Non-compliance assessment and law enforcement efficacy in the eMalahleni Local Municipality Mpumalanga

By

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ABSTRACT

Compliance refers to complying with legislation and/or licensing requirements, while regulation refers to the use of legislative powers to ensure compliance with the law (commercial law, 2016). It may also entail measures to ensure that companies comply with both industry and government regulations. Wastewater treatment works are required to comply with the operational standards of Green drop requirements and regulations from the Department of Water and Sanitation and are advocated by the National water Act, (Act 36 of 1998).

As the highest law in the country, the Constitution of South Africa (Act 108 of 1996) represents the most overarching legal framework for wastewater services regulation. Where the Constitution, together with the Municipal Structures Act (Act 117 of 1998) and the Water Services Act (Act 108 of 1997), assign the responsibility for the provision of wastewater services to the local sphere of government (municipalities). In this regard some municipalities have been classified as WSAs that are responsible for providing water services within their areas of jurisdiction (RSA, 1997).

This study pursue to assess the non-compliance effluent and impact of partially treated effluent discharged into water resource and the environment from wastewater treatment plants in eMalahleni local municipality, identifying challenges and risk. This was achieved through cross section study using qualitative data collection method. Data was collected through previous National Green drop assessments conducted by the Department of Water and Sanitation, resident's interviews and local newspapers as well with physical operational plant assessment.

Three questionnaires concerning the understanding and identification of the cause and impact of the discharged non-compliance effluent into a water resources and environment was investigated; (a) challenges leading to non-compliance of effluent (b) the impact of non-compliance effluent on environment (c) law enforcement challenges in water and wastewater management.

Overall, the findings revealed that the two study wastewater treatment works operation is not satisfactory, they are not fully applying nor implementing the operational requirements of wastewater as stipulated by the regulator department and not implementing all the recommendations provided during National Green drop assessments conducted on this Municipality. There is an indication of plants operated by unskilled personnel who still require training on operations of wastewater treatment works. Both plants were found to be at high risk, do not comply with Ammonia and was concluded that will be placed under surveillance due to possibility of posing a health threats to the surroundings. The Municipality tap drinking water was no longer safe to drink and had a brown colour, it was found that the residents were not pleased with the water situation in eMalahleni. Local business were affected, guest at Hotels were told not to drink water from the taps. Challenges included a lack of commitment from management, attitude of operators, poor maintenance and budget, lack of an

updated wastewater risk abetment plan, process audits and asset management, as well as politics and lack of public awareness.

In conclusion, there are measures and regulations in place that can solve the non-compliance effluent challenges and increase compliance. This involves, among other things, ensuring compliance with the country's water legislation, particularly water quality requirements, and taking enforcement actions in cases of non-compliance (DWAF, 2003; Ntombela, 2013), however they were ignored. It is concluded that all findings contributed to unsafe drinking water in eMalahleni. In light of these research findings, it is recommended that all Green drop requirements measures outlined be implemented so that compliance can be achieved. If this is not successful, the relevant DWS regional office will issue a directive, and if the conditions of the directive are not adhered to criminal charges may be laid against the municipality (DWA, 2010).

LIST OF ACRONYMS

BNR	Biological Nutrients Removal
CMA	Catchment Management Agency
CSIR	Council of Scientific and Industrial Research
CPF	Community Policing Forum
CRR	Cumulative Risk Rating
DAF	Dissolved Air Floatation
DEAT	Department of Environmental Affairs and Tourism
DEFF	Department of Environment, Forestry and fisheries
DNHPD	Department of National Health and Population Development
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
DWM	Developmental Water Management
GDS	Green Drop System
IWQM	Integrated Water Quality Management
NGRA	National Green Drop Assessment
NWRS	National Water Resource Strategy
NWA	National Water Act
PAT	Progress Assessment Tool
PST	Primary Settling Tank
RAS	Return Activated Sludge
SST	Secondary Settling Tank
TDS	Total Dissolved Solids
WISA	Water Institute of Southern Africa
WWTP	Wastewater Treatment Plant

DECLARATIONS

I hereby assert that this thesis is my own dissertation and has not never been submitted for assessment at any institution and is submitted for a Master's degree in Water Resource Management at the University of Pretoria.

Signature …… …

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1.1 Research Background

As a developing country and developments increase, wastewater plants receive high volumes of wastewater, which affect the design capacity of the treatment plant and result in inadequate wastewater effluent at discharge and alter the quality of the raw water in the receiving system (Bakari, Sayef, 2017). Water quality automatically becomes an issue, this increases the need for quality drinking water treatment and makes it expensive to treat.

The National Water Act 36 of 1998- states that water resource must be protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors;

i. Meeting the basic human needs of present and future generations
ii. Promoting equitable access to clean water
iii. Promoting the efficient, sustainable and beneficial use of water in the public interest
iv. Facilitating social and economic development
v. Providing for growing demand for water use and safety of dams
vi. Protecting aquatic and associated ecosystem and their biological diversity
vii. Reducing and preventing pollution and degradation of water resources

The Water and Sanitation Department as the main regulator, using the National Water Act as an umbrella, launched the Green drop and Blue drop certification program in 2008, which is the main driver of the program and relates to the standard of wastewater. The program aims to promote industry and stakeholder growth and encourage good water quality compliance through sector influencing and empowerment. During the green drop and Blue drop evaluation phase, the certificate is granted to the complied sector at a score above 90 per cent.

"*In our country of about 50 Million people, we face the challenge of freshwater scarcity, which is exacerbated by over-exploitation and population of its sources, its growing demand, unsustainable usage and wastage…in this regard; my department has developed innovative measures to ensure that is adequate water of useable quality for current and future generations"*

(Edna Molewa, Stockholm Industry Water Awards: Sweden, 2011)

Unfortunately, most wastewater treatment plants do not comply with the specifications and legislation, so far many wastewater treatment plants still face a challenge in discharging effluent that is secure for receiving water bodies, the environment and the ecosystem at large. Naauwpoort and Riverview wastewater treatment plants in the local municipality of eMalahleni in Mpumalanga have been reported to be at high risk. (DWS, 2011).

1.2 Research Problem

Nonetheless the by-laws (law enforcement) of the Municipality, Green drop specifications and interventions given for the wastewater treatment plants in operation, these plants repeatedly discharge non-compliance effluents. The increase and expansion of development together with population growth has put more pressure on wastewater treatment plant design efficiency, leading to a continuous increase in water resource and environmental pollution.

1.3 Research Questions

The research addressed the following questions

a) What are the challenges leading to the increase of high non-compliance quality discharge to water resources?
b) What is the impact of non- compliance effluent to water resources from wastewater treatment works?
c) And what are challenges /issues related to law-enforcement management for effluent compliance and implementation?

1.4 Objectives of the study

The aim of the study was to assess the non-compliance effluent and identify the challenges of operational system of the wastewater treatment plants and identify issues related to law enforcement impeding compliance. Also the study needed to showcase the benefit of implementing regulatory requirements for plant optimisation.

The objectives of the study were to;

a) To assess the non-compliance and non- law enforcement issues within the municipality
b) To assess the effluent quality and the impact of non-compliance of effluent on the public.
c) To recommend the changes or modification that will be required to enhance compliance.

1.5 The role of the researcher

The researcher was the interviewer and co-ordinator of the study. IsiZulu, Swati and English was used for data collection, isiZulu is the dominant language used in eMalahleni and it made it easier for the interviewers to participate. The data collected and observation was analysed and written up. The questionnaires were encouraged by the overall findings during data collection.

PART 2: LITERATURE REVIEW

2.1 INTRODUCTION

Wastewater treatment is a system used to convert wastewater into an effluent that can be returned to the water resource with minimal environmental impact or directly reused (irrigation). By-products from wastewater treatment systems, such as filtering, grit and sewage sludge, can also be treated at a wastewater treatment facility. (Metcalf & Eddy, 2003).

The most challenging problem for wastewater treatment works is non-compliance of discharge effluent, which is extremely growing, driven by high population growth and developments. Further growth and population rise mean a high volume of sewage in treatment plants that over-capacitate the design capability of the works (Joshua N. Edokpayi & John O. Odiyo, 2016) resulting in insufficient treated effluent and increasing contamination in the receipt of water resources. The discharge of untreated and improperly treated wastewater into water sources has both long- and short environmental and human health effects (CSIR, 2010).

To address the problem of increasing water resource pollution, the Department of Water and Sanitation has introduce Green drop assessment regulations, which assist with baseline requirements to enhance the operation efficiency of the treatment works and minimise pollution (DWS , 2008). In addition, the department has also commenced the remedial procedure, where corrective action could be implemented after all approaches have been exhausted to resolve the situation of persistent non-compliance.

After the start of the initiative, municipalities and water board have been evaluated and eMalahleni local municipality participated where poor performance was achieved and in high risk in 2009 and 2011 National Green drop assessments. Conferring to evaluation outcomes, the municipality's overall management performance of the WWQ was reasonably low, with significant improvement effort expected in all areas.

2.2 Municipal wastewater treatment works configuration and processes steps

Sewage, or domestic wastewater, is a form of wastewater emitted by a population of people. It is defined by volume or flow rate, physical state, chemical and toxic constituents and their bacteriological status (which organisms it contains and in what quantities).It includes household waste liquid from toilets, baths, showers, kitchens, and sinks draining into sewers (Metcalf & Eddy, 1972). In certain regions, wastewater also contains industrial and commercial liquid waste.

The goal of wastewater treatment is to create the effluent that will do as little damage as possible when is released into the natural area, thus avoiding contamination compared to the discharge of raw wastewater directly into the atmosphere. Treatment of sewage typically requires three phases of primary, secondary and tertiary treatment.

