69				

Table 41 reveals p-value results that are <0.05 and as a result the null hypothesis is rejected in favour of alternative hypothesis. There is a significant difference between 2010 and 2014 for calcium concentrations. The results further show an increase of calcium concentration between 2010 and 2014. Calcium results continued to meet the numerical limit of SANS 241.

Table 41: Tzaneen water supply system's p-value for calcium in the distribution system

Anova: Single Factor						
Calcium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	47	449.89	9.572128	12.39986	37%	
_2012	49	903.66	18.44204	358.006	103%	
_2012	53	1086.27	20.49566	543.4659	114%	
_2013	58	1248.27	21.5219	537.1769	108%	
_2014	23	571.05	24.82826	499.029	90%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5408.122	4	1352.03	3.47218	0.008931623	2.411768
Within Groups	87612.63	225	389.3895			
Total	93020.75	229				

Anova: Single Factor						
Calcium						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	47	449.89	9.572128	12.39986	37%	
_2014	23	571.05	24.82826	499.029	90%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3594.319	1	3594.319	21.16313	1.89367E-05	3.981896
Within Groups	11549.03	68	169.8387			

Table 42 below shows p-value results for colour for the years from 2010 until 2014. It also presents the p-value for the years 2010 and 2014. Calcium p-values of <0.05 shows significant difference between 2010 and 2014 and as a result rejects the null hypothesis of the study. Colour average results fluctuated between 2010 and 2014 but remained within the numerical limit of the standard.

Table 42: Tzaneen water supply system's p-value for colour in the distribution system

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	43	173	4.023256	12.73754	89%
_2012	47	314	6.680851	20.09158	67%
_2012	56	433.5	7.741071	25.57265	65%
_2013	109	606	5.559633	18.95243	78%
_2014	57	495	8.684211	77.57707	101%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	719.7514	4	179.9378	5.967563	0.000123065	2.401055
Within Groups	9256.863	307	30.15265			
Total	9976.615	311				

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	43	173	4.023256	12.73754	89%
_2014	57	495	8.684211	77.57707	101%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	532.4675	1	532.4675	10.69454	0.001483452	3.938111
Within Groups	4879.293	98	49.7887			
Total	5411.76	99				

Table 43 presents p-value results for conductivity from 2010 until 2014. It also shows p-values for 2010 and 2014. Both p-value results are >0.05 and as a result the null hypothesis cannot be rejected. The p-values in 2010 and 2014 further confirm that there is not a significant difference for conductivity average results in the study period. Conductivity results had been compliant with the numerical limit of the standard and as shown in Table 43, the results had improved between 2010 and 2014.

Table 43: Tzaneen water supply system's p-value for conductivity in the distribution system

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	71	1189.66	16.75577	4640.064	407%
_2012	82	1041.13	12.69671	148.4786	96%
_2012	88	1278.05	14.5233	239.8924	107%
_2013	112	1789.08	15.97393	222.0645	93%
_2014	56	724.38	12.93536	129.594	88%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	987.7911	4	246.9478	0.256155	0.905850966	2.394027
Within Groups	389478.7	404	964.0562			
Total	390466.5	408				

Anova: Single Factor
Conductivity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	71	1189.66	16.75577	4640.064	407%
_2014	56	724.38	12.93536	129.594	88%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	456.9454	1	456.9454	0.172078	0.678982789	3.916932
Within Groups	331932.1	125	2655.457			
Total	332389.1	126				

Table 44belowpresents pH (expressed as [H+]) overall p-values of >0.05 and as a result the study cannot reject the null hypothesis. The Table further presents p-values of > 0.05for pH (expressed as [H+]) results in 2010 and 2014 for the Tzaneen water supply systems. The pH (expressed as [H+]) average results increased in 2011 and 2014 compared to the other years. The study noted that pH results between 2010 and 2014 had been within the numerical limit of the SANS 241 as presented in Annexure A, Tables 25 – 29.

Table 44: Tzaneen water supply system's p-value for pH (expressed as [H+])

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
_2010	72	1.32E-06	1.83877E-08	2.3466E-15	263%
_2011	66	1.9E-06	2.88085E-08	6.5778E-15	282%
_2012	89	1.14E-06	1.28125E-08	4.5918E-16	167%
_2013	110	1.53E-06	1.39311E-08	4.1619E-16	146%
_2014	55	1.05E-06	1.90931E-08	5.0965E-16	118%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.19734E-14	4	2.99334E-15	1.63743761	0.164055915	2.395003
Within Groups	7.07461E-13	387	1.82807E-15			
Total	7.19435E-13	391				

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
_2010	72	1.32E-06	1.83877E-08	2.3466E-15	263%
_2014	55	1.05E-06	1.90931E-08	5.0965E-16	118%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.55164E-17	1	1.55164E-17	0.009991	0.920540204	3.916932
Within Groups	1.94129E-13	125	1.55303E-15			
Total	1.94145E-13	126				

Turbidity average results in the Tzaneen water supply system is <1 from 2010 until 2014 and as a result shows that the turbidity of water is acceptable. Table 45 reveals p-values between 2010 and 2014 as >0.05.There is not a significant difference for turbidity in the drinking water. Turbidity results remained within the numerical limit of the standard.

Table 45: Tzaneen water supply system's p-value for turbidity in water

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	29	12.02	0.414483	0.064254	61%
_2011	56	31.7	0.566071	0.428352	116%
_2012	92	57.54	0.625435	0.754104	139%
_2013	111	66.936	0.603027	2.515433	263%
_2014	57	39.1	0.685965	0.919274	140%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.544056	4	0.386014	0.310889	0.870646688	2.398211
Within Groups	422.1589	340	1.241644			
Total	423.703	344				

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	29	12.02	0.414483	0.064254	61%
_2014	57	39.1	0.685965	0.919274	140%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.416632	1	1.416632	2.233492	0.138795596	3.954568
Within Groups	53.27849	84	0.634268			
Total	54.69512	85				

Table 46 shows p-values for free chlorine as <0.05from 2010 until 2014. The overall p-value implies free chlorine results are significantly varied in the water. Free chlorine average results suggest that residual disinfection had been adequately between 2010 and 2014.

Table 46: Tzaneen water supply system's p-value for free chlorine in the distribution system

Anova: Single Factor						
Free chlorine						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	41	19.42	0.473659	0.105944	69%	
_2011	66	29.39	0.445303	0.048376	49%	
_2012	39	22.77	0.583846	0.035335	32%	
_2013	7	3.84	0.548571	0.017181	24%	
_2014	5	0.5	0.1	0	0%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.256556	4	0.314139	5.444407	0.000399246	2.430772
Within Groups	8.828004	153	0.057699			
Total	10.08456	157				

Anova: Single Factor						
Free chlorine						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	41	19.42	0.473659	0.105944	69%	
_2014	5	0.5	0.1	0	0%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.622223	1	0.622223	6.460454	0.014628325	4.061706
Within Groups	4.237751	44	0.096313			
Total	4.859974	45				

4.5.3.2 Letsitele water supply systems p-value results

The study presents p-value results for Letsitele water supply system. Letsitele water supply system is part of Tzaneen Local Municipality. The study has used all water quality determinands results presented for Letsitele water supply system.

Table 47 presents p-values of <0.05 and the *E.coli* results were significantly varied from 2010 and 2014. The results show that microbiological quality of water deteriorated in 2013 and 2014. The results in 2010 and 2014 further confirms that the null hypothesis cannot be rejected as the p-values are >0.05.

Table 47: Letsitele water supply system's p-value for *E.coli* in the distribution system

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	32	0	0	0	#DIV/0!	
_2011	25	0	0	0	#DIV/0!	
_2012	28	0	0	0	#DIV/0!	
_2013	41	11	0.268293	0.20122	167%	
_2014	14	1	0.071429	0.071429	374%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.994077	4	0.498519	7.496652	1.7481E-05	2.438739
Within Groups	8.977352	135	0.066499			
Total	10.97143	139				

Anova: Single Factor						
E.coli						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*	
_2010	32	0	0	0	#DIV/0!	
_2014	14	1	0.071429	0.071429	374%	
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.049689	1	0.049689	2.354515	0.1320807	4.061706
Within Groups	0.928571	44	0.021104			
Total	0.978261	45				

The results further show *E.coli* results did not meet the numerical limit of the standard. It should be noted that *E.coli* analysis results should be zero or absent to deem water fit for consumption and the results from 2010 to 2012 ad an average of zero counts.

Table 48 results show signs of a relative increase of calcium concentration between 2010 and 2014. The p-value is > 0.05 and implies that there is no significant difference between 2010 and 2014. Calcium average results range between 29.09353 and 52.213333. The 2010 and 2014 results show p-values of <0.05 and as a result there is a significant difference in both years. Calcium results averages in the water increased in 2014 compared to 2010. Calcium results between 2010 and 2014 met the requirements for SANS 241.

Table 48: Letsitele water supply system's p-value for calcium in the distribution

Anova: Single Factor
Calcium

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	24	707.24	29.46833	235.3246	52%
_2011	17	494.59	29.09353	575.2599	82%
_2012	17	695.63	40.91941	1029.281	78%
_2013	25	964.74	38.5896	711.0428	69%
_2014	6	313.28	52.21333	805.7301	54%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3981.948	4	995.4869	1.602584	0.18122818	2.480322
Within Groups	52178.79	84	621.1761			
Total	56160.74	88				

Anova: Single Factor
Calcium

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	24	707.24	29.46833	235.3246	52%
_2014	6	313.28	52.21333	805.7301	54%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2483.208	1	2483.208	7.364576	0.01125409	4.195972
Within Groups	9441.117	28	337.1827			
Total	11924.32	29				

Table 49 below presents p-values for iron concentration for the years 2010 until 2014. It also shows the p-values in 2010 and 2014. Both p-value results are >0.05 and this suggests that there is not a significant difference between 2010 and 2014.It should be noted that the results show an improvement in iron concentration for this period. Some of the iron results exceeded the numerical limit of the standard in 2010 and 2013 but other years the results were compliant with the standard.

Table 49: Letsitele water supply system's p-value for iron in the distribution system

Anova: Single Factor
Iron

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	1133.02	87.15538	16417.68	147%
_2011	5	0.88	0.176	0.01178	62%
_2012	5	386	77.2	1696.7	53%
_2013	19	712.109	37.47942	1836.921	114%
_2014	6	252	42	430.8	49%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	37273.65	4	9318.413	1.676411	0.172969614	2.588836
Within Groups	239017.6	43	5558.55			
Total	276291.3	47				

Anova: Single Factor
Iron

SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	1133.02	87.15538	16417.68	147%
_2014	6	252	42	430.8	49%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8370.668	2	4185.334	0.336228	0.71938776	3.633723
Within Groups	199166.2	16	12447.89			
Total	207536.9	18				

Magnesium results in water fluctuated between 2010 and 2014 as shown in Table 50 below. The p-value of magnesium is <0.05 and as a result the study rejects the null hypothesis in favour of the alternative hypothesis. Table 50shows significant variance of average results and 2013 had the highest average compared to other years. The p–value of 2010 and 2014 is >0.05 and suggests that the study cannot reject the null hypothesis therefore there is no significant difference for magnesium results in 2010 and 2014. Magnesium levels were within the drinking water quality standard.