- **Primary treatment**

This comprises of holding the sewage temporarily in a calm reservoir whereby heavy solids will settle to the bottom, while oil, grease and lighter solids rise to the top. The set and floating materials shall be separated and the remaining liquid may be discharged or subjected to secondary treatment. (Khopkar, S.M, 2004). Most of the sewage treatment plants that are connected to the integrated sewer grid have a bypass structure after the primary treatment facility. It ensures that secondary and tertiary treatment systems are bypassed during exceptionally heavy rainfall events in order to protect them from hydraulic overloading and that only primary treatment is provided for the mixing of waste and storm water.

- **Secondary treatment**

This process reduces the biological matter that has been dissolved and suspended. Secondary treatment is typically performed by natural, waterborne micro-organisms in a regulated environment. This process reduces the biological matter that has been dissolved and suspended. Secondary treatment is typically performed by natural, waterborne micro-organisms in a regulated environment.

- **Tertiary treatment**

This third and last step is comprised of removing phosphates and nitrates from the water supply In order to enable discharge to a highly sensitive or vulnerable ecosystem (springs, low-flow Rivers, coral reefs,). Treated sewage is usually disinfected physical or chemical leading to release into a river, stream, bay or wetland, or may be used for irrigation, e.g. Golf course, green way or park. If it is reasonably clean and authorized (DWA, 2009), it may also be used for agricultural purposes or groundwater recharge.

Plant A, Naauwpoort WWTP in eMalahleni Local Municipality has a 3 -stage Phoredox system commonly known as Biological Nutrients Removal system (BNR). This wastewater treatment system with 10ML design capability requires enough Oxygen, *Acinetobacter, Nitrobacter* and *Nitrosomonas* bacteria to play a role in the treatment processes that differ from the environment appropriate for their survival. The key to the treatment is to maintain the condition that the bacteria are active and able to function as intended. The plant discharges its final treated effluent into the Naauwpoortspruit stream, final destination being the Witbank dam.

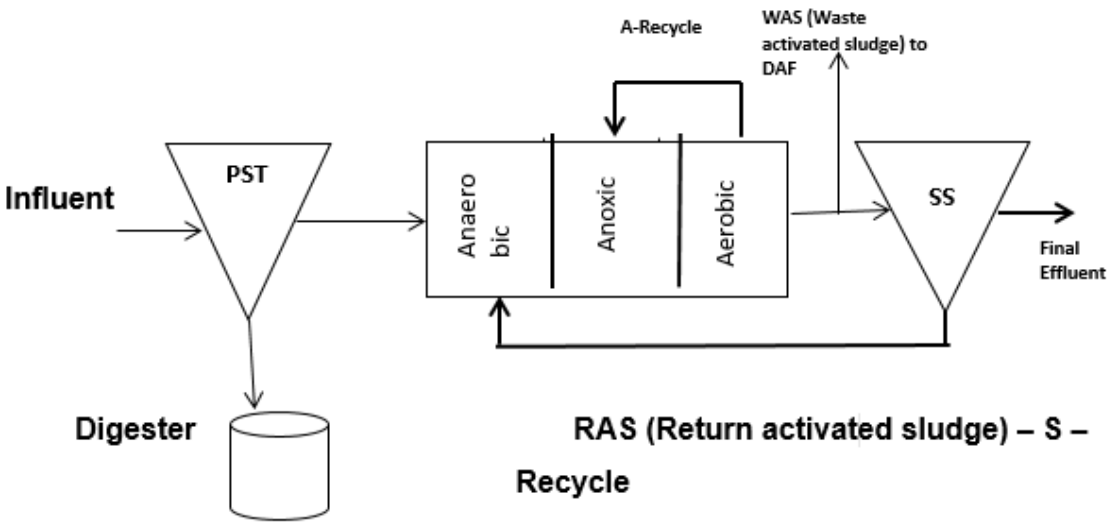

Figure 1: Municipal wastewater treatment work configuration, Naauwpoort WWTP. Typical Plant flow diagram

Whereas Plant B, Riverview WWTP is a combination of Bio-Filter and Biological Nutrient Removal System with a design capacity of 11ML per day. Oxygen is the engine driver of the two processes for the effective treatment of sewage and the generation of compliance effluent. Treatment works applies the General Authorization Standards and discharge thru small canal that flows into the Olifants River.

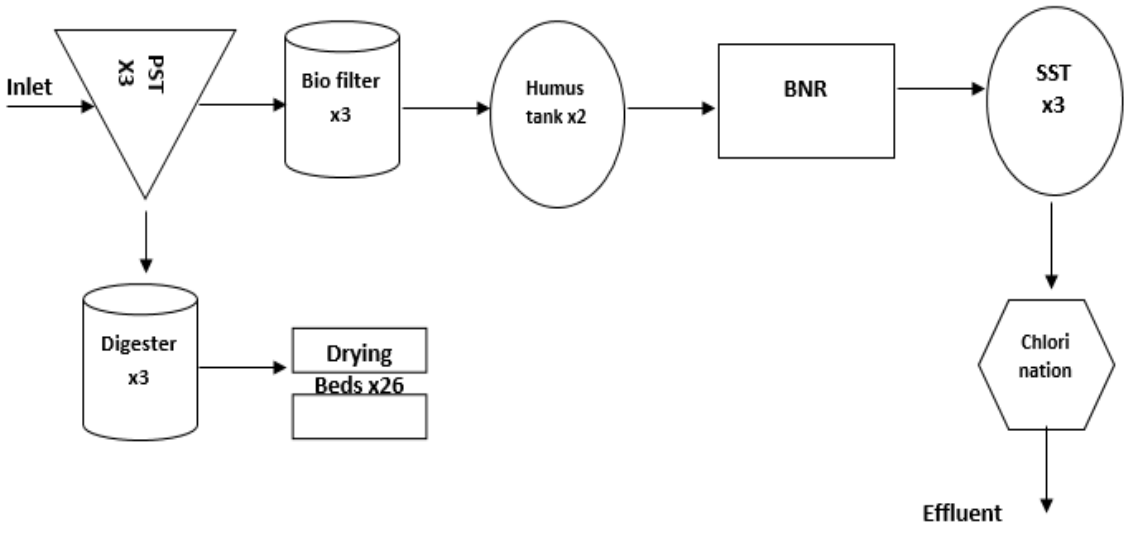

Figure 2: General Municipal wastewater treatment work configuration, plant B- Combination of Bio -filter and BNR system.

2.2.1 Plant operation and Water Use Licence Authorisation

a) Naauwpoort WWTW

Sewage enters a treatment plant and flows through a filter that removes large floating artifacts, such as rags and sticks, which can block pipes or damage equipment. When the sewage has been screened, it passes into the grit chamber, where ash, sand, and small stones are allowed to settle manually. The available mechanical raked bar screen removes all the debris at this plant, and Naauwpoort has a secondary manual bar screen, which is also used after a fine screen. The screened solids are stored and subsequently disposed of in municipal landfills.

Grease and fat are separated by use of primary clarifiers with mechanical surface skimmers for fat and grease removal, pumped and deposited to dissolve air flotation (DAF) tanks for further treatment. As accumulated Sludge is drained out to the anaerobic digester at the bottom of the primary sediment tank for further treatment.

Settled water liquor is treated with anaerobic, anoxic and aerobic biological processes and phosphorus removal from wastewater before it is discharged into surface. Naauwpoort WWTP uses mechanical aerators to provide oxygen to the aerobic reactor. In order to achieve Biological Nutrient Removal, the method uses bacteria and protozoa to absorb biodegradable soluble organic contaminants (e.g. carbohydrates, fats, organic short-chain carbon molecules, etc.) and attaches many of the less soluble components to the floc (Danesh, S, Oleszkiewicz, J.A, 1997).

The system has an A-recycle that provides a minimum of oxygen to the anoxic zone for the denitrification process, and S-recycles that activates and supplies food to bacteria that it uses as a source of energy. The following biological processes occur during sewage treatment (panel D.D. FochtA. C.Chang. (2008);

- First process; the biological conversion of Ammonium to Nitrate nitrogen is called **Nitrification** ($NH_3 = NO_2 + NO_3$). The process is enabled by the bacteria *Nitrosomonas* and *Nitrobacter* which require sufficient oxygen environment for growth and metabolism of nitrogen. This step must therefore proceed under aerobic conditions at the level of dissolved oxygen of 1.0 mg/L or more.

- Second step of the process; the biological conversion of Nitrate (NO3) to nitrogen gas (N2) by facultative heterotrophic bacteria is called Denitrification. The method can be described as follows;

$$NO^{-}3 + {}^{5}/_{6}\,CH_3OH \rightarrow {}^{1}/_{2}\,N_2 + {}^{5}/_{6}\,CO_2 + {}^{7}/_{6}\,H_2O + OH^{-}$$

  Denitrification, often enabled by bacteria, in order to convert nitrate to nitrogen gas, the amount of oxygen dissolved must be at or near zero.

The process is performed under anoxic conditions, when the dissolved Oxygen concentration is less than 0.5 mg/l, ideally less than 0.2 mg/l. In this process bacteria break up nitrate (NO_3) to produce oxygen (O_2), nitrate is reduced to nitrous oxide (N_2O) and, in addition, to nitrogen gas (N_2). Because nitrogen gas has poor water solubility, it escapes into the atmosphere as a gas bubble. Bacteria also require a carbon food source for energy and conversion of nitrogen. If the sewage has low BOD, the carbon food source will be insufficient for bacterial growth and denitrification will not proceed efficiently

Mixed liquor flow to the secondary settling tank to isolate the biological floc or filter material produced in the conventional treatment aeration tank. The aim is to provide a final stage of treatment to further increase the condition of the effluent before it is discharged into the receiving area. Effluent polishing of the effluent is achieved by disinfecting the effluent prior to discharge. Final effluent is discharge into the Naauwpoortspruit which flows directly into the Witbank dam.

b) Riverview WWTP

Riverview WWTW has a combination of a biological filtration system and an activated sludge system. Bio filtration is a pollution reduction method using biodegradable contaminants (Flemming, Wingender, 2010).Sewage passes through screens and waste from large unwanted materials is removed. It then flows into the grit chamber, where fine solids are collected and extracted manually. Clear sewage flows to the three primary setting tanks supplied by the division box, the solids settle down at the bottom of the tank and are collected as sludge and pumped into three anaerobic digesters for sludge treatment. The sludge is pumped to twenty-six (26) sludge drying beds after fermentation.