Table 50: Letsitele water supply system's p-value for magnesium in the distribution system

Anova: Single Factor
Magnesium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	152.26	11.71231	98.31442	85%
_2011	7	10.86	1.551429	2.853514	109%
_2012	5	1.41	0.282	0.10867	117%
_2013	19	235.17	12.37737	118.019	88%
_2014	6	33.67	5.611667	65.93874	145%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1144.102	4	286.0254	3.525023	0.01382148	2.578739
Within Groups	3651.364	45	81.14143			
Total	4795.466	49				

Anova: Single Factor
Magnesium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	152.26	11.71231	98.31442	85%
_2014	6	33.67	5.611667	65.93874	145%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	152.7889	1	152.7889	1.720748	0.20703626	4.451322
Within Groups	1509.467	17	88.79216			
Total	1662.256	18				

Table 51 presents p-values for manganese concentration in the years from 2010 until 2014. It also shows the p-values for 2010 and 2014. Manganese average results fluctuated from 2010 to2014 with p-value results as <0.05. Manganese average results p-value reveals that there was a significant difference between 2010 and 2014.Manganese average results in 2010 and 2014 p-values are >0.05 and implies that the study cannot reject the null hypothesis. The results fell within the numerical limit of the standard for domestic use (SANS 241).

Table 51: Letsitele water supply system's p-value for manganese in water

Anova: Single Factor
Manganese
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	381.1	29.31538	289.4097	58%
_2011	5	0.09	0.018	2E-05	25%
_2012	3	41	13.66667	72.33333	62%
_2013	18	511.025	28.39028	264.6388	57%
_2014	6	123	20.5	201.1	69%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3971.178	4	992.7945	4.353435	0.00512932	2.605975
Within Groups	9121.943	40	228.0486			
Total	13093.12	44				

Anova: Single Factor
Manganese
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	13	381.1	29.31538	289.4097	58%
_2014	6	123	20.5	201.1	69%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	319.0241	1	319.0241	1.211011	0.28647106	4.451322
Within Groups	4478.417	17	263.4363			
Total	4797.441	18				

Table 52 shows p-values for nitrate as >0.05 and as a result the study cannot reject the null hypothesis of the study. Nitrate concentration had been consistent between 2010 and 2014 except in 2011 where the nitrate average results exceeded 2 mg/l while other years remained within 1 mg/l and below. Nitrate result averages remained within the drinking water quality standard limits for domestic use.

Table 52: Letsitele water supply system's p-value for nitrate in the distribution system

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	7.65	0.85	0.81	106%
_2011	8	16.95	2.11875	8.779213	140%
_2012	5	7.09	1.418	1.26842	79%
_2013	7	7.97	1.138571	1.679748	114%
_2014	4	4.92	1.23	0.7196	69%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.37142	4	1.842855	0.60531	0.66205684	2.714076
Within Groups	85.24545	28	3.04448			
Total	92.61687	32				

Anova: Single Factor
Nitrate
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	7.65	0.85	0.81	106%
_2014	4	4.92	1.23	0.7196	69%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.399877	1	0.399877	0.509173	0.49035978	4.844336
Within Groups	8.6388	11	0.785345			
Total	9.038677	12				

Sodium concentrations in the water fluctuated between 2010 and 2014 in the Letsitele water supply system. Table 53 shows overall p-values from 2010 until 2014 of <0.05 and as a result the study reveals that there was significant difference. P-values suggest that the null hypothesis is rejected. P-values of >0.05 in 2010 and 2014 implies that there is not a significant difference in both years. The study noted that sodium average results for each year are within the drinking water standard.

Table 53: Letsitele water supply system's p-value for sodium in the distribution system

Sodium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	22	311.6	14.16364	78.02176	62%
_2011	18	96.37	5.353889	41.50657	120%
_2012	17	95.47	5.615882	79.25243	159%
_2013	17	440.8	25.92941	780.641	108%
_2014	6	110.11	18.35167	56.95002	41%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5020.204	4	1255.051	5.744077	0.00043523	2.493696
Within Groups	16387.11	75	218.4948			
Total	21407.32	79				

Anova: Single Factor
Sodium
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficent
_2010	22	311.6	14.16364	78.0217576	62%
_2014	6	110.11	18.35167	56.9500167	41%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	82.68668	1	82.68668	1.11784825	0.30010732	4.225201
Within Groups	1923.207	26	73.9695			
Total	2005.894	27				

Table 54 shows p-values of >0.05 between 2010 and 2014 for sulfate in the distribution system. The p-value shows results were not significantly varied from 2010 to 2014. The p-value in 2010 and 2014 shows significantly varied and as a result rejects the null hypothesis. Sulfate average results were within the SANS 241 numerical limits for domestic use.

Table 54: Letsitele water supply system's p-value for sulfate in the distribution system

Anova: Single Factor
Sulfate
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*
_2010	24	125.1	5.2125	17.30723	80%
_2011	18	216	12	103.6529	85%
_2012	17	220.1	12.94706	122.8339	86%
_2013	17	490.3	28.84118	2749.276	182%
_2014	6	59.11	9.851667	32.93602	58%

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5774.763	4	1443.691	2.302556	0.06600348	2.490447
Within Groups	48278.61	77	626.9949			
Total	54053.37	81				

Anova: Single Factor
Sulfate
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*
_2010	24	125.1	5.2125	17.30723	24%
_2014	6	59.11	9.851667	32.93602	17%

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	103.305	1	103.305	5.140041	0.031294485	4.195972
Within Groups	562.7463	28	20.09808			
Total	666.0513	29				

Table 55 indicates average results for conductivity from 2010 until 2014 with p-values of >0.05 and as a result the study cannot reject the null hypothesis. The p-value results in 2010 and 2014 shows significantly difference (P<0.05). The results relatively increased between 2010 and 2014. The results remained within the numerical limit of the drinking water standard. The conductivity results increased in 2014 compared with the 2010 average results.

Table 55: Letsitele water supply system's p-value for conductivity in the distribution

Anova: Single Factor
Conductivity
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*
_2010	32	783.24	24.47625	70.0711274	34%
_2011	25	602.35	24.094	301.319492	72%
_2012	28	756.12	27.00429	263.076737	60%
_2013	50	1259.16	25.1832	265.575602	65%
_2014	14	432.75	30.91071	79.6162225	29%

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	553.3859	4	138.3465	0.65199768	0.62637756	2.434503
Within Groups	30555.16	144	212.1886			
Total	31108.55	148				

Anova: Single Factor
Conductivity
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Coefficient*
_2010	32	783.24	24.47625	70.07113	34%
_2014	14	432.75	30.91071	79.61622	29%

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	403.2227	1	403.2227	5.531838	0.02321351	4.061706
Within Groups	3207.216	44	72.89127			
Total	3610.439	45				

Table 56 presents averages for colour with P-value results of >0.05 and implies that the study cannot reject the null hypothesis. The p-value shows that there was not a significant difference between 2010 and 2014. Results for colour were within the numerical limit of the standard for domestic water supply except in 2014 as shown in Table 33, Annexure A.

Table 56: Letsitele water supply system's p-value for colour in the distribution system

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	101	5.315789	21.00585	86%
_2011	12	96	8	25.27273	63%
_2012	16	116	7.25	32.46667	79%
_2013	49	365	7.44898	21.16922	62%
_2014	14	100	7.142857	26.13187	72%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	76.47618	4	19.11905	0.80334	0.52572323	2.45821
Within Groups	2498.942	105	23.79945			
Total	2575.418	109				

Anova: Single Factor
Colour
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	19	101	5.315789	21.00585	86%
_2014	14	100	7.142857	26.13187	72%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.90772	1	26.90772	1.162046	0.28935867	4.159615
Within Groups	717.8195	31	23.15547			
Total	744.7273	32				

The p-value of pH (expressed as [H+]) between 2010 and 2014 is <0.05 and as a result there is a significant difference as presented in Table 57 below. The study has noted fluctuation of the pH (expressed as [H+]) average results shown in the Table 57 below between 2010 and 2014. The Table 57 further presents p-values for pH (expressed as [H+]) results for 2010 and 2014 within the Letsitele water supply system. The p-value is >0.05 and as a result the study cannot reject the null hypothesis for those two years. The study noted pH results are within the numerical limit of the SANS 241 as presented in Annexure A, Tables 31 – 35 and Annexure B, municipalities' drinking water quality actual data.

Table 57: Letsitele water supply system's p-value for pH (expressed as (H+]) in the distribution system

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
_2010	32	2.31E-06	7.21432E-08	7.7533E-15	122%
_2011	25	1.68E-06	6.70324E-08	1.5149E-14	184%
_2012	28	8.57E-07	3.06167E-08	8.3194E-16	94%
_2013	51	9.88E-07	1.93692E-08	5.6054E-16	122%
_2014	14	6.26E-07	4.47064E-08	7.7627E-16	62%

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Gro	7.4431E-14	4	1.86077E-14	4.06023199	0.00377079	2.434065
Within Group	6.6452E-13	145	4.5829E-15			
Total	7.3895E-13	149				

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	
_2010	32	2.31E-06	7.21432E-08	7.7533E-15	1.220531354
_2014	14	6.26E-07	4.47064E-08	7.7627E-16	0.623214943

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Gro	7.3314E-15	1	7.33139E-15	1.2880336	0.262555547	4.061706
Within Group	2.5044E-13	44	5.69193E-15			
Total	2.5778E-13	45				

Table 58 presents turbidity average results of each year and all results are below 1 NTU which is within the numeric limit of the standard. P-value results are >0.05 and implies that the study cannot reject the null hypothesis; the results are not significantly varied. P-values for turbidity in 2010 and 2014 also show that there is not a significant difference between 2010 and 2014.

Table 58: Letsitele water supply system's p-value for turbidity in the distribution system

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	2	0.222222	0.009169	43%
_2011	12	7.16	0.596667	1.128261	178%
_2012	27	14.1	0.522222	0.661441	156%
_2013	29	16.603	0.572517	0.759389	152%
_2014	14	3.47	0.247857	0.009957	40%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.810876	4	0.452719	0.762302	0.55266142	2.47774
Within Groups	51.07401	86	0.593884			
Total	52.88489	90				

Anova: Single Factor
Turbidity
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	9	2	0.222222	0.009169	43%
_2014	14	3.47	0.247857	0.009957	40%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.0036	1	0.0036	0.372801	0.548033448	4.324794
Within Groups	0.202791	21	0.009657			
Total	0.206391	22				

Table 59 shows p-values of <0.05 and as a result the study reject the null hypothesis. The p-value shows that there was significant difference of average results between 2010 and 2014. Table 59 further indicate that free chlorine average results in 2010 and 2014 cannot reject the null hypothesis. Free chlorine fluctuated between 2010 and 2014 as shown in the Table 59 below. It should be noted the deterioration of free chlorine between 2013 and 2014 due to insufficient residual disinfection in the distribution system as shown in Annexure A, Table 32 and 35.