The supernatant water from the digester is either returned to the system or released into the field for grass irrigation. Sewage from PST flows to equaliser which feed the three Biofilter for biological treatments, the biofilter includes medium grain filters (e.g. sand) covered by biofilms. It is the treatment step where Ammonia (NH_3) is later oxidized to nitrate for nitrogen gas release (Denitrification) at later stage. Phosphorus is eliminated in anaerobic-anoxic zones, denitrifying dephosphatation allows the removal of oxygen chambers, and closing dephosphatation in anaerobic-anoxic cycle allows the separation of nitrification and denitrification in the biofilter system. (Andrzej Walega, Krzysztof Chmielowski, 2018). The process requires sufficient oxygen, in this design the rotary arms supply Oxygen as it sprinkles water over the top media.

Water from the Bio filter flows to the humus tank to settle the particles, from the humus tank to the recirculation sump, where it is later pumped to BNR for further biological treatment. The system consist of anaerobic, anoxic and aeration tank. Oxygen is supplied by mechanical aerators on the aeration zone. Mixed liquor from

BNR feed the two secondary settling tanks where the sludge is accumulated at the bottom of the tank, either discarded or added to the network. The SST effluent is then chlorinated and discharged into the Olifants River.

c) Water use license authorisation (www.dwa.gov.za)

The Department of Water and Sanitation requires water sectors to have water use authorisation for water use and discharge to manage compliance. Below are list of authorisation;

Existing Lawful Use – This makes use of water lawfully used prior to the coming into force of the NWA to continue until it can be transformed into a license by compulsory licensing.

Water Use – Licenses are issued under the NWA and require the approval of an application by the Department of Water and Sanitation.

These authorisations may be one of the following (section 21, NWA, 1998):

1. **Schedule 1 use**- -small quantities of water for household use only. No license application needs to be made.
2. **General Authorisations** - In general, larger volumes of water may be approved for a particular form of water use or group of water users. These users need to register their use, but they do not need a license.
3. **Existing Lawful Use** – This allows the use of water that was legally used prior to the entry into force of the NWA to continue until it can be transformed into a license through compulsory licensing.
4. **Licensed Water Use –** Licenses are given under the NWA and require the approval of an application by the Department of Water and Sanitation.

These two municipal wastewater treatment plants use the General Authorisation, this Authorisation can be used where authorisation has not yet been issued, and therefore the treatment works are expected to comply with the requirements of the regulation and the General Limits. The Effluent Monitoring System must be in operation for the continuous calculation of the quality and quantity of wastewater discharge at the appropriate locations and at various locations for the evaluation of the chemical, physical and biological characteristics of the wastewater discharge.

2.2.2 Water Quality Effluent

Water quality is a term used to define the physical, chemical, biological and aesthetic properties of water that decide its fitness for a variety of uses and to protect the health and integrity of aquatic ecosystems**.** (DWAF, 1996).

The availability of water and its physical, chemical, and biological composition (collectively referred to as water quality) affect the different uses of water, which also

have a direct impact on culture and the economy, as well as the capacity of marine habitats to sustain healthy ecosystems. Control of these factors must be placed in place to facilitate enforcement of wastewater treatment plants and protection of effective use of water resources and the environment. Monthly compliance is carried out once a month on both WWTP, the municipal in-house laboratory is not certified and therefore utilizes an external certified laboratory. However, the results of in-house laboratory analysis as well as operational analysis are used for plant optimisation.

2.2.2.1 Water quality monitoring programme

A water quality monitoring programme is important for environmental protection, identifying pollution events and non-compliance parameters. It must be aligned with the determinants to be monitored and authorisation granted by the Department of Water and Sanitation to the treatment works (Vivian K. Blake, 2014), monitoring consists of observations and measurements that are analysed and recorded to provide information and knowledge on the treatment phases of the work.

It must be done in order to understand the efficiency of the plant. The level of monitoring often depends on and takes into account the size of the works, the outflow and the safety of the receiving environment. Weekly and monthly monitoring is done in these two treatment works.

Monitoring is done on the following;

a) Operational monitoring

Both WWTP conduct operational monitoring to ensure the consistency and effectiveness of plant output. This includes inflow and outflow, which provides an indication of the capability of the system and ensures that the quantity of outflow measurements is within the relevant authorisation. Sampling points identified in the work to ensure the efficacy of each treatment unit are;

- Influent (raw sewage)
- effluent (treated sewage), and
- Each unit process(only those applicable by authorisation)

Sludge testing is not currently carried out, and the sludge generated at both wastewater treatment plants is not classified. The Municipality is in the process of classifying sludge with the Department of Water and Sanitation and the re-use of sludge will be regulated by the classification given.

Table 1: parameters monitored at operational

PARAMETERS (mg/l)	Limits
pH	5,5-9,5 ph units
Total Phosphorus/ phosphates	10 mg/l
Ammonia	6 mg/l
Nitrate	15 mg/l
Chlorine	0,25 mg/l

b) Compliance monitoring

Compliance monitoring is carried out for the protection of the ecosystem, rivers, re-use for irrigation and, for the most part, for activities taking place in the receiving environment (Regulation 17, Water Policy 2014).

The monitoring frequency is determined by the authorisation granted to works, and it outlines the standards and limits for discharge, the effluent quality is characterised as following;

- 90% microbiological compliance
- 90% chemical compliance ; and
- 90% physical compliance

Both of the studied WWTP are granted General Authorisation limits, therefore compliance monitoring is performed on a monthly basis. Compliance sampling is separate from operational. The Municipality lab is not certified, they appointed external certified lab to undertake the compliance analysis. The following are general sampling points, and municipality is concentrating at the outlet of works only.

Compliance sampling points are;

- **Outlet of works (final treated effluent)**
- Upstream (before the point of final effluent discharge)
- Downstream (after the final effluent discharge point)

All the results of the analysis are expected to align with the applicable standards and the improvement of the process operation is optimized on the basis of the performance. Determinants monitored for compliance are listed in table below;

Table 2: determinants for receiving water bodies

PARAMETERS	Limits
pH	ph units
Electrical conductivity	70 mS/m
Nitrates (as N)	15 mg/l
Ammonia (as N)	6 mg/l
Chlorine (mg,L)	0,25
Chemical Oxygen Demand (COD)	75 mg/l
Orthophosphate (as P)	10 mg/l
E.coli	1000 ml

2.2.2.2 Non-compliance effluent impacts

Water quality is already on a steady decline, and studies by the Department of Water Affairs (DWA 2011a & 2012) and the Council for Scientific Industrial Research (CSIR, 2010) highlighted some of the challenges currently facing the study field. Water quality concerns affecting South African water bodies include salinization, sedimentation, accumulation of nutrients and eutrophication, microbial pollution (Olatunde S. Durowoju 2017). The impacts of these concerns are expressed on a range of scales, ranging from national to local water management areas to sub-catchments.
The research by Peter J. Ashton and James M. Dabrowski (2011) confirms that nutrient content and microbiological problems are contributing to a decline in the quality of water in the Olifant River and its tributaries with runoff from mining and other land-uses contributing phosphates and sewerage spill overs contributing ammonia, significant organic matter and microbiological problems. Accumulation of these nutrients in rivers and dams beyond the natural requirements resulting in enrichment or eutrophication of nutrients, which may have an effect on the composition and functioning of the natural aquatic biota (DEAT, 2000).

This rise in diffuse pollution has resulted in a steady decline in water quality in the Witbank dam catchment area. Water quality in the dam itself decreased from 50 mg/l-1 sulphate and 100 mg/l-1 total dissolved solids (TDS) to more than 150 mg/l-1 sulphate and 400 mg/l-1 TDS (S.A.P Brown). The direct effect is the excessive growth of algae and macrophytes (rooted and free-floating water plants) which have an impact on recreation and sporting activities; the presence of toxic metabolites in blue-green algae (cyanobacteria); the presence of taste and odor-causing agent's

compounds in treated drinking water, and difficulty in treating the water for potable and/or industrial use.

2.2.3 Sludge treatment and disposal

Sewage sludge is a solid, semi-solid or sludge waste material generated as a by-product of the wastewater treatment plants (Metcalf, Eddy, Inc. (2003). These residues are generally known as primary and secondary sludge. Primary sludge is generated by sedimentation and other primary processes, while secondary sludge is enabled by bio-treatment waste biomass.

Primary sludge is withdrawn from the primary settling tanks into anaerobic digesters on both treatment works. The digesters provide the appropriate process conditions to ferment the sludge under anaerobic conditions. The sludge is fermented from raw sludge smelly material to a substance, which is fairly odour-free (stabilized) because the bacteria decomposed all the organic matter into carbon dioxide, methane and water, softly and sufficiently stabilised to be disposed of without causing nuisance conditions.

The pumping process is carried out by operators in both works, including the digester feed schedule for load control, removal of digested sludge and supernatant liquor, temperature regulation and monitoring of various digester process control indicators.

Anaerobic digestion has advantages and disadvantage, most advantage being the low cost. Below are advantages of the process (P. Jenicek; J. Koubova, 2010);

- The organic content of the sludge is greatly decreased by conversion to gaseous end products. This ensures that the sludge is stabilized after digestion;
- The odor of the sludge is eliminated. The final digested sludge has a typical "tarry" odor;
- The fat are broken down by the process;
- There is a substantial decrease in the number of pathogenic bacteria;
- There is a pronounced physical improvement after digestion as the sludge mass and volume are greatly reduced;
- The liquid fraction (supernatant) contains increased levels of ammonia due to the breakdown of organic nitrogen (proteins). This makes the digested sludge liquor potentially ideal for use in agriculture;
- Digested sludge can be quickly dewatered and dried;
- Biogas is a mixture of carbon dioxide (CO_2) and methane (CH_4) that can be used to heat the digester or to produce electricity.

Disadvantages of the process:

- A relatively high initial capital cost is involved, which appears to limit the process to medium and large job sizes;
- The slow rate of bacterial growth takes a long time to start and restricts the versatility of the process to respond to changing feed loads, temperatures and other environmental conditions;
- The process is vulnerable to interruption if it is not checked regularly and if corrective action is not taken in a timely manner.

2.2.3.1 Anaerobic Digestion Process

However, process of microbiology can be defined easily and clearly as occurring in two phases, involving two different types of bacteria;
First stage: the organic material existing in the feed sludge is processed into organic compounds (also known as volatile fatty acids) by the acid-forming bacteria.
Second stage: these organic acids act as a substrate (food) for the strictly anaerobic methane-producing bacteria that turn the acids into methane and carbon dioxide.

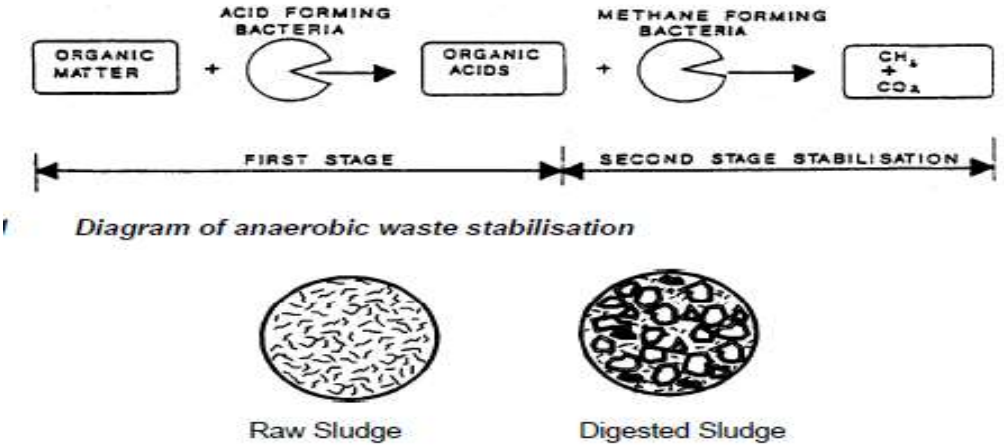

Diagram of anaerobic waste stabilisation

Figure 3: Sludge treatment processes of anaerobic digester

The goal and the end product of the process is:

a) To produce well-stabilised sludge in which 40 - 60% of the volatile solids have been converted to gas
b) A combustible gas consisting of 60 - 75% methane with the remainder mainly being carbon dioxide.

After treatment, sludge is freely drained into the drying beds, while the supernatant water is collected and returned to the head of the treatment plant or used for irrigation. The aim of sludge treatment is to prevent pollution and minimize (disease-causing) organisms that are harmful to humans and the environment. It is therefore necessary to contain, treat and classify sludge such waste.

2.2.3.2 Basic operation of Dissolved air floatation

Naauwpoort WWTP Secondary sludge (activated) is collected from secondary settling tanks where is pumped into the dissolved air flotation thickening for further treated**.** Thickening is the method used to increase the sludge content of the solids by separating and eliminating a portion of the liquid phase (Kiuru, H.; Vahala, R 2000). Gravity thickening requires use of the force of gravity as the main agent in the seeding and thickening process. Naauwpoort WWTP use mechanical mixer to supply air to the tank, a further 15 to 21 days sludge retention time is provided to the tank depending on the thickening that is achieved. The supernatant water gravitates to the head of the treatment plant, while the stabilized, thickened sludge is removed to the drying beds. Riverview WWTP use anaerobic digester system only for sludge treatment.

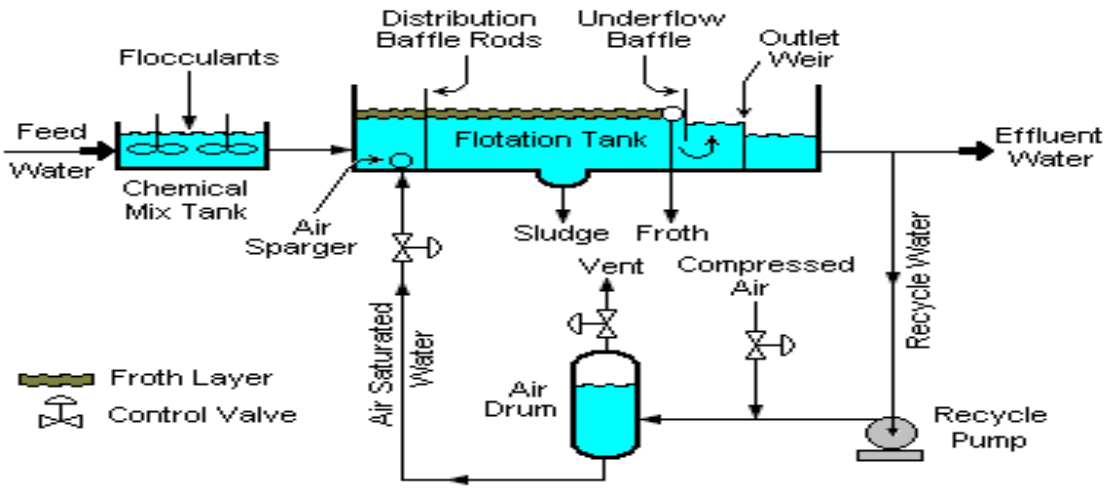

Figure 4: A typical Dissolved air flotation unit

2.2.4 Sludge disposal and Utilisation

Every wastewater treatment plant produces sludge, which is partly present in the incoming flow, or is the by-product of the biological process used to treat the wastewater. The responsibility for finding safe and acceptable sludge disposal methods rests with the municipality operating the works. The South African Department of National Health and Population Development (DNHPD, 1992) have published the "Guide: Permissible Utilisation and Disposal of Sewage Sludge" by means of which sludge application to land is managed in terms of the Health Act (No. 63 of 1977). The aim of these Guidelines is to assist and give direction to all responsible for, and concerned with, wastewater treatment and to promote safe handling, disposal and utilisation of wastewater sludge.

Another informative document has been compiled by the Sludge Management Division of the Water Institute of Southern Africa titled "Sewage Sludge Utilisation and Disposal" (WISA, 1993) which sets out the sludge management situation in South Africa with particular reference to land disposal of sludge (which is the principal disposal means in South Africa).

All wastewater treatment plants are required to classify the collected sludge with the Department of Water and Sanitation for any use. Produced sludge at these two treatment works is not classified and its disposal safety to the environment is not guaranteed. Application is not done, therefore all accumulated sludge is stockpiled at the works. The stored dried sludge may also have its own effect on the soil and water supply, as the treatment works are just a few kilometres from the water resource. During heavy rains, sludge can be washed away and find its way into the water resource and increase pollution. Over time, ground water may also be polluted by infiltration.

2.3 Characteristics and State of Waterbodies

Numerous investigations and reports have dealt with the state and characteristics of the individual waterbodies of the study area and the catchment (and sub-catchment) at large. There are several records also available to varying degrees for public access from which information could be derived on a qualitative and semi-quantitative basis to assess the water quality. The Department of Water Affairs (2011) undertook the Natural Water Reserves study to inform and continue the WRCS process of water resource classification for effective management.

The study designated the water resource as having moderate ecological importance (EI) and moderate ecological significance (ES) which is an upgrade from the River Health Programme (2005), most likely due to different evaluation criteria rather than an improvement in true river health as it designate a POOR score (rating E) to its present ecological state (PES).

The report noted issues for consideration as: “biophysical; urban impacts”. Over the Department of Water and Sanitation (2012) has determine that the biophysical situation and non-compliance effluent impacts are the most serious issues related to the system and define it as “degraded” (classification D). The study of (S.A.P Brown).Water quality in the Witbank dam itself decreased from 50 mg/l-1 sulphate and 100 mg/l-1 total dissolved solids (TDS) to more than 150 mg/l-1 sulphate and 400 mg/l-1 TDS. And although Olifants River is currently known to be the most contaminated water supply

2.3.1 Population growth and impact on design capacity

Population growth means a larger number of households connecting to sewage. The rate of influent flows increases, impacting the design efficiency and performance of the wastewater treatment plant. Treatment work experience operating limitations of

overflow, reduced retention period, insufficient plant supply of oxygen and reduced chlorine contact time.

The immense effect is that the treatment works are slowly becoming costly to maintain, that the technological process is under-performing and that the faeces will not end up in sewage treatment, which also contributes to sewage entering the water resource and affects the quality of the water due to the decrease in treatment work. Overall it result in the production of poor quality effluent at discharge. This causes the consistency of the water in the receiving water source to deteriorate and the consumers of the surrounding water to become affected. Possible waterborne diseases increase and end consumers are at risk.

2.4 Existing strategies plans, policies and Regulation

2.4.1 The Green drop regulation programme (2008)

The Department of Water and Sanitation (2008) as the principal regulator, using the Water Act, (Act 30 of 2004) as an umbrella, introduced the Green drop and Blue drop certification programme, where the Green drop is the main driver for the programme and it applies to wastewater quality. The programme aims at supporting the development of the sectors, stakeholders and advocate towards compliance of good water quality by influencing and empowering the sectors. The certificate is given to the complied sector at a score above 90% during the Green drop and Blue drop assessment period.

Green Drop Report (2011) further confirmed that the program seeks to define and establish core competencies for the sector that, if improved, will progressively and sustainably increase the level of wastewater management in South Africa. This form of encouragement and risk-based regulation ensures a commitment to synergy with the current goodwill displayed by municipalities and existing government support services to provide the requisite emphasis, commitment and preparation.

Overall, the initiative affirms the standards and responsibilities of water service institutions, thus shielding customers from potentially unsustainable and hazardous facilities. Currently, PAT tests are being carried out to track wastewater treatment plants and compliance preparations.