Table 59: Letsitele water supply system's p-value of free chlorine distribution system

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	15	9.27	0.618	0.02851714	27%
_2011	15	6.86	0.457333	0.04092095	44%
_2012	12	7.64	0.636667	0.07067879	42%
_2013	11	6.45	0.586364	0.12866545	61%
_2014	12	11.98	0.998333	0.56016061	75%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.07484	4	0.51871	3.3836196	0.01459375	2.525215
Within Groups	9.198021	60	0.1533			
Total	11.27286	64				

Anova: Single Factor
Free chlorine
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient
_2010	15	9.27	0.618	0.028517	27%
_2014	12	11.98	0.998333	0.560161	75%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.964356	1	0.964356	3.674574	0.066745802	4.241699
Within Groups	6.561007	25	0.26244			
Total	7.525363	26				

5. Conclusion and Recommendations

5.1 Conclusion

The study has noted significant improvement in terms of microbiological compliance from 2010 until 2014 within City of Tshwane as shown on the Figure 6. City of Tshwane has maintained a consistent microbiological compliance for the 5 year period. This consistent compliance may not be necessarily associated with the implementation of the incentive based regulation. The Department may have had an influence on strengthening the microbial compliance with the municipality to enable the water supply system to achieve the Blue Drop Status.

Microbiological quality compliance was excellent between 2010 and 2014 as presented in Figure 6 where microbial compliance exceeded 99.9% as shown in both Figure 6 and Annexure A. As the results show *E.coli* were non-compliant with the standard, however, the municipality kept on improving water quality. City of Tshwane further showed some commitment through implementation of its water safety planning and incident or failure management protocol to address non-compliant incidences (CoT, 2013). City Council's incident management responds to all acute health risks within 24 hours to address all possible risks may be posed to consumers as shown on the Annexure D.

Implementation of Blue Drop certification encourages the implementation of best practices such as the water safety planning process and incident management protocol which need to be adopted by the municipalities to improve drinking water quality compliance such as microbial which may pose a health risk to consumers. An excellent microbiological water quality had been maintained in the distribution system at Pretoria Central and South. This had been supported by the water quality compliance as shown in Annexure A, in Table 1 and Table 6. Microbiological water quality compliance had been classified as excellent (SABS, 2006).

Pretoria Central and South's chemical water quality had been consistent with the numerical limit of the standard (SANS: 241)inthe distribution system. City of Tshwane's chemical compliance has been classified as excellent from 2010 until 2014. The study has noted that few chemical determinands such as iron in Figure 11 and manganese in Figure 13 which results remained within the numerical limit of the standard. Pretoria Central and South chemical determinands trends as presented in Figure 11 to 19 pose no health risk neither fail to comply with the standard.

Physical determinands compliance for Pretoria Central and South water supply systems had been above 99% from 2010 until 2014 as shown on Figure 6 and Annexure A, Table 6. The study noted a few incidents where turbidity results exceeded the numerical limit of the standard in the distribution system as indicated in Figure 8. Statistics of variance, One-way ANOVA rejected null hypothesis for turbidity, pH, conductivity and colour, with the p-value results of <0.05. The study has noted that the significant difference due to fluctuation of physical determinands results between 2010 and 2014 and result showing significant difference of physical determinands.

Operational determinands compliance improvement had been noted from 2010 until 2014 within the Pretoria Central and South supply systems as presented in Figure 6 and Annexure A, Table 6. Figure 6 shows operational determinands compliance against the standard was below 85% in 2010 but gradually improved to above 95% in 2014.The study has also noted a slight decline from 2012 until 2013 before increasing to 95% in 2014. The improvement of operational determinand in the distribution system is significant compared to the decline observed in 2013. The results of free chlorine vary on a daily basis hence the p-value reflect variation of the free chlorine in the distribution network and considering an improvement shown in Figure 6. These results show that the municipality is in control of free chlorine concentration in the distribution system. Operational compliance should be maintained to enable to improve microbial compliance of drinking water.

Greater Sekhukhune District Municipality's microbiological quality compliance within the Burgersfort water supply system improved from poor microbiological water quality in 2010 to excellent in2011 until 2014 as presented in Figure10. Table 16 noted that there is no significant different for *E.coli* between 2010 and 2014. The manner in which the compliance is measured for this determinand should be considered as it had an influence on the p-value of the study as compliant results need to be zero and any value result of a failure affects the p-value. Microbiological compliance for Flag Boshielo water supply system has also has been consistently maintained between 2010 and 2014 as presented in Figure 14.

The study has noted that the municipality need to develop and implement the risk management principles at Groblersdal water supply system to improve microbiological water quality. Microbiological water quality had been compromised without clear improvement between 2010 and 2014. The study has also confirmed with the municipality that there was a need to address water quality non-compliant process such as incident management protocol.

Chemical compliance at Burgersfort water supply systems improved from below 95% in 2010 to excellent performance in 2014. The decline in 2013 was noted but compliance remained excellent as required by the standard (SABS, 2006). Flag Boshielo also improved from below 70% to above 99.9% and classified excellent as required by the SANS 241. The study noted nitrate results exceeded the numerical limit but the results improved between 2011 to 2014 as shown in the Annexure A, Table 13 – 17. Groblersdal water supply system chemical water quality was inconsistent from 2010 until 2014. The chemical results show that the municipality should further put more effort on the chemical determinands to ensure that all chemical determinands meet the numerical limit of the standard. Control measures such as multiple barrier approach between water sources, water treatment works and distribution need to be implemented to ensure chemical water comply with the chemical numerical limits.

Statistics of variance, One-way ANOVA used to determine the significant difference of results and the study rejected the null hypothesis for nitrates for two water supply systems with p-value results of <0.05.But Nitrate concentrations in water had improved significantly as shown in Table 19, 25 and 30.The average results show improvement compliance against the standard with the nitrate levels between

2010 and 2014. Municipal Chemical determinands compliance had improved and were within the numerical limits of the standard in 2014

The three water supply systems within the Greater Sekhukhune District Municipality presents different physical determinands compliance as presented on the Figure 10, 14 and 17. Figure 10shows improvement for physical compliance within the Burgersfort water supply system. Groblersdal water supply system maintained physical compliance with the standard between 2010 and 2014. However, Flag Boshielo supply system show decline of physical compliance between 2012 and 2014 as shown on the Figure 14. Turbidity, conductivity and pH average results vary each year hence the p-value show significant difference between 2010 and 2014. The study has noted improvement of physical compliance between 2012 and 2014.Flag Boshielo water supply system has been excellent until 2013 before it declined therefore the municipality need to maintained physical determinands excellent compliance. This decline was due to poor turbidity results not meeting the numerical limit of the standard in 2014.The study noted irregular submission of physical determinands particularly turbidity analyses in 2014

Physical water quality determinands varies but without posing risks on drinking water quality in the distribution system. The study noted significant difference for a number of physical water quality determinands during the study period but due to variation of average results. The average results of physical determinands may not have a negative influence on the quality of water supplied by the municipality.

Greater Sekhukhune District Municipality submitted erratic operational determinand data in the BDS from 2010 until 2014. Figure 13 shows insufficient submission of free chlorine analysis until 2011 for the Burgersfort water supply system. Operational compliance between 2010 and 2011 declined from above 70% to below 60%. Absence of free chlorine means that water was not treated with chlorine (WRC, 1998). Operational determinands compliance was classified as poor and as a result regrowth of micro-organisms in the distribution system may take place. Figure 13 further shows free chlorine concentrations below 0.2 mg/land there is not sufficient free chlorine in water as required by the standard (SABS, 2006 and WRC, 1998).

Figure 14 presents a different picture for operational determinand compliance within the Flag Boshielo water supply system where compliance is above 99.9% from 2010 until 2014. The results confirm that drinking water was protected from harmful micro-organisms in the distribution system. Adequate concentration of free chlorine is an indication of the efficacy of the disinfection process and thus a rapid indicator of the probable microbiological safety or otherwise treated water (WRC, 1998). The study noted high concentrations of free chlorine between from 2012 until 2014 as shown in Figure 16.

Groblersdal water supply system, Figure 17 further shows fluctuating operational determinand compliance which leaves high risks in the distribution network. Greater Sekhukhune District Municipality is not consistent in managing free chlorine in the distribution systems especially in Groblersdal and

Burgersfort water supply systems. Compliance of operational determinands seemed compromised in both water supply systems. Statistic of variance, One-way ANOVA's p-value of the free chlorine as presented in Table 28 shows Flag Boshielo water supply's p-value for free chlorine is < 0.05 therefore the null hypothesis is rejected as there is significant difference in the concentration of free chlorine in the distribution system. Free chlorine concentration varies in the distribution system depending on the quality of water.

Tzaneen water supply system, microbiological quality compliance was below 99.9% in 2010 and improved to an excellent compliance (SABS, 2006) of above 99.9% from 2011 until 2014. Therefore it can be concluded that a slight improvement was achieved by the municipality. The study notes that Letsitele water supply system's microbiological quality compliance has been compliant with the standard from 2010 until 2012 as shown on the Figure 24. The quality of water provided posed no microbiological health risks to consumers. But the study noted significant decline in 2013 and 2014 where the microbiological quality compliance of water was below 99.9% as shown on the Annexure A, Table 34 and 35. The Municipality is inconsistent in terms of managing microbiological quality of water in the distribution system. The study has noted a p-value for microbiological quality (*E.coli*) of >0.05, as result the null hypothesis cannot be rejected since there is no statistically significant difference from 2010 until 2014.

Chemical compliance for both Tzaneen and Letsitele water supply systems were within the standard numerical limit. The Tzaneen Local Municipality has been complying with the SABS drinking water standard limits from 2010 until 2014 (SABS, 2006). Chemical water quality determinands meet numerical limits of the drinking water quality standard. Chemical determinands does not vary each year while the results remained within the numerical limit of the standard. Watson and Lawrence (2003) suggest that some chemical determinands such as nutrients, metals, dissolved organic compounds levels in raw water may vary with seasons, hence some results as presented in Table 20, 25 and 35 reveal that sulfate, nitrates and iron results had improved respectively.

Physical determinands compliance for the Tzaneen water supply system within the Tzaneen Local Municipality has been classified as excellent by the SANS 241 standard. The study has observed a decline of compliance with the standard in 2011 and 2012 where compliance was classified as poor in SANS 241 standard (SABS, 2006). Figure 21 and 22 show some results of both turbidity and conductivity analysis exceeding numerical limit required by the standard. The results contributed to poor performance for the water supply system. The study has been informed by the Tzaneen Local Municipality that both turbidity and conductivity results exceeding numerical limits of the standard are regarded as incidents and were corrected. The municipality states the results were followed up by the incident management protocol between laboratory section and technical staff adjustment of treatment processes and followed by water quality analysis for relevant determinand (TLM, 2012).

Letsitele water supply system's physical compliance has been classified as excellent from 2010 until 2014. The results shown in Figure 24 were above 99.9% in 2010 and 2014. However, there were turbidity results exceeding numerical limit of the standard hence the Figure 24 further reveals a decline from 2011 until 2013. Statistical p-value for drinking water quality, physical determinands results for Letsitele water supply systems turbidity is > 0.05 as shown in the Table 59. Turbidity in water deteriorated in the distribution system hence the p-value results show that the null hypothesis cannot be rejected. There are not sufficient results that prove that there was a significant change of any of the physical determinands compliance within the municipality following the introduction of the Blue Drop certification programme.

Tzaneen Local Municipality operational determinand shows some compliance in the Tzaneen water supply system. Figure 20 shows an improvement of free chlorine compliance with the standard from 2010 until 2014 which confirms that achieving excellent compliance in the distribution is possible based on the excellent classification with the standard limits. Letsitele water supply system's operational determinand compliance as shown in Figure 24 was classified as excellent in 2010 but the compliance fluctuated between 2010 and 2014.

The compliance shows that Tzaneen Local Municipality do not have adequate control of free chlorine concentrations in the distribution system. Figure 23 shows inconsistency of free chlorine in the distribution system which may be a sign of poor control of free chlorine in the distribution system. Water supply systems need acceptable level of chlorine in the distribution network prescribed by the drinking water standard. Water quality determinands results fluctuated but were within the drinking water standards as the table's average results for iron, magnesium, nitrate, sodium, sulfate, calcium, conductivity, turbidity and pH.

The study reveals that an introduction of the Blue Drop Certification Programme should continue to be implemented by the Department of Water and Sanitation however more work should be done to improve the programme. The p-values of some chemical, physical and operational water determinands reject the null hypothesis to all three municipalities. Drinking water quality compliance against the standard shows deep or sharp improvement for operational determinand (free chlorine) in the distribution network for City of Tshwane, Groblersdal and Tzaneen water supply systems as shown on the water quality compliance figures.

The study had access and evaluated Tzaneen water safety planning and linked it with the risk assessment findings, microbial contaminants identified as high risks and control measures were put in place to address anomalies. The study has noted that where there is water quality non-compliant with the standard, there should be management procedure in place that should be implemented to resolve the drinking water quality failure as shown at Tzaneen Local Municipality. Tzaneen Local Municipality provided procedure including resampling results to prove that drinking water had been resolved. The management process showed an accountability of the municipality to provide clean drinking water.

Pretoria Central, Burgersfort and Tzaneen water supply system show consistent compliance with microbiological water quality in the distribution system. Chemical water quality determinands had been improved and maintained as shown on the water quality compliance results. The study has noted an improvement of nitrate compliance with the standard at Greater Sekhukhune District Municipality between 2010 and 2014. Chemical water quality determinands average results varied within the water supply systems but without posing any health risks or exceeding the numerical limits of the standard. The water quality results show that following the introduction of the Blue Drop Certification Programme there are signs of drinking water quality improvements. Where compliance had been excellent such as City of Tshwane, at least the excellent compliance is maintained by the municipalities.

The aim of the incentive based regulation is to improve the drinking water quality from abstraction to the consumer taps (DWA, 2013). It should be noted that the numerical limit of the standard guides the water suppliers. Where the determinand result is within the limit, the supplier is not required to further reduce concentration hence the null hypothesis may reflect not significant improvement of some determinands due to compliant with the standard such as *E.coli* which need to be zero. Microbial compliance at City of Tshwane provides consistent compliance therefore there could be slightly significant changes. However, deterioration could be possible as shown at Letsitele system for operational determinand compliance decline in 2014 and this was due to insufficient free chlorine in water and limited results submitted

The Blue Drop Programme encourages the WSAs to be accountable and be proactive to address drinking water quality incidents hence all responsibilities rest with the WSI to improve drinking water quality (DWA, 2012). The Blue Drop Certification as incentive based regulation acknowledges the importance of management of all risks that are considered to be a threat to drinking water quality management (DWA, 2012). The Blue Drop Certification programme does not only imply the actual quality of the tap water but also the ability of the WSI to sustain quality as shown in the water supply systems such as Pretoria Central and Tzaneen.

It also takes note of the preparedness to deal with the water quality failures incidents that may pose a risk to the public. It further establishes the importance of Process Controllers responsibility towards treatment processes to improve good drinking water quality production and manage all risks. The technical staff has targets of excellence as required by SANS 241 and Blue Drop requirements and standard.

5.2 Recommendations

The introduction of the Blue Drop Certification Programme has been seen as catalyst of change in the water sector and as a result drinking water quality compliance could be improved. The study has noted water quality determinands improvements in some of the water supply systems while in some supply systems there was no improvement. The Department of Water and Sanitation should continue to encourage municipalities to comply with microbiological quality of water as a basic requirement to all Water Services Institutions.

Greater Sekhukhune District Municipality must replicate effort to all other supply systems to ensure that the drinking water quality is compliant with the standard. Microbiological water quality compliance improved from poor to excellent in Burgersfort and Flag Boshielo water supply systems while microbial water quality deteriorated in the Groblersdal water supply system. The municipality should implement appropriate control measures to improve drinking water quality in all the water supply systems. Groblersdal water supply system show results with the presence of *E.coli* in the water and this may compromise the health of the consumers.

The study has observed a similar trend in the Tzaneen Local Municipality where Tzaneen water supply system is in compliant with the SANS 241 requirements (SABS, 2006) but Letsitele water supply system show non-compliance for both *E.coli* and free chlorine. Maintaining presence of free chlorine in the distribution system may protect drinking water against pathogenic microorganisms. The study has noted a steady improvement of free chlorine in the distribution system within both the Pretoria Central and South supply systems and this should encourage other Water Services Institutions to maintain acceptable free chlorine levels in water in the distribution networks. The presence of *E.coli* in water indicates contamination of water with faecal waste that may contain other harmful or disease causing organisms, including bacteria, viruses, or parasites (Gwimbi, 2011). Gwimbi (2011) continues to state that the provision of good quality drinking water is an important means of improving public health.

The Department of Water and Sanitation as a regulator has to ensure that microbiological water quality should not be compromised. Drinking water contaminated with *E. coli* is known to cause stomach and intestinal illness including diarrhoea and nausea, and can even lead to death (Gwimbi, 2011). While the Department maintains incentive based regulation, the basic requirement such as physical determinands compliance is important.

The presence of physical determinands in water such as turbidity should comply with the numerical limit of the standard since non-compliance have negative implications on the quality of the water and the health of consumers. It may be very difficult to achieve the breakpoint of chlorination when water with high levels of turbidity is treated (WRC, 1998). Water quality analysis results confirmed that municipalities can comply with the standard limits from final water up to point of use in the supply system when appropriate control measures are implemented in all areas within the municipalities.

The study has used the secondary water quality data submitted by the WSI to the Department of Water and Sanitation. The main purpose was to reflect the history of the management of the drinking water quality of the municipalities following an introduction of the Blue Drop Certification in the water sector. The study has determined distribution of sampling points used to take water samples by the WSIs and ensure that these results represent the entire study area. The samples have been submitted to an accredited laboratory for analysis as shown on the Annexure C.The study could have considered coordinates of the sampling points and linked the results with its origin to avoid water samples to be taken where quality is acceptable.

The study could have investigated the water sampling procedure and determine whether the sampling of drinking water is according to the sampling guidelines as sampling can thus not be done in isolation, but needs to be integrated into the other steps necessary to manage the quality of domestic water supplies. WRC sampling guideline states that communication between the various role players within the water quality management cycle is crucial to ensure that the waterquality information that is generated is meaningful and correct (WRC, 2000).The accuracy of water quality results obtained in the laboratory is just as dependent on the correctness of the sampling technique as it is dependent on the accuracy of the analytical procedures. Therefore the sampling exercise requires careful planning beforehand (WRC, 2000). Future studies should be done to focus on the processes and procedures followed by municipal water sampling to ensure that the sampling guidelines are implemented correctly to achieve accurate results.

5.3 Calculations of p-values for pH results

Hydrogen ion concentration averages were calculated by using the One-ANOVA calculation to determine p-value results for pH for this study. The calculation formula had been used to determine Hydrogen [H+] concentration average in water to appropriately determine average of H+. The study used the formula of [H+] = 10^-pH to determine hydrogen results. This section compares H+ p-values and pH. These results help to ensure that appropriate calculations are used to calculate pH of the water. It should be noted that ANOVA is based on calculating averages of the data, whereas the pH is expressed on a logarithmic scale, which doesn't allow for direct calculation of averages, hence the study has calculated [H+], which is a linear scale and allows for the use of ANOVA for comparisons.The following Tables of p-values results are presented to compare p-value between calculating [H+] and pH averages.

Table 60 below shows p-value results for pH (expressed as [H+]) and pH actual results from 2010 until 2014. P-values for both calculations are <0.05 and implies the rejection of the null hypothesis and show significant difference of pH (expressed as [H+]) and pH actual results between 2010 and 2014.pH (expressed as [H+]) has a lower p-value than the actual pH results as presented in Table 60 below.

Table 60: Pretoria Central and South Water Supply system pH (expressed as [H+]) and pH actual results

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of Variation
_2010	1120	2.08E-05	1.854E-08	1.48E-16	66%
_2011	1120	2.84E-05	2.53033E-08	8.97E-16	118%
_2012	1120	1.26E-05	1.12201E-08	8.84E-17	84%
_2013	1064	1.45E-05	1.36157E-08	7.37E-17	63%
_2014	1120	1.97E-05	1.75703E-08	1.84E-16	77%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.29489E-13	4	3.23722E-14	115.4607	1.00547E-94	2.373535
Within Groups	1.55412E-12	5543	2.80375E-16			
Total	1.6836E-12	5547				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	1120	8769.502	7.822928	0.086468
_2011	1120	8757.17	7.811927	0.302457
_2012	1120	9022.636	8.048739	0.084373
_2013	1064	8432.509	7.92529	0.048422
_2014	1120	8794.69	7.845397	0.079326

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	43.67677	4	10.91919	90.28043	1.84E-74	2.373535
Within Groups	670.412	5543	0.120947			
Total	714.0887	5547				

Table 61 below shows expressions of pH (expressed as [H+]) and pH actual p-values with results of >0.05 which imply that there is a significant difference and as a result the null hypothesis is rejected. Both expressions reject the null hypothesis but the actual pH p-value presents the lowest p-value than the calculated pH (expressed as [H+]).