2.4.2 National Water Resource Strategy (2012)

The NWRS-2 (that is version two of the National Water Resource Strategy) is an update and strategic redirection document for water resource management in South Africa, based on progress from the first version (NWRS-1) published in 2004. The document is required by the National Water Act (Act no. 36 of 1998) and is given legal standing by that legislation. The NWRS-2 provides water sector priorities since 2013 – to date, which is constantly reviewed and updated. By its own admission, the NWRS-2 is focussed at better realising the equity goals of the NWA stating that significant water sector changes and improvement had come about since 1994, but

that the allocation and reallocation of raw water to historically deprived communities for productive purposes "had not progressed as expected"

Therefore the NWRS-2 attempts to address shortcomings in the NWRS-1 and direct water management energies towards realisation of these equity goals. The interconnectivity of water resources with economic productivity and the vital link between economic productivity and job creation places a particular emphasis on the protection and management of water resources (in quality and quantity) so that economic and social development is not hindered (rather than being a “stumbling block”).

The NWRS-2 states that South Africa potentially has sufficient water resources for present and future needs but that “effective and timeous implementation of extended and smart water management options” is required to ensure this. The document identifies South Africa as a water scarce country and that water protection may be threatened if not properly planned.

The core water strategies derived from this document are identified and summarised as:

- Core Strategy 1: implementation of equity policy: investment in infrastructure to meet the needs of the vulnerable; production and implementation of resource management strategies to assist and organize poor communities; continuous monitoring and constructive feedback; involvement of stakeholders.

- Core Strategy 2: Putting water at the center of integrated strategic planning and decision-making: recognising water’s strategic role in micro and macro sector plans and centring it in integrated planning and decision-making; national budget reallocations; Paradigm shift in the value system to have sufficient value for water in order to understand real supply costs; implant water management in the business and sector management spheres.

- Core Strategy 3: Ensuring equitable growth and production of water: water is central in various national and regional growth plans, but explicitly acknowledged and provided for, especially considering spatial, economic and viability constraints.

- Core Strategy 4: Contributing to a reasonable and sustainable South Africa: water is acknowledged as a public good with additional roles in being a social and economic good and the NWA specifies that it must be used “beneficially and in the public interest” which brings into focus the issues of meeting basic human needs, eradicating poverty and creating jobs.

Therefore water should be used to support economic and social development through job creation and not just for direct consumption. However evaluation of benefit of use should be evaluated such that maximum benefit is derived, whether direct or indirect.

- Core Strategy 5: Protecting water ecosystem: key issues are identified (in addition to climate change) that is placing increased pressure on water resources, namely: over-abstraction, water-hungry invasive plants;

  Water quality issues as a result of non-source contamination (fertilizers and saline intrusion) and point-source pollution (mining, industrial and wastewater treatment works); habitat loss, including from landfills; bulldozing in riparian areas, sand-winning, mining production, urban sprawl and expanding agricultural cultivation and development in estuarine functional zone.

- Core Strategy 6: Implementation of water quality, water conservation and water demand management: failure of NWRS-1 to ensure adequate water for needs, water conservation and water demand management is established and states that this is a "non-negotiable performance area and must be implemented immediately in all water users sectors and municipalities that are specifically eligible"

- Core Strategy 7: Optimization and extension of water supplies: the scope for the production of new freshwater resources is restricted and the optimization of existing and local resources must be accomplished. Such optimization and "stretching" mechanisms are known as: groundwater production, re-use of water, rainwater harvesting, desalination of brackish or seawater, improved management systems and control of illegal water use. Re-use by reintroduction to waterbodies and downstream use has limitations in terms of water quality problems and cleaning and direct re-use should be encouraged, whilst utilising to the greatest extent the “indirect” reuse mechanism with quality control instruments in place. Consumptive uses (such as agriculture) must be optimised and measures found to reduce consumption and efficiency losses.

- Core strategy 8: Achieving effective governance of water and Development Water Management (DWM): the sector leadership, regulatory framework and water management institutions are highlighted as the main issues to realising this strategy. Catchment Management Agencies (CMA’s) are identified as critical in the governance of water and 9 CMAs are delineated in place of the 19 originally done in the NWRS-1. It is required that “marriage of policy, mandate, performance information and the budget” must be realised and that effective basic financial and budgetary management are the means.

- Core Strategy 9: Embedding sustainable business principles and practices: because unsustainable water management poses significant and widespread risks, sustainable practices must be incorporated into water resource and infrastructure management. This includes the principles: “striving for efficiency from source to tap”, “implementation of life cycle planning and sustainable management of assets and services” particularly in the water and waste water sectors, “sustainable financial management” defining financial responsibilities in a transparent manner and “applying sound management principles and practices within a developmental framework”

- Core Strategy 10: Implementing the investment framework for the water sector: the implementation of an "investment framework and strategy" has already been undertaken by the DW and will inform the budgeting and integrated planning of water infrastructure and management. It should be successful and constructive and consistent with national objectives. Improved means of finance and management need to be sought and enforced.

2.4.3 Water quality management policies and strategies for South Africa (2015)

The existing water quality management policy from the perspective of the Water Resources Directive (DWAF, 2006) focuses primarily on measures to control the use and conservation of the water quality portion of the soil, watercourses, groundwater and sources. The policy does recognise that the specialised nature of WQM does require that this component of water resource management is addressed clearly, but also notes the important linkages to water quantity and aquatic ecosystem integrity. The policy thus requires that water quality is not managed in isolation and to support this, explains how water quality issues can be incorporated into the management of water resources. With this in mind, the vision of the current policy, as set out in the Resource Management Policy on Water Quality (DWAF, 2006) and the Ground Water Policy (DWAF, 2000), is to ensure that water is appropriate for its intended usage. The vision also broadens to ensure that a sustainable and equitable balance is found between the use and conservation of water quality in water supplies for the good of all South Africans.

The flowing are concerns reflected in the policy statement:

- Salinization;
- Eutrophication;
- Micro-pollutants;
- Micro-biological pollutants; and
- Erosion and sedimentation.

These water quality challenges are still facing South Africa. It may be that in the current context these challenges would be prioritised differently, but nonetheless

these water quality problems still exist. In light of this, it may be found that there is a need to refine, revise, rework and refocus the existing policies.
The heart of the challenge facing South African is finding an appropriate balance between protecting the water resources and using water resources for the economic and social upliftment of the country. One of the aims of the development of a WQM Policy and IWQM Strategy is to realise this balance between protection and use, and to ensure that impacts on the environment and the functions it performs is effectively remediated.

2.5 Effectiveness of the existing policies and Regulations

Developing the implementation plans to put policy, regulation and strategies into practice, is not easy, it is critical to align such plans with the range of planning instruments that exists in organisations or sectors. The strategy needs to be realistic and very specific in terms of roles and responsibilities, resource (financial and human capacity) requirements and linkages and dependencies between key activities.

Then progress and effects of implementing the plan will form a key component for converting policy into practice. In undertaking this process it is a natural development to look at the organisational aspects of giving effect to the plan, and as such an analysis has to be undertaken together with the development of the implementation plan that will result in recommendations regarding an enabling organisational design. It is recognised that organisational change often touches on political sensitivities and, as such, this will need to be managed with care (DWA).

The implementation of the strategies for control, pollution prevention and management of water resources is a challenge nationally, is often ignored due to high political intervention in most public sectors making it more difficult to achieve (Olatunde S. Durowoju, 2017). It all result in increase of pollution in water resources, the environment is in a vulnerable condition that is unsafe for human needs and economy. While Private sectors are most willing and complying with the policies compared to the public sector, the sector has funding problems for implementation to take place.

The National Green drop assessment has collapsed as funding remains the big challenge. The programme require professionals with skills and the expertise in order for it to be successful. The last assessment published and completed was in 2011, Green drop certificates were awarded to the organisations, water boards and farmers who complied with the requirements. Organisations cannot use the certificate obtained 8 years later as characteristic of water quality has changed and compliance determinates needs to be re-assessed. The program is no longer effective, but participation in the PAT assessment is continuously carried out for the preparation of the programme and compliance monitoring.

2.6 Conclusion

In this chapter, the emphasis was on the wastewater treatment processes adopted by the Municipality in the work configurations, the management of the effluent quality handled by the treatment plant along with the development and management of the sludge. The goal was to evaluate the efficacy and operational efficiency of all treatment work in compliance and regulation. To identify gabs, insufficient wastewater treatment impacts on water quality, and to establish benchmarks for regulatory standards for wastewater treatment work on environmental compliance and pollution prevention.

It was noted that pollution continues to increase and the quality of surface water varies over time. At present, production has deteriorated. Operational and compliance control determinants have been identified and the sampling point has been driven by the authorisation given. However, the feasibility of policies and regulatory approaches have been highlighted, clearly showing that the non-availability of funds to implement and improve wastewater treatment works is still a major problem for the public sector.

PART 3: METHODOLOGY

3.1 Study Area

The research was done at eMalahleni Local Municipality, in the east and west of Witbank town where the two wastewater treatment works serve. eMalahleni is one of the fast growing towns in Mpumalanga, in the 2001 census, it was found to have a population of 61,098, 50.6 % female and 49.5 % male (Statistics South Africa, 2001). The last update of 2011 census indicated that the city population increased and stood at 108,674 people (Statistics South Africa, 2011).

The two wastewater treatment works are allocated at the urban area and situated few kilometres from water resources, where both discharge the final treated effluent into. Naauwpoort WWTP discharge into the Naauwpoortspruit which flows directly into the Witbank dam, while Riverview WWTP discharge into the Olifant River (Zitha Goldswain, 2014). Witbank dam is used as the abstraction source for the eMalahleni drinking water treatment plant that supplies most part of Witbank area. eMalahleni Local Municipality, the statutory local water service authority for Witbank, has already surpassed its 90 ML/d permission for Witbank Dam by 11 ML/d (Gunther et al., 2006).

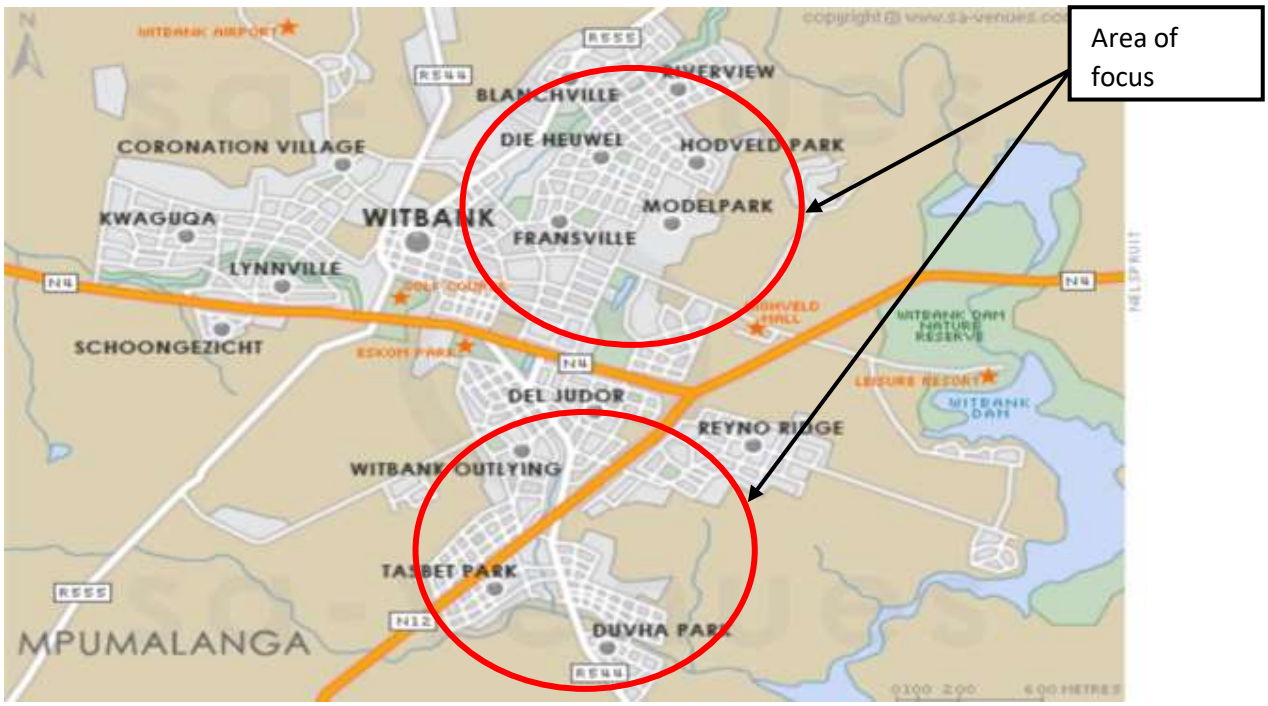

Figure 5: Area served by Naauwpoort WWTP and Riverview WWTP

3.2 Research study plan

A cross section study was done using qualitative data collection approaches, which assisted in information gathering. The approaches assist in providing clear understanding of the treatment processes practiced within the two wastewater

treatment works and finding potential challenges affecting the compliance within the works and the surrounding community.

3.3 Data collection

Firstly, the use of published Nationally Green drop assessment data conducted by Department of Water and Sanitation in 2009, 2011 and the published provisional Green drop report 2013/2014 (PAT assessment) was looked at to assess the plant performance. This helped the researcher to identify possible risks and to consider the overall impact of plant compliance grades.

Secondly, plant visit observations to monitor plant operations were conducted. It included operational and maintenance problems (day-to-day), incident response management, and operational analysis. This led to the conclusion of the operational efficiency of the works, the detection of operational gabs that hinder the discharge quality of the effluent and the current operational application.

A series of questionnaires were asked to process controllers who operate these plants on a daily basis, to assess the awareness of Green Drop Requirements as a compliance guide for all stakeholders and water agencies, to avoid contamination and mitigate health threats to local communities and downstream users. Also the use of interviews with people living within and around the study area on the effect of non-compliance and contamination on how water supplies has affected their lives. This assisted the researcher in risk identification during wet and dry seasons.

Finally, the state of water quality of the receiving water body was reviewed thru the Department of Water and Wastewater Dams and Rivers for the current status of water quality information and for a previous study on the quality of these water supplies.

3.3.1 Green Drop assessment result

In 2009 and 2011 the Department of Water and Sanitation conducted the National Green drop assessment exercise mainly to evaluate all wastewater treatment works across the country on compliance, to record data for non-compliance (DWA 2009 ;2011). The aim was to reward the green drop certificate. The results of the assessment and all findings of the data were recorded and published to the public. This distinctly South African technique has managed to enhance municipal wastewater management and keep the public and stakeholders aware and up-to-date with accurate and up-to-date details.

The mandate of the program was clearly to demonstrate dedication and enthusiasm to achieving excellence in water management, coupled with a risk-based regulatory approach that established a strong connection by providing best management practices paired with risk management to inform the sector where key priorities lay.

Green Drop is enforced by the Department on a biennial basis, with the alternative year being the year on which the progress assessment tool (PAT) analysis is carried.

The 'risk' is described and measured as the Cumulative Risk Rating (CRR), which is a risk calculated against the Design Capacity of the Plant. which also represents hydraulic loading on the receiving water body, operational flow exceeding and below capacity; the number of non-compliance patterns in the quality of the effluent discharged to the receiving water body and the compliance or non-compliance in the case of effluent discharge.

3.3.1.1 Green drop assessment report 2009

The 2009 Green Drop assessment Results indicates that the average of 18% overall compliance was achieved by the municipality (Green Drop report, DWA- 2009). The regulatory impression of the efficiency of wastewater quality control as a whole, based on the assessment results, was relatively poor, with a considerable improvement effort required in all areas. On card report score, Naauwpoort WWTP achieved 11.5% on overall Green drop criteria while Riverview WWTP achieved a 14.5% Green drop score. It was concluded that the municipality's output during the evaluation period was unsatisfactory and that the municipality's overall performance in wastewater quality control was reasonably low, with substantial enhancement effort expected in all areas. The two study areas were placed under regulatory surveillance. The Department used the criteria on the below table to measure compliance.

Table 3: Green drop report card scoring criteria (Green Drop, 2009).

Criteria	Score	Symbol	Description	Requirements (& weighting)
Adequacy of Process Control, Maintenance and Management Skill	100% (10)	A	Fully complies with all requirements.	1. Treatment works complying with Reg. 2834 of Water Act., in terms of Classification and Registration. (20%) 2. Process Controllers are complying with skills requirements of Reg. 2834 of Water Act. (50%) 3. Availability of skilled maintenance skills. (10%) 4. Operations and Maintenance manual is in place. (20%)
	80%-90% (8-9)	B	Complies with all requirements except for 1.	
	70% (7)	C	Not complying with 2 Requirements.	
	50% (5)	D	Not complying with criteria No. 2 or complying with No.2 and none of the other.	
	30% (3-4)	E	Not complying with criteria No. 1 & 2 or No. 2 & 4.	
	10% - 20% (1-2)	F	Not complying with the majority of the requirements.	
	0% (& no info)	G	Not complying with any of the requirements or the complete lack of info.	

Efficiency of Waste Water Quality Monitoring Programme	**100% (10)**	**A**	Fully complies with all requirements.	1. Details of an effective Operational Monitoring Programme. 2. Details of an effective Compliance Monitoring Programme. 3. Proof of sufficient samples and determinands taken from sample sites.
	70% (7)	**B**	Complies with all requirements except for 1.	
	60% (6)	**C**	Not complying with requirement No. 2 and another requirement. Or not complying with any other 3 requirements.	
	30% (3)	**E**	Only complying with 1 Requirement. (1 or 2)	
	15% (1.5)	**F**	Not complying with majority of the criteria. Only complying with one requirement.	
	0% (& no info)	**G**	Not complying with any of the requirements or the complete lack of info.	

Table 4 : Green drop report card scoring criteria (continue)

Criteria	Score	Symbol	Description	Requirements (& weighting)
Regular Submission of Waste Water Quality Results to DWA.	100% (12/12months)	A	Fully complied with criterion	1. Results must be submitted 12 months a year.
	0% (<10 months)	G	Less than 12 sets of data submitted to DWA. No data submitted.	
Waste Water Compliance with License conditions / General Authorizations or Special Limits.	100% (35)	A	Fully complies with criteria.	1. Proof of waste water quality compliance data for the past 12 months and copy of standards used. 2. Provide figures per determinand; number of analysis per determinand & the number of non-complying analysis per determinand. 3. % compliance per determinand (measured against overall compliance %).
	80% (28)	C	Complies with most criteria, except for 1.	
	60% (21)	D	Does not comply with criteria 1 & 2.	
	20% (7)	E	Does not comply with criteria 3.	
	0%	G	Did not comply with both sub-criteria or failed to submit sufficient data for assessment purposes.	
Waste Water Quality Failure Response Management	100% (20)	A	Fully complies with criteria.	1. Proof of a documented Effluent Quality Incident Management Protocol (or protocol similar in function) specifying roles and responsibilities. 2. Provide evidence of implementation.
	60% (12)	C	Have evidence to proof incident management control, but has no documented protocol.	
	40% (8)	E	Has a documented protocol in place but not evidence to proof implementation.	
	0%	G	Not complying with criteria or failed to submit sufficient information for assessment purposes.	
Waste Water Treatment works capacity	100% (5)	A	Fully complies with criteria	
	80% (4)	B	Complies with all criteria except for one.	
	60% (3)	C	Not complying with 2 criteria or Criterion 2.	
	40% (2)	E		
	20% (1)	F	Only complies with 1 criterion.	
	0% (0)	G	Not complying with criteria or failed to submit sufficient information for assessment purposes.	