Table 61: Pretoria Central and South for pH (expressed as[H+]) and pH actual results

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of Variation
_2010	1120	2.08E-05	1.854E-08	1.48E-16	66%
_2014	1120	1.97E-05	1.75703E-08	1.84E-16	77%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.2703E-16	1	5.2703E-16	3.176261	0.074850922	3.845614
Within Groups	3.71678E-13	2240	1.65928E-16			
Total	3.72205E-13	2241				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
2010	1120	8769.502	7.822928	0.086468
2014	1120	8794.69	7.845397	0.079326

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.282977	1	0.282977	3.413606	0.064793	3.845614
Within Groups	185.6891	2240	0.082897			
Total	185.9721	2241				

Table 62 shows p-values of < 0.05for pH (expressed as [H+]) and pH actual results in the years from 2010 until 2014 and thus imply that there is significant difference from 2010 to 2014 and as a result the null hypothesis is rejected. Both expressions show significant difference, but the pH actual results present the lowest expression than the p-value for pH (expressed as [H+]).

Table 62: Burgersfort p-value for pH (expressed as [H+]) and pH actual results between 2010 and 2014

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	18	2.19227E-07	1.21793E-08	8.58005E-17	76%
2011	24	2.87721E-07	1.19884E-08	1.41371E-16	99%
2012	23	4.11E-07	1.78696E-08	1.67871E-16	73%
2013	21	1.6859E-07	8.02808E-09	1.05516E-17	40%
2014	25	1.57458E-07	6.29832E-09	7.83976E-18	44%

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Grou	1.86723E-15	4	4.66806E-16	5.621305145	0.000383513	2.457380022
Within Group	8.80249E-15	106	8.30424E-17			
Total	1.06697E-14	110				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	18	145.35	8.075	0.184262
_2011	24	192.9	8.0375	0.09288
_2012	23	179.7	7.813043	0.048458
_2013	21	171.1	8.147619	0.063619
_2014	25	206	8.24	0.0375

ANOVA

ce of Varia	SS	df	MS	F	P-value	F crit
Between (	2.388762	4	0.59719	7.441041	2.54E-05	2.45738
Within Gr	8.507168	106	0.080256			
Total	10.89593	110				

Table 63 below presents pH expressions for pH (expressed as [H+]) and actual results from 2010 until 2014. Table 63 above shows p-values for pH (expressed as [H+]) as <0.05 and the pH actual expression >0.05 in 2010 and 2014. Both expressions provide different results thus one rejects the null hypothesis while the other cannot reject. It should be noted that pH (expressed as [H+]) was preferred as the actual hydrogen ion results have been calculated using hydrogen ion formula provided below.

Table 63: Burgersfort p-value for pH (expression as [H+]) and pH actual results

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	18	2.19227E-07	1.21793E-08	8.58005E-17	76%
2014	25	1.57458E-07	6.29832E-09	7.83976E-18	44%

ANOVA

urce of Variati	SS	df	MS	F	P-value	F crit
Between Grou	3.61942E-16	1	3.61942E-16	9.011401249	0.004553498	4.078545731
Within Group:	1.64676E-15	41	4.01649E-17			
Total	2.0087E-15	42				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	18	145.35	8.075	0.184262
_2014	25	206	8.24	0.0375

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.284913	1	0.284913	2.896855	0.096325	4.078546
Within Groups	4.03245	41	0.098352			
Total	4.317363	42				

Table 64 below shows p-values for pH (expressed as [H+]) and pH actual results as >0.05 in the years from 2010 until 2014. Both expressions p-value cannot reject the null hypothesis in this period. P-value for pH (expressed as [H+]) shows the highest expression than the actual pH.

Table 64: Flag Boshielo pH (expressed [H+]) and pH actual results p-values

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	22	5.59464E-07	2.54302E-08	4.0419E-16	79%
2011	18	5.00183E-07	2.77879E-08	9.70398E-16	112%
2012	24	5.00737E-07	2.0864E-08	1.4911E-16	59%
2013	20	3.49819E-07	1.74909E-08	2.19191E-16	85%
2014	22	5.29105E-07	2.40502E-08	1.99372E-16	59%

ANOVA

ource of Variatio	SS	df	MS	F	P-value	F crit
Between Groups	1.2833E-15	4	3.20826E-16	0.881348032	0.47798419	2.461698
Within Groups	3.67657E-14	101	3.64017E-16			
Total	3.8049E-14	105				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	22	169.93	7.724091	0.125302
_2011	18	139.35	7.741667	0.169132
_2012	24	186.75	7.78125	0.113246
_2013	20	158.7	7.935	0.183574
_2014	22	169.5	7.704545	0.08774

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.6991	4	0.174775	1.313248	0.270179	2.461698
Within Groups	13.44169	101	0.133086			
Total	14.14079	105				

Table 65 shows p-value expressions for pH (expressed as [H+]) and pH actual results as >0.05 in the years 2010 until 2014. The p-value results show that there is not a significant difference in 2010 and 2014 as presented on the Table 65 below. Both p-value expressions reject the null hypothesis but pH actual results show the highest expression of p-value.

Table 65: Flag Boshielo p-value for pH (expressed [H+]) and pH actual results in 2010 and 2014

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	22	5.59464E-07	2.54302E-08	4.0419E-16	79%
2014	22	5.29105E-07	2.40502E-08	1.99372E-16	59%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.09472E-17	1	2.09472E-17	0.069411859	0.793483353	4.072654
Within Groups	1.26748E-14	42	3.01781E-16			
Total	1.26958E-14	43				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	22	169.93	7.724091	0.125302
_2014	22	169.5	7.704545	0.08774

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.004202	1	0.004202	0.03945	0.843518	4.072653759
Within Groups	4.473877	42	0.106521			
Total	4.47808	43				

Table 66 shows p-value expressions for pH (expressed as [H+]) and pH actual results as <0.05 for both calculations. Both results imply that there is a significant difference in 2010 and 2014. Both expressions reject the null hypothesis. Table 66 shows that pH (expressed as [H+]) has the highest expression that reject the null hypothesis in 2010 and 2014.

Table 66: Groblersdal p-value for pH (expressed [H+]) and pH actual results in 2010 and 2014

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
2010	24	8.3E-07	3.44798E-08	1.3E-15	104%
2011	15	1.7E-07	1.13447E-08	9.8E-17	87%
2012	11	8.7E-08	7.8751E-09	1.5E-17	50%
2013	12	1.3E-07	1.05069E-08	8.2E-17	86%
2014	14	3E-07	2.14626E-08	5.4E-16	108%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.88309E-15	4	2.22077E-15	4.02042	0.005377189	2.500760421
Within Groups	3.92185E-14	71	5.52373E-16			
Total	4.81016E-14	75				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	24	184.17	7.67375	0.252146
_2011	15	121.07	8.071333	0.109412
_2012	11	89.58	8.143636	0.034465
_2013	12	97.29	8.1075	0.127693
_2014	14	110.19	7.870714	0.199699

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.802992	4	0.700748	4.260957	0.003793	2.50076
Within Groups	11.67651	71	0.164458			
Total	14.4795	75				

Table 67 below presents p-value results for both pH (expressed as [H+]) and pH actual results. Both p-values are >0.05 and imply that there is significant difference between 2010 and 2014 and as a result the null hypothesis is rejected. It is noted in Table 67 that pH (expressed as [H+]) shows the highest p-value expression than the pH actual results.

Table 67: Tzaneen p-value for pH (expressed as [H+]) and pH actual results between 2010 and 2014

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
_2010	72	1.32E-06	1.83877E-08	2.3466E-15	263%
_2011	66	1.9E-06	2.88085E-08	6.5778E-15	282%
_2012	89	1.14E-06	1.28125E-08	4.5918E-16	167%
_2013	110	1.53E-06	1.39311E-08	4.1619E-16	146%
_2014	55	1.05E-06	1.90931E-08	5.0965E-16	118%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.19734E-14	4	2.99334E-15	1.63743761	0.164055915	2.395003
Within Groups	7.07461E-13	387	1.82807E-15			
Total	7.19435E-13	391				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	72	607.62	8.439167	0.667768
_2011	66	553.14	8.380909	0.847344
_2012	89	767.23	8.620562	1.77281
_2013	110	919.39	8.358091	0.543748
_2014	55	448.43	8.153273	0.511837

ANOVA

ce of Varic	SS	df	MS	F	P-value	F crit
Between (	7.98231	4	1.995578	2.2359	0.064575	2.395003
Within Gr	345.4039	387	0.892516			
Total	353.3862	391				

Table 68 below shows p-values for pH (expressed as [H+]) and pH actual results in the years 2010 and 2014.The p-value expression result of the pH (expressed as [H+]) calculation is >0.05 and the pH actual results have p-value expressions of <0.05and implies that there is a significant difference between the pH data in 2010 and 2014 and as a result the null hypothesis is rejected.

Table 68: Tzaneen p-value for pH (expressed as [H+]) and pH actual results in 2010 and 2014

Anova: Single Factor
pH (Expressed as [H+])
SUMMARY

Groups	Count	Sum	Average	Variance	Coefficient of variation
_2010	72	1.32E-06	1.83877E-08	2.3466E-15	263%
_2014	55	1.05E-06	1.90931E-08	5.0965E-16	118%

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.55164E-17	1	1.55164E-17	0.009991	0.920540204	3.916932
Within Groups	1.94129E-13	125	1.55303E-15			
Total	1.94145E-13	126				

Anova: Single Factor
pH
SUMMARY

Groups	Count	Sum	Average	Variance
_2010	72	607.62	8.439167	0.667768
_2014	55	448.43	8.153273	0.511837

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.548598	1	2.548598	4.244791	0.041446	3.916932
Within Groups	75.05076	125	0.600406			
Total	77.59936	126				

Table 69 shows p-values for pH (expressed as [H+]) and pH actual results as <0.05 for both expressions in the years from 2010 until 2014. The p-value results imply that there is a significant difference between 2010 and 2014 and as a result the null hypothesis is rejected. pH (expressed as [H+]) has the highest expression as shown on the Table 69 below.

Table 69: Letsitelep-value for pH (expressed [H+]) and pH actual results between 2010 and 2014.