Table 5 : The Green Drop report card of Naauwpoort WWTP, eMalahleni LM 1, NGDA 2009.

Criteria	Waste Water Treatment Systems			
	Ganala(Kriel)	Klipspruit	Naauwpoort	Phola/Ogies
Process Control, Maintenance & Management Skill	F	G	F	F
Monitoring Programme Efficiency	E	D	D	D
Credibility of Waste Water Sample Analysis	D	D	E	D
Regular Submission of Waste Water Quality Results to DWA	G	G	G	G
Waste Water Quality Compliance	F	G	G	G
Waste Water Failures Response Management	D	B	G	F
Waste Water Treatment Works Capacity	D	C	D	F
Green Drop Score	21%	26%	11.5%	18%

Table 6: The Green Drop report card of Riverview WWTP, eMalahleni LM 2, NGDA 2009.

Criteria	Waste Water Treatment Systems		
	Rietspruit	Riverview	Wilge
Process Control, Maintenance & Management Skill	F	F	G
Monitoring Programme Efficiency	C	C	D
Credibility of Waste Water Sample Analysis	D	D	C
Regular Submission of Waste Water Quality Results to DWA	G	G	G
Waste Water Quality Compliance	F	G	G
Waste Water Failures Response Management	G	G	D
Waste Water Treatment Works Capacity	D	E	E
Green Drop Score	17%	14.5%	16.5%

3.3.1.2 Green drop assessment report 2011

The Municipality was granted the opportunity to participate in the National Green Drop Programme following regulatory review of the poor outcomes found in the 2009 assessment. Overall performance of 45.6 % in 2011 National Green Drop assessment was reached and still determined that the performance was unsatisfactory, implying that the wastewater services were not operated in accordance with the expectations of the regulatory programme (DWA, 2011). The Green Drop standards have not been met, in matters pertaining to technical knowledge, performance monitoring, asset management and effluent quality compliance.

Table 7: Municipal Green Drop Scores and compliance of Naauwpoort WWTP and Riverview WWTP, NGDA 2011

Performance Area / Systems	Ferrobank	Naauwpoort	Riverview
Process Control, Maintenance & Management skills	34	43	43
Monitoring Programme	80	80	90
Credibility of Sample Analyses	100	100	100
Submission of Results	50	50	50
Wastewater Quality Compliance	15	15	15
Failure Response Management	34	34	34
Bylaws	100	100	100
Treatment & Collector Capacity	48	62	55
Asset Management	5	35	5
Bonus Scores	8.8	8.8	8.8
Penalties	0	0	0
Green Drop Score (2011)	**46.0% (↑)**	**52.9% (↑)**	**48.7% (↑)**
Green Drop Score (2009)	NA-0%	11.5%	15.5%
Treatment Capacity (Ml/d)	15.5	10	11
Operational % i.t.o. Capacity	NI (assume >100%)	119%	114%
Cumulative Risk Rating (CRR)	18	16	20
% i.t.o. Maximum Risk Rating	78.3% (↑)	69.6% (↑)	87.0% (↑)

Plant A scored 52.9%, it was a massive improvement indicated by the treatment works with accumulative Risk Rating (CRR) of 16 and it was at 69.6% on maximum risk rating (MRR), while plant B also showed improvement of 48.7% compliance compared to the 2009 (11.5%) compliance, the treatment works had CRR of 20 with Maximum risk rating of 87%. Nonetheless, is most pleasing to notice that scientific (data) integrity and the enforcement of the By-laws have been resolved and full credits have been achieved. Significant 100 percent positive trend reference point for improved Green Drop scores compared to 2009 status.

Despite positive changes, the situation in eMalahleni was considered to be poor from a regulatory point of view as it continues to pose threats to environment and public

health (reference: unacceptable conditions found during site inspections). The Municipality has also not been able to arrest and correct the possible risks. The plants were in high-risk positions and could have been transferred to critical risk groups by the next Green Drop evaluation to be carried out in 2012/13 if decisive intervention and sufficient resources were not applied to actual performance issues.

The following green drop findings was observed and recorded during the assessment, and demanded the attention of municipal management and governance (NGDA, 2011). The study plants are part of the findings;

- Naauwpoort wastewater plant surpass the design capacity, which has an impact on the plant's ability to meet the effluent quality discharge limits,
- No of the studied wastewater treatment plants had gathered information on the Green Drop System or could show any proof of submission of results to the Department of Water Affairs as required by law;
- Neither of the systems have appropriate plans in place to develop or sustain appropriate capacity in the collection and treatment systems, and
- Lastly, the principles and methodologies for asset management have not been implemented.

A further site inspection was conducted at Naauwpoort WWTP to validate the GDA, below are findings;

Inlet work was found to be functional, but the screenings found their way to the biological wastewater treatment process. Grit removal was badly affected by pump blockages (damages) and hardened grit build-up was noticeable in the grit canals, and the Grit classifier found that it was not working. This is a clear indication of poor plant management and it affected the overall efficiency of the plant.

Five aerators were not operating at the BNR facility, no sign of on-site process control, and bad sludge and management characteristics were evident. The disinfection method has been carried out, but the effectiveness has not been verified. Sludge drying beds were not maintained and are not well managed for sludge disposal.

3.3.1.3 The 2014 Progress Assessment Tool (PTA)

The PAT framework was implemented following failure to perform National Green Drop assessments due to difficulties following the National Blue Green Drop reports released in 2011. The report presented details on the performance of the Water Services Authorities (WSA's) in relation to the accumulated Risk Rating for wastewater treatment works from July 2012 to June 2013. A total of 152 municipalities and 824 plants were evaluated, with a total of 5 000 ML of wastewater per day or 1 825 000 ML of wastewater per year (DWA, 2014). The study not only

provided risk audit details related to the compliance of effluent quality as per site-specific water use Authorization or default specifications based on the sensitivity of the receiving environment as part of best practice, but also included;

- Assessment of the Wastewater Risk Abatement Plan, which really is a risk-based approach to wastewater treatment and to mitigate and reduce associated risks;
- Capital and refurbishment expenditure for the financial year 2012-2013 (Rand)
- Availability of technical expertise for plant service and support for management

The Status Report was focused on municipal self-assessment and confirmed to the public by the Department of Water and Sanitation to ensure reliability and validated information. The DWS team, which has acted as a moderator for the information provided by the Water Service Institutions, is made up of a technical community that not only evaluates quality, but also ensures that regulatory guidance is given to municipal wastewater management on necessary improvements.

The primary goal of this regulatory approach was/is to define, assess and build the skills needed for the sector, which, if improved, would progressively and sustainably increase the level of wastewater management in South Africa. The 2014 Green Drop Progress Report presents a three-level risk profile and a six-year trend review of wastewater treatment plants;

- A national overview that collects and elevates detailed system-level findings to those of a regional overview, which can then be compared and inculcated as a national view of the efficacy of wastewater treatment. Comparative analyses of provincial outcomes are useful indicators and comparisons for the various position players ;
- Province specific risk data and information to demonstrate the strengths, shortcomings and performance of the WSI Community within the province or region;
- System relevant risk data and information per WSI (municipal, private WSI) on the efficiency of each wastewater treatment system;

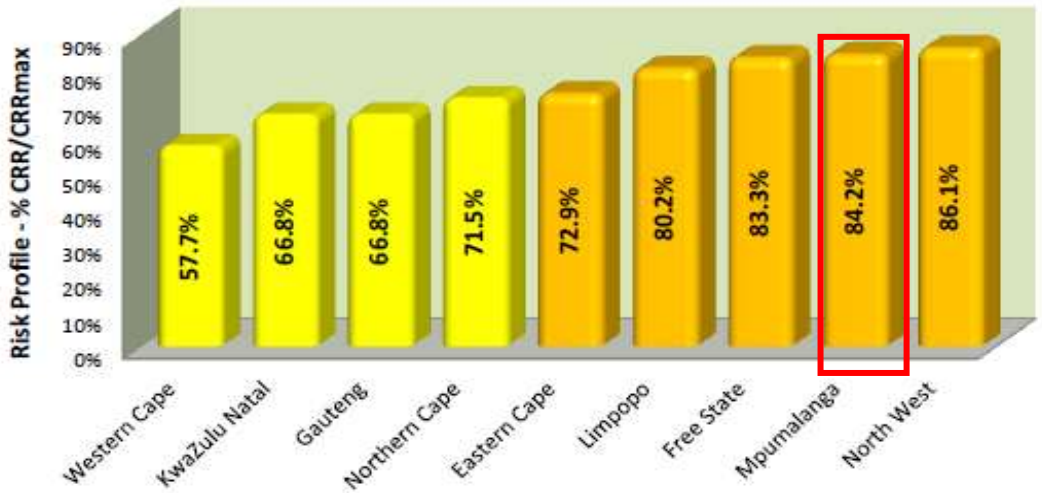

Figure 6: National performance log, Mpumalanga -2014, Performance position in South Africa.

Above figure is the provincial risk profile for 2014. Municipality of eMalahleni is one of the Municipality of Mpumalanga which had a critical risk status and a high of 96.6 % CRR_{max} variance in 2014 (DWA 2014-PAT report). The overall national performance as a province was 84.2 % high risk. On the same year of assessment, Riverview WWTP was found at critical risk while Naauwpoort WWTP was on those which are at high risk space. A comment on the evaluation of all municipal plants in sensitive and high-risk areas was put under regulatory surveillance. Subsequently, these plants were placed under regulatory oversight and thus required immediate action. Currently PAT assessment are carried out and used as the monitoring tool in all the plants.

3.3.2 Plant monitoring

During a day visit, a high flow of white foam into the plant was observed, and simple foam indicates high nutrients. Witbank News also reported in 2014 that the same foam was regularly seen coming from the Riverview WWTP as a major contributor to water quality problems as it discharge into the Olifants River. The normal operation of the plant was well carried out by the operators, and there was an operating logbook which records the daily activities of the plant. They do two 12 hours shifts of day and night, and exchange findings and activities that took place before knocking off.