Anova: Single Factor						
pH (Expressed as [H+])						
SUMMARY						
Groups	Count	Sum	Average	Variance	Coefficient of variation	
_2010	32	2.31E-06	7.21432E-08	7.7533E-15	122%	
_2011	25	1.68E-06	6.70324E-08	1.5149E-14	184%	
_2012	28	8.57E-07	3.06167E-08	8.3194E-16	94%	
_2013	51	9.88E-07	1.93692E-08	5.6054E-16	122%	
_2014	14	6.26E-07	4.47064E-08	7.7627E-16	62%	
ANOVA						
urce of Variati	SS	df	MS	F	P-value	F crit
Between Gro	7.4431E-14	4	1.86077E-14	4.06023199	0.00377079	2.434065
Within Group	6.6452E-13	145	4.5829E-15			
Total	7.3895E-13	149				

Anova: Single Factor						
pH						
SUMMARY						
Groups	Count	Sum	Average	Variance		
_2010	32	237.36	7.4175	0.252323		
_2011	25	189.19	7.5676	0.374527		
_2012	28	215.46	7.695	0.179596		
_2013	51	418.52	8.206275	0.674396		
_2014	14	104.18	7.441429	0.100059		
ANOVA						
ce of Varic	SS	df	MS	F	P-value	F crit
Between (	16.37222	4	4.093055	10.47088	1.77E-07	2.434065
Within Gr	56.68032	145	0.390899			
Total	73.05254	149				

Table 70 shows p-values for both pH (expressed as [H+] and pH actual results as >0.05 in 2010 and 2014. Both expressions reject the null hypothesis and there is not a significant difference for the pH results in 2010 and 2014. Table 70 notes that pH actual results show the highest p-value expression in the Table 70.

Table 70: Letsitele p-value for pH (expressed [H+]) and pH actual results in 2010 and 2014

Anova: Single Factor						
pH (Expressed as [H+])						
SUMMARY						
Groups	Count	Sum	Average	Variance		
_2010	32	2.31E-06	7.21432E-08	7.7533E-15	1.220531354	
_2014	14	6.26E-07	4.47064E-08	7.7627E-16	0.623214943	
ANOVA						
urce of Variati	SS	df	MS	F	P-value	F crit
Between Gro	7.3314E-15	1	7.33139E-15	1.2880336	0.262555547	4.061706
Within Group	2.5044E-13	44	5.69193E-15			
Total	2.5778E-13	45				

Anova: Single Factor						
pH						
SUMMARY						
Groups	Count	Sum	Average	Variance		
_2010	32	237.36	7.4175	0.252323		
_2014	14	104.18	7.441429	0.100059		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.005576	1	0.005576	0.026895	0.870483	4.061706
Within Groups	9.122771	44	0.207336			
Total	9.128348	45				

5.4 Calculations of pH conclusion

The p-values for both calculation methods give different or similar expressions as shown from Table 61 and 71. The study also noted both the calculations achieving contradictory conclusion of rejecting or not rejecting the null hypothesis based on the p-value calculated. But it should be noted that the study has used pH (expressed as [H+]which is a linear scale and allows for the use of ANOVA for comparisons to avoid distortion of p-value for pH results.

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7. Annexures

Annexure A: Tables of City of Tshwane, Greater Sekhukhune District Water Quality compliance Reports

Table 1: 2010 City of Tshwane Pretoria Central and South Water Quality Compliance Report

PRETORIA Central & South (Rietvlei WTW & Rand Water) Water Quality Report					
		2010 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2010**	**Achieved compliance 2010**
Physical determinands				**3,730**	**99.7%**
Colour	(mg / l as Pt)	Aesthetic	< 20	200	99.6%
Conductivity	(mS / m)	Aesthetic	< 150	1,200	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	1,130	100.0%
Turbidity	(NTU)	Aesthetic	< 1	1,200	99.2%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**1,600**	**99.9%**
Arsenic	(µg / l as CN)	Acute Health	< 50	200	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	200	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	200	99.4%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	200	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	200	99.8%
Nitrate	(mg / l as N)	Acute Health	< 10	200	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	200	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	200	100.0%
Microbiological determinands				**890**	**99.8%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	890	99.8%
Operational determinands				**980**	**83.1%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	980	83.1%

Table 2: 2011 City of Tshwane Pretoria Central and South Water Quality Compliance Report

PRETORIA Central & South (Rietvlei WTW & Rand Water) Water Quality Report					
		2011 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2011**	**Achieved compliance 2011**
Physical determinands				**3,369**	**99.4%**
Colour	(mg / l as Pt)	Aesthetic	< 20	200	99.7%
Conductivity	(mS / m)	Aesthetic	< 150	837	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	1,130	99.9%
Turbidity	(NTU)	Aesthetic	< 1	1,200	98.4%
Odour	(TON)	Aesthetic	< 5	2	100.0%
Chemical determinands				**1,600**	**99.7%**
Arsenic	(µg / l as CN)	Acute Health	< 50	200	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	200	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	200	97.9%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	200	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	200	99.4%
Nitrate	(mg / l as N)	Acute Health	< 10	200	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	200	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	200	100.0%
Microbiological determinands				**1,095**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	1,095	100.0%
Operational determinands				**998**	**84.5%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	998	84.5%

Table 3: 2012 City of Tshwane Pretoria Central and South Water Quality Compliance Report

PRETORIA Central & South (Rietvlei WTW & Rand Water) Water Quality Report					
		2012 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2012	Achieved compliance 2012
Physical determinands				3,734	99.1%
Colour	(mg / l as Pt)	Aesthetic	< 20	200	99.4%
Conductivity	(mS / m)	Aesthetic	< 150	1,200	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	1,130	100.0%
Turbidity	(NTU)	Aesthetic	< 1	1,200	97.4%
Odour	(TON)	Aesthetic	< 5	4	100.0%
Chemical determinands				1,600	86.8%
Arsenic	(µg / l as CN)	Acute Health	< 50	200	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	200	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	200	95.5%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	200	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	200	99.1%
Nitrate	(mg / l as N)	Acute Health	< 10	200	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	200	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	200	100.0%
Microbiological determinands				1,143	99.6%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	1,143	99.6%
Operational determinands				1,200	93.1%
Free Chlorine	(mg / l)	Operational	≥ 0.2	1,200	93.1%

Table 4: City of Tshwane 2013 Pretoria Central and South water supply system Water Quality Report

PRETORIA Central & South (Rietvlei WTW & Rand Water) Water Quality Report					
		2013 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2013	Achieved compliance 2013
Physical determinands				3,417	99.6%
Colour	(mg / l as Pt)	Aesthetic	< 20	200	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	953	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	1,064	100.0%
Turbidity	(NTU)	Aesthetic	< 1	1,200	98.9%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				1,600	87.2%
Arsenic	(µg / l as CN)	Acute Health	< 50	200	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	200	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	200	98.5%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	200	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	200	99.1%
Nitrate	(mg / l as N)	Acute Health	< 10	200	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	200	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	200	100.0%
Microbiological determinands				1,093	99.8%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	1,093	99.8%
Operational determinands				1,036	91.8%
Free Chlorine	(mg / l)	Operational	≥ 0.2	1,036	91.8%

Table 5: 2014 City of Tshwane Pretoria Central and South Water Quality Compliance Report

PRETORIA Central & South (Rietvlei WTW & Rand Water) Water Quality Report					
		2014 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2014	Achieved compliance 2014
Physical determinands				**3,594**	**99.6%**
Colour	(mg / l as Pt)	Aesthetic	< 20	200	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	1,131	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	1,130	100.0%
Turbidity	(NTU)	Aesthetic	< 1	1,133	98.8%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**1,600**	**87.1%**
Arsenic	(µg / l as CN)	Acute Health	< 50	200	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	200	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	200	97.4%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	200	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	200	99.6%
Nitrate	(mg / l as N)	Acute Health	< 10	200	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	200	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	200	100.0%
Microbiological determinands				**1,173**	**99.8%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	1,173	99.8%
Operational determinands				**1,107**	**96.8%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	1,107	96.8%

Table 6: City of Tshwane Pretoria Central and South Water Quality Summary Report

City of Tshwane 5 Year Summary of Water Quality Report per category

Category	2010	2011	2012	2013	2014
Physical determinands	**99.7%**	**99.4%**	**99.0%**	**99.6%**	**99.6%**
Chemical determinands	**99.9%**	**99.6%**	**99.2%**	**99.7%**	**99.6%**
Microbiological determinands	**99.8%**	**100.0%**	**99.6%**	**99.8%**	**99.8%**
Operational determinands	**83.1%**	**84.5%**	**93.1%**	**91.8%**	**96.8%**

Table 7: 2010 Greater Sekhukhune District Municipality Burgersfort water Quality Report

Burgersfort Water Supply System Water Quality Report					
		2010 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2010	Achieved compliance 2010
Physical determinands				45	95.6%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	18	94.4%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	18	100.0%
Turbidity	(NTU)	Aesthetic	< 1	9	88.9%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				45	93.3%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	7	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	7	85.7%
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	18	88.9%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	13	100.0%
Microbiological determinands				16	93.8%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	16	93.8%
Operational determinands				4	75.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	4	75.0%

Table 8: 2011 Greater Sekhukhune District Municipality Burgersfort water Quality Compliance Report

Burgersfort Water Supply System Water Quality Report					
		2011 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2011	Achieved compliance 2011
Physical determinands				64	90.6%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	24	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	24	100.0%
Turbidity	(NTU)	Aesthetic	< 1	16	62.5%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				75	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	11	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	16	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	24	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	24	100.0%
Microbiological determinands				24	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	24	100.0%
Operational determinands				6	33.3%
Free Chlorine	(mg / l)	Operational	≥ 0.2	6	33.3%

Table 9: 2012 Greater Sekhukhune District Municipality Burgersfort water Quality Compliance Report

Burgersfort Water Supply System Water Quality Report					
		2012 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2012**	**Achieved compliance 2012**
Physical determinands				**69**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	23	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	23	100.0%
Turbidity	(NTU)	Aesthetic	< 1	23	100.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**76**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	15	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	15	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	23	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulfate	(mg / l as SO4)	Acute Health	< 400	23	100.0%
Microbiological determinands				**22**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	22	100.0%
Operational determinands				**no data**	**no data**
Free Chlorine	(mg / l)	Operational	≥ 0.2	0	no data

Table 10: 2013 Greater Sekhukhune District Municipality Burgersfort water Quality Compliance Report

Burgersfort Water Supply System Water Quality Report					
		2013 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2013**	**Achieved compliance 2013**
Physical determinands				**63**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	21	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	21	100.0%
Turbidity	(NTU)	Aesthetic	< 1	21	100.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**42**	**97.6%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	21	95.2%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	21	100.0%
Microbiological determinands				**21**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	21	100.0%
Operational determinands				**no data**	**no data**
Free Chlorine	(mg / l)	Operational	≥ 0.2	0	no data

Table 11: 2014 Greater Sekhukhune District Municipality Burgersfort water Quality Compliance Report

Burgersfort Water Supply System Water Quality Report					
		2014 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2014	Achieved compliance 2014
Physical determinands				70	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	24	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	25	100.0%
Turbidity	(NTU)	Aesthetic	< 1	21	100.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				48	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	24	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	24	100.0%
Microbiological determinands				23	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	23	100.0%
Operational determinands				no data	no data
Free Chlorine	(mg / l)	Operational	≥ 0.2	0	no data

Table 12: 5 Year Greater Sekhukhune District Municipality Burgersfort water Quality Report Summary

Burgersfort water supply system					
Category	2010	2011	2012	2013	2014
Physical determinands	95.6%	90.6%	100.0%	100.0%	100.0%
Chemical determinands	92.3%	100.0%	100.0%	97.6%	100.0%
Microbiological determinands	93.8%	100.0%	100.0%	100.0%	100.0%
Operational determinands	75.0%	55.0%			

Table 13: 2010 Greater Sekhukhune District Municipality Flag Boshielo water Quality Compliance Report

Flag Boshielo Water Supply System Water Quality Report					
		2010 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2010	Achieved compliance 2010
Physical determinands				39	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	17	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	22	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				23	13.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	20	0.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	3	100.0%
Microbiological determinands				20	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	20	100.0%
Operational determinands				19	33.3%
Free Chlorine	(mg / l)	Operational	≥ 0.2	19	33.3%

Table 14: 2011 Greater Sekhukhune District Municipality Flag Boshielo Water Quality Compliance Report

Flag Boshielo Water Supply System Water Quality Report					
		2011 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2011	Achieved compliance 2011
Physical determinands				40	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	18	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	22	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				25	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	18	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	7	100.0%
Microbiological determinands				22	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	22	100.0%
Operational determinands				13	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	13	100.0%

Table 15: 2012 Greater Sekhukhune District Municipality Flag Boshielo water Quality Compliance Report

Flag Boshielo Water Supply System Water Quality Report					
		2012 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2012**	**Achieved compliance 2012**
Physical determinands				**48**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	24	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	24	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**36**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	24	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	12	100.0%
Microbiological determinands				**24**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	24	100.0%
Operational determinands				**24**	**100.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	24	100.0%

Table 16: 2013 Greater Sekhukhune District Municipality Flag Boshielo water Quality Compliance Report

Flag Boshielo Water Supply System Water Quality Report					
		2013 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2013**	**Achieved compliance 2013**
Physical determinands				**24**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	12	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	12	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**21**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	12	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	9	100.0%
Microbiological determinands				**20**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	20	100.0%
Operational determinands				**12**	**100.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	12	100.0%

Table 17: 2014 Greater Sekhukhune District Municipality Flag Boshielo Water Quality Compliance Report

Flag Boshielo Water Supply System Water Quality Report					
		2014 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2014	Achieved compliance 2014
Physical determinands				**53**	**83.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	22	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	22	100.0%
Turbidity	(NTU)	Aesthetic	< 1	9	**0.0%**
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**32**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	22	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	10	100.0%
Microbiological determinands				**22**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	22	100.0%
Operational determinands				**22**	**100.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	22	100.0%

Table 18: 5 year Greater Sekhukhune District Municipality Flag Boshielowater Quality Compliance Report Summary

Category	2010	2011	2012	2013	2014
Physical determinands	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**69.0%**
Chemical determinands	**60.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Microbiological determinands	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Operational determinands	**33.3%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 19: 2010 Greater Sekhukhune District Municipality Groblersdal Water Quality Compliance Report

Groblersdal Water Supply System Water Quality Report					
		2010 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2010	Achieved compliance 2010
Physical determinands				**50**	**96.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	6	**66.7%**
Conductivity	(mS / m)	Aesthetic	< 150	19	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	24	100.0%
Turbidity	(NTU)	Aesthetic	< 1	1	100.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**76**	**98.7%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	7	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	6	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	6	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	6	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	19	**94.7%**
Sodium	(mg / l as Na)	Aesthetic	< 200	6	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	26	100.0%
Microbiological determinands				**8**	**94.1%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	8	**94.1%**
Operational determinands				**17**	**58.8%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	17	**58.8%**

Table 20: 2011 Greater Sekhukhune District Municipality Groblersdal Water Quality Compliance Report

		2011 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2011	Achieved compliance 2011
Physical determinands				**31**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	1	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	15	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	15	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**34**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	1	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	1	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	1	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	1	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	14	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	1	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	15	100.0%
Microbiological determinands				**14**	**92.9%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	14	**92.9%**
Operational determinands				**15**	**80.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	15	**80.0%**

Table 21: 2012 Greater Sekhukhune District Municipality Groblersdal water Quality Compliance Report

Groblersdal Water Supply System Water Quality Report					
		2012 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2012	Achieved compliance 2012
Physical determinands				22	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	11	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	11	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				22	95.5%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	11	90.9%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	11	100.0%
Microbiological determinands				11	72.7%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	11	72.7%
Operational determinands				11	72.7%
Free Chlorine	(mg / l)	Operational	≥ 0.2	11	72.7%

Table 22: 2013 Greater Sekhukhune District Municipality Groblersdal water Quality Compliance Report

Groblersdal Water Supply System Water Quality Report					
		2013 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2013	Achieved compliance 2013
Physical determinands				24	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	12	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	12	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				24	95.8%
Cyanide (Recoverable)	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	12	91.7%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	12	100.0%
Microbiological determinands				12	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	12	100.0%
Operational determinands				12	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	12	100.0%

Table 23: 2014 Greater Sekhukhune District Municipality Groblersdal water Quality Compliance Report

		2014 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2014**	**Achieved compliance 2014**
Physical determinands				**28**	**100.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	0	no data
Conductivity	(mS / m)	Aesthetic	< 150	14	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	14	100.0%
Turbidity	(NTU)	Aesthetic	< 1	0	no data
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**52**	**100.0%**
Cyanide (Recoverable)	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	0	no data
Iron	(µg / l as Fe)	Aesthetic	< 200	0	no data
Magnesium	(mg / l as Mg)	Aesthetic	< 70	0	no data
Manganese	(µg / l as Mn)	Aesthetic	< 100	0	no data
Nitrate	(mg / l as N)	Acute Health	< 10	26	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	0	no data
Sulphate	(mg / l as SO4)	Acute Health	< 400	26	100.0%
Microbiological determinands				**26**	**92.9%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	26	92.9%
Operational determinands				**26**	**85.7%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	26	85.7%

Table 24: 5 Year Groblersdal Water Quality Compliance Summary

Category	2010	2011	2012	2013	2014
Physical determinands	**96.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Chemical determinands	**98.7%**	**100.0%**	**95.5%**	**95.8%**	**100.0%**
Microbiological determinands	**94.1%**	**92.9%**	**72.7%**	**100.0%**	**92.9%**
Operational determinands	**58.8%**	**80.0%**	**72.7%**	**100.0%**	**85.7%**

Table 25: 2010 Tzaneen Water Quality Compliance Report

Greater Tzaneen Municipality Water Quality Report					
		2010 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2010	Achieved compliance 2010
Physical determinands				216	96.3%
Colour	(mg / l as Pt)	Aesthetic	< 20	43	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	72	98.6%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	72	91.7%
Turbidity	(NTU)	Aesthetic	< 1	29	96.6%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				226	98.7%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	47	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	23	87.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	24	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	22	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	20	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	43	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	47	100.0%
Microbiological determinands				78	98.7%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	78	98.7%
Operational determinands				41	80.5%
Free Chlorine	(mg / l)	Operational	≥ 0.2	41	80.5%

Table 26: 2011 Tzaneen Water Quality Compliance Report

Greater Tzaneen Municipality Water Quality Report					
		2011 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2011	Achieved compliance 2011
Physical determinands				190	93.7%
Colour	(mg / l as Pt)	Aesthetic	< 20	35	97.1%
Conductivity	(mS / m)	Aesthetic	< 150	57	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	55	85.5%
Turbidity	(NTU)	Aesthetic	< 1	43	93.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				162	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	32	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	13	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	19	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	13	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	20	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	32	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	33	100.0%
Microbiological determinands				56	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	56	100.0%
Operational determinands				51	82.4%
Free Chlorine	(mg / l)	Operational	≥ 0.2	51	82.4%

Table 27: Tzaneen Water Quality Compliance Report

Greater Tzaneen Municipality Water Quality Report					
		2012 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2012	Achieved compliance 2012
Physical determinands				233	92.7%
Colour	(mg / l as Pt)	Aesthetic	< 20	40	97.5%
Conductivity	(mS / m)	Aesthetic	< 150	63	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	66	86.4%
Turbidity	(NTU)	Aesthetic	< 1	64	89.1%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				150	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	36	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	12	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	12	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	6	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	12	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	36	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	36	100.0%
Microbiological determinands				65	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	65	100.0%
Operational determinands				27	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	27	100.0%

Table 28: 2013 Tzaneen Water Quality Compliance Report

Greater Tzaneen Municipality Water Quality Report					
		2013 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2013	Achieved compliance 2013
Physical determinands				332	95.8%
Colour	(mg / l as Pt)	Aesthetic	< 20	82	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	84	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	82	93.9%
Turbidity	(NTU)	Aesthetic	< 1	82	91.5%
Odour	(TON)	Aesthetic	< 5	2	0.0%
Chemical determinands				230	99.6%
Arsenic	(µg / l as CN)	Acute Health	< 50	2	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	37	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	35	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	35	97.1%
Manganese	(µg / l as Mn)	Aesthetic	< 100	35	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	12	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	37	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	37	100.0%
Microbiological determinands				66	69.7%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	66	69.7%
Operational determinands				4	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	4	100.0%

Table 29: 2014 Tzaneen Water Quality Compliance Report

Greater Tzaneen Municipality Water Quality Report					
		2014 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2014	Achieved compliance 2014
Physical determinands				176	89.8%
Colour	(mg / l as Pt)	Aesthetic	< 20	43	90.7%
Conductivity	(mS / m)	Aesthetic	< 150	42	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	44	100.0%
Turbidity	(NTU)	Aesthetic	< 1	43	76.7%
Odour	(TON)	Aesthetic	< 5	4	0.0%
Chemical determinands				117	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	4	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	17	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	17	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	17	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	17	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	11	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	17	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	17	100.0%
Microbiological determinands				56	95.2%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	56	95.2%
Operational determinands				5	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	5	100.0%

Table 30: 5 Year Tzaneen Water Quality Report Summary

Category	2010	2011	2012	2013	2014
Physical determinands	96.3%	93.7%	92.7%	95.8%	89.8%
Chemical determinands	98.7%	100.0%	100.0%	99.6%	96.6%
Microbiological determinands	98.7%	100.0%	100.0%	69.7%	95.2%
Operational determinands	80.5%	82.4%	100.0%	100.0%	0.0%

Table 31: 2010 Letsitele Water Quality Compliance Report

Letsitele Water Quality Report					
		2010 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2010	Achieved compliance 2010
Physical determinands				108	100.0%
Colour	(mg / l as Pt)	Aesthetic	< 20	19	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	40	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	40	100.0%
Turbidity	(NTU)	Aesthetic	< 1	9	100.0%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				150	99.3%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	32	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	13	92.3%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	13	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	13	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	17	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	30	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	32	100.0%
Microbiological determinands				40	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	40	100.0%
Operational determinands				15	100.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	15	100.0%

Table 32: Letsitele Water Quality Compliance Report

Letsitele Water Quality Report					
		2011 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2011	Achieved compliance 2011
Physical determinands				75	98.7%
Colour	(mg / l as Pt)	Aesthetic	< 20	12	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	25	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	25	100.0%
Turbidity	(NTU)	Aesthetic	< 1	13	92.3%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				78	100.0%
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	17	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	5	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	7	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	5	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	8	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	18	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	18	100.0%
Microbiological determinands				25	100.0%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	25	100.0%
Operational determinands				15	86.7%
Free Chlorine	(mg / l)	Operational	≥ 0.2	15	86.7%

Table 33: 2011Letsitele Water Quality Compliance Report

Letsitele Water Quality Report					
		2012 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2012**	**Achieved compliance 2012**
Physical determinands				**100**	**98.0%**
Colour	(mg / l as Pt)	Aesthetic	< 20	16	**93.8%**
Conductivity	(mS / m)	Aesthetic	< 150	28	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	28	100.0%
Turbidity	(NTU)	Aesthetic	< 1	28	96.4%
Odour	(TON)	Aesthetic	< 5	0	no data
Chemical determinands				**69**	**100.0%**
Arsenic	(µg / l as CN)	Acute Health	< 50	0	no data
Calcium	(mg / l as Ca)	Aesthetic	< 150	17	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	5	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	5	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	3	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	5	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	17	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	17	100.0%
Microbiological determinands				**28**	**100.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	28	100.0%
Operational determinands				**12**	**100.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	12	100.0%

Table 34: 2013 Letsitele Water Quality Compliance Report

Letsitele Water Quality Report					
		2013 Calendar year			
Determinand	**Units of measure**	**Risk**	**SANS 2006 Class I requirement**	**No of results 2013**	**Achieved compliance 2013**
Physical determinands				**115**	**96.5%**
Colour	(mg / l as Pt)	Aesthetic	< 20	27	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	29	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	29	100.0%
Turbidity	(NTU)	Aesthetic	< 1	29	**89.7%**
Odour	(TON)	Aesthetic	< 5	1	**0.0%**
Chemical determinands				**104**	**99.0%**
Cyanide (Recoverable)	(µg / l as CN)	Acute Health	< 50	1	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	21	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	15	**93.3%**
Magnesium	(mg / l as Mg)	Aesthetic	< 70	15	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	15	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	3	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	17	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	17	100.0%
Microbiological determinands				**25**	**56.0%**
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	25	**56.0%**
Operational determinands				**11**	**100.0%**
Free Chlorine	(mg / l)	Operational	≥ 0.2	11	100.0%

Table 35: Letsitele Water Quality Compliance Report

Letsitele Water Quality Report					
		2014 Calendar year			
Determinand	Units of measure	Risk	SANS 2006 Class I requirement	No of results 2014	Achieved compliance 2014
Physical determinands				57	98.2%
Colour	(mg / l as Pt)	Aesthetic	< 20	14	100.0%
Conductivity	(mS / m)	Aesthetic	< 150	14	100.0%
pH	(pH units)	Operational	≥ 5 to ≤ 9.5	14	100.0%
Turbidity	(NTU)	Aesthetic	< 1	14	100.0%
Odour	(TON)	Aesthetic	< 5	1	0.0%
Chemical determinands				41	100.0%
Cyanide (Recoverable)	(µg / l as CN)	Acute Health	< 50	1	100.0%
Calcium	(mg / l as Ca)	Aesthetic	< 150	6	100.0%
Iron	(µg / l as Fe)	Aesthetic	< 200	6	100.0%
Magnesium	(mg / l as Mg)	Aesthetic	< 70	6	100.0%
Manganese	(µg / l as Mn)	Aesthetic	< 100	6	100.0%
Nitrate	(mg / l as N)	Acute Health	< 10	4	100.0%
Sodium	(mg / l as Na)	Aesthetic	< 200	6	100.0%
Sulphate	(mg / l as SO4)	Acute Health	< 400	6	100.0%
Microbiological determinands				24	92.9%
E. Coli	(cfu per 100 ml)	Acute Health	Non-Detect	24	92.9%
Operational determinands				12	0.0%
Free Chlorine	(mg / l)	Operational	≥ 0.2	12	0.0%

Table 36: Letsitele Water Quality Compliance Report

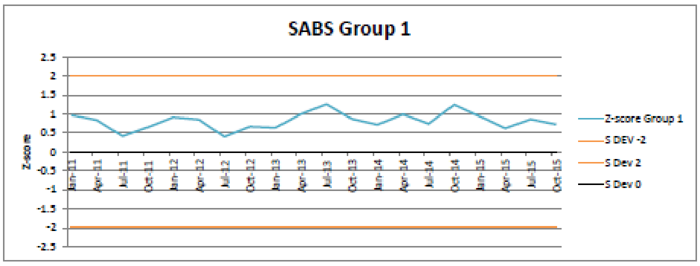
Category	2010	2011	2012	2013	2014
Physical determinands	100.0%	98.7%	98.0%	96.5%	98.2%
Chemical determinands	99.3%	100.0%	100.0%	99.0%	97.6%
Microbiological determinands	100.0%	100.0%	100.0%	56.0%	92.9%
Operational determinands	100.0%	86.7%	100.0%	100.0%	0.00%

Annexure B: A2010 – 2014 Municipalities Drinking Water Quality Actual data on excel spreadsheeton the attached CD.

Annexure C: Tshwane z-score Certificate

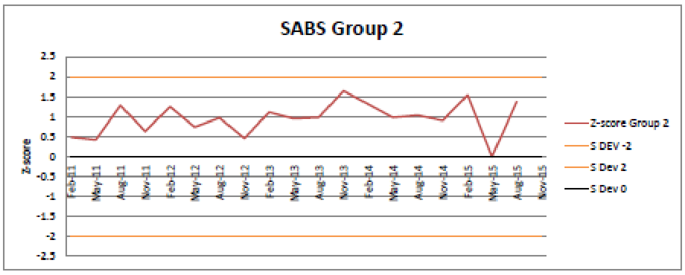
SABS Water check z-scores 2011-2015 B115
Group1

Date	Z-score Group 1	S DEV -2	S Dev 2	S Dev 0
Jan-11	0.97	-2	2	0
Apr-11	0.84	-2	2	0
Jul-11	0.42	-2	2	0
Oct-11	0.65	-2	2	0
Jan-12	0.91	-2	2	0
Apr-12	0.85	-2	2	0
Jul-12	0.4	-2	2	0
Oct-12	0.67	-2	2	0
Jan-13	0.64	-2	2	0
Apr-13	1	-2	2	0
Jul-13	1.26	-2	2	0
Oct-13	0.87	-2	2	0
Jan-14	0.72	-2	2	0
Apr-14	0.99	-2	2	0
Jul-14	0.74	-2	2	0
Oct-14	1.24	-2	2	0
Jan-15	0.94	-2	2	0
Apr-15	0.62	-2	2	0
Jul-15	0.86	-2	2	0
Oct-15	0.73	-2	2	0



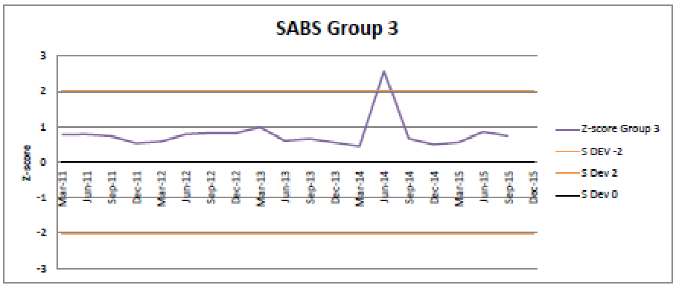
SABS Water check z-scores 2011-2015 B115
Group2

Date	Z-score Group 2	S DEV -2	S Dev 2	S Dev 0
Feb-11	0.48	-2	2	0
May-11	0.42	-2	2	0
Aug-11	1.28	-2	2	0
Nov-11	0.63	-2	2	0
Feb-12	1.25	-2	2	0
May-12	0.74	-2	2	0
Aug-12	0.97	-2	2	0
Nov-12	0.45	-2	2	0
Feb-13	1.11	-2	2	0
May-13	0.95	-2	2	0
Aug-13	0.98	-2	2	0
Nov-13	1.64	-2	2	0
May-14	0.98	-2	2	0
Aug-14	1.03	-2	2	0
Nov-14	0.9	-2	2	0
Feb-15	1.54	-2	2	0
May-15	Not Done	-2	2	0
Aug-15	1.38	-2	2	0
Nov-15		-2	2	0



SABS Water check z-scores 2011-2015 B115
Group3

Date	Z-score Group 3	S DEV -2	S Dev 2	S Dev 0
Mar-11	0.77	-2	2	0
Jun-11	0.78	-2	2	0
Sep-11	0.73	-2	2	0
Dec-11	0.54	-2	2	0
Mar-12	0.58	-2	2	0
Jun-12	0.78	-2	2	0
Sep-12	0.82	-2	2	0
Dec-12	0.81	-2	2	0
Mar-13	0.98	-2	2	0
Jun-13	0.61	-2	2	0
Sep-13	0.66	-2	2	0
Mar-14	0.45	-2	2	0
Jun-14	2.56	-2	2	0
Sep-14	0.67	-2	2	0
Dec-14	0.5	-2	2	0
Mar-15	0.56	-2	2	0
Jun-15	0.85	-2	2	0
Sep-15	0.73	-2	2	0
Dec-15		-2	2	0



Annexure D: City of Tshwane Incident management Protocol

CITY OF TSHWANE
IGNITING EXCELLENCE

INCIDENT MANAC

DOC NO:	WS/WTW/DOC 29
ISSUE DATE:	2013/03/01
REV NO:	*1*

Alert Levels	Risk - Acceptable SANS 241- 2011 limit exceeded	Response Time	Health Implications	Incident Management
Level 1 Identified Incident - initial unconfirmed failure	**Acute Health** E.coli, NO3 (N),NO2 (N), SO4, CN, viruses, parasites	24 Hours	Immediate unacceptable health risk if incident is confirmed	Internal
	Operational Total coliforms, HPC, coliphages, turbidity, pH, Aluminium, chlorine residual		Indicator of Treatment efficiency	
	Chronic Health F-, Sb, As, Cd, Cr, Co,Cu,Fe >2000, Pb, Mn>500, Hg, Ni, Se, U, V, TOC, THM's, Microcystins	72 Hours	unacceptable health risk if high levels ingested over extended period.	
	Aesthetic color, EC, T&O, TDS, NTU >5, SO4 >250, Ammonia (N), CL-, Na, Zn, Fe, Mn, Phenols.		taste, odour & colour - health risk if values exceed SANS241 limits	