Potable Photometer Palintest was available for operational analysis and an inlet and outlet flow test was performed for plant optimisation. The test indicated a high concentration of Ammonia and Phosphates at discharge. Chlorine chips were used to disinfect the treated effluent before discharge. It has been stated that monthly compliance samples are obtained once a month by a private firm for analysis in an accredited laboratory.

During plant visits, it is noted that 60 % of operators are old and experienced, while 40 % are young adult operators of mixed age who have the NQF standard of wastewater treatment qualifications that they have gained during their time at the facility. Daily incidents and technical issues are registered and reported for an action plan, when the work is beyond their capabilities, they outsourced. The operators are expected to learn additional skills, as most of them operate as they know, more on safe chemical handling and compliance with the requisite secure protective clothing while operating at a chemical plant.

3.3.3 Interviews with the Occupants

A semi-structural questionnaires was conducted targeting the residents living within and surrounding the study area by the researcher to collect data on the impact of pollution on their lives.

Collection

A total of 20 random households residing near wastewater treatment plants and surrounding areas have been chosen as a population survey and used for data collection. Questions were addressed to two family members per household where both young and old were questioned, However the residents instructed not to give their actual names during this exercise, nonetheless they were able to participate without hesitation.

Data collection tool and process

Since the area is most dominant in the Zulu and Sepedi-speaking community, prepared questions were asked in their primary language, and a limited amount of English was also used where appropriate. Questions included all the general effect that wastewater treatment plants have on their social and health lives.

All participants decided to engage in the exercise on their own and those who were not available were replaced. The questioning was completed on their private houses as they indicated that it will be safe and easy for them to speak their mind without being judged and recorded. The idea brought up by the residency made the interview easy and very engaging as the prepared questions were asked and a healthy feedback regarding the safe operation of wastewater treatment plants information was provided at the spot by the researcher.

In addition, a courageous women, Ms. Clarissa du Plessis, who lives on the banks of the Olifants River, has decided to make her voice heard in an attempt to save the water resource in a local newspaper. Du Plessis said she cannot longer sit still and see how the Olifants River is being strangled. She continued to state that she has seen how the Olifants River in all its elements for the past 21 years,

“The Olifants River used to be a beautiful river, with clean drinking water. However the river turned into a toxic river, infested with the invasive aquatic weed Eichhomia

Crassipes, better known as the Water Hyacinth," she said passionately, (Witbank News, August 13,2014)

Figure 7: This is a picture regularly seen, white foam coming from Riverview Wastewater Treatment plant and running into Olifants River.

3.3.4 Water Quality status

It is well known that the Olifants River, the Witbank Dam and the tributaries that feed into these two water bodies are polluted and the quality of the water is declining daily. Collectively, downstream is affected by a high concentration of mining and urban effects, like wastewater treatment works (WWTWs). In 2014, the Bosveld phosphates paid R2.55 Million fine after locals collected data to show that the Ga-Selati River, a tributary of the Olifants, had been polluted (DEFF, 2015). Pursuant to Section 34(1) and (3) of the 1998 National Environmental Management Act, the accused was ordered by the court to pay a total of one million, four hundred and fifty thousand rand's (R1 450 000) within 14 days from the date of the judgment, in addition to a number of suspended sentences (additional fines of R1 100 000) for contravention of the National Environmental Management Act and the National Water Act.

The published article found that raw sewage also flows into the Witbank Dam from which the town has been obtaining drinking water since 2011 (Schalk Mouton, 2013) and that the two Witbank local hotels had to warn their guests not to use tap water due to its metal and faecal pollution. Inadequate treated sewage has a major effect on the ecosystem when it is discharged or makes its way into a water supply, and Witbank City has a history of polluted water.

A variety of water quality studies have been performed in the Olifants River basin. All tests have shown that the quality of water is poor and at high risk. The 2010 situation in the Olifants River highlights the problem that arises when a single keystone

species, such as the Nile crocodile, is used as the sole indicator of the health of aquatic ecosystems. Amounting to their stealthy nature and their ability to avoid interactions with humans, crocodiles are difficult to reliably track (Ashton, P.J 2010). The death of one or more crocodiles implies that there has been an adverse impact, other harmful effects may have occurred at a lower trophic stage, making it difficult to collect, isolate and interpret evidence to determine the source of the issue. (DWS-Report on Water Quality, 2011-Aurecon).

Historical data were used to assess the status of water quality and the six parameters were chosen to provide an indicator of fitness for the use of water resources by specified user groups.

- Electrical Conductivity (EC) (mS/m): to provide an indication of salinization of water resources (increase in salinization of the country's water resources);
- Orthophosphate (PO_4-P) (mg/l): as an indicator of the nutrient levels in water resources (eutrophication is becoming a threat). Nitrate (NO3+NO2-N) (mg/l) was assessed but showed a 97% compliance to ideal RWQOs due to the fact that the upper limit is set at 6 mg/l based on the most sensitive user.
- Sulphate ($SO_4$2-) (mg/l): as an indicator of mining impacts. Sulphate is a major issue in many catchment areas
- Chloride (Cl-) (mg/l): as an indicator of agricultural impacts, sewage effluent discharges and industrial impacts;
- Ammonia (NH_3-N) (mg/l): as an indicator of toxicity; and
- pH (ph units): as an indicator for mining impacts as well as natural variability nationally

3.3.4.1 Olifants Water Quality Status

The water quality series data for the period 2006 to 2008 were statistically analysed and correlated to Resource Water Quality Objectives (RWQOs) to assess the water quality parameters of concern throughout the different sections of the catchment. Trends were also evaluated for over the period 1999 to 2008 (DWA, 2011b, c). The bellow is the summary analysis results highlighting the following:

- Salinity-related effects due to mining, power generation and industry in the upper sections of the WMA are illustrated with EC and sulphate concentrations at high rates.
- The unsustainable EC concentrations at the lower reaches of the Elands River are caused by the return of irrigation flows and the accumulation due to the evaporation of the low flow of water.

- In areas, the pH slightly reaches the upper limit of 8.4. However, localized acid conditions are present in sub-catchments associated with acid mine drainage. Generally, the acid mine drainage comes from defunct coal mines.
- The trophic status of the dams is mesotrophic. However, eutrophic conditions have been found in the upper reaches of the Loskop Dam. They culminated in the flowering of blue-green algae. Eutrophic levels in the upper reaches of the Loskop Dam are attributed to high nutrient inputs from the wastewater treatment plant below the Witbank Dam.
- The amounts of phosphate in Selati and lower Olifants below the confluence of Selati are inappropriate. These are connected with waste streams and effluents from the mining and industrial activities around Phalaborwa.
- Information on the concentration of heavy metals in the catchment area is limited. However, the available data indicate unacceptably high levels in the catchment areas. In fact, high concentrations of aluminium have been cited as a potential cause of fish deaths in Loskop Dam.
- Intensive farming practices in the Elands and Moses Rivers could contribute herbicides and pesticides to people downstream.

Data quality

The initial monitoring point selection for sites in the Olifants River catchment area was based, along with other things, on the availability of data for trend analysis. The set of data points (post-processing) per selected testing and the effects of data quality control tests on these data sets. (WCR, 2014), is shown in Table below,

Table 8: The number of data available for review at monitoring points in the Olifants River catchment area (following initial data processing) and the number and proportion of those remaining after data quality control tests have been carried out,

Monitoring Point Name	All records	Filtered records	
B7H004 Klaserie River at Fleur De Lys	550	84	15%
B7H007 at Oxford on Olifants River	973	561	58%
B7H009 at Finale Liverpool on Olifants River	541	382	71%
B7H014 Selati River at Calais	339	137	40%
B7H015 Olifants River at Mamba/Kruger National Park	718	573	80%
B7H017 Olifants River at Balule Rest Camp/Kruger National Park	443	359	81%
B7H019 Ga-Selati River at Loole/Foskor	488	343	70%

Monitoring Point Name	All records	Filtered records	
B1H002 at Elandspruit on Spookspruit	1442	600	42%
B1H004 Klip Spruit at Zaaihoek	1416	591	42%
B1H005 Olifants River at Wolvekrans	989	744	75%
B1H015 Middelburg Dam on Little Olifants River: downstream	1285	1104	86%
B1H018 Olifants River at Middelkraal	661	482	73%
B1H019 Naauwpoort 335 Js on Noupoortspruit	834	684	82%
B1H020 at Vaalkranz U/S Vandyksdrift on Koringspruit	811	561	69%
B1H021 Steenkool Spruit at Middeldrift	770	594	77%
B2H007 at Waaikraal on Koffiespruit	916	577	63%
B2H014 at Onverwacht on Wilgerivier	616	359	58%
B2H015 at Zusterstroom on Wilgerivier	503	339	67%
B3H001 Olifants River at Loskop North	724	547	76%
B3H005 Moses River at Mosesriviermond	282	130	46%
B3H017 Loskop Dam on Olifants River: downstream weir	498	405	81%
B3H021 Elands River at Scherp Arabie	398	301	76%
B4H003 Steelpoort River at Buffelskloof	1274	707	55%
B4H007 Little Spekboom River at Potloodspruit	1183	209	18%
B4H011 Steelpoort River at Alverton	605	423	70%
B5H004 Flag Boshielo (Arabie) Dam on Olifants River: downstream weir	547	424	78%
B6H001 Blyde River at Willemsoord	734	264	36%

3.3.4.1 Witbank Dam Catchment water quality status

The Witbank Dam catchment area is situated at the headwaters of the Olifants River, the Witbank Dam catchment area is 3,256 km2 and has an estimated annual run-off of 125 × 106 m3. Eutrophication is the key problem of water quality in the region. In addition to agricultural operations, urban sewage treatment plant effluents provide 38% of the recorded catchment sources and 44% of the recorded phosphorus discharge to the dam (S.A.P. Brown). Phosphorus is a limiting nutrient in the dam and has not substantially improved the concentration of total phosphorus over the last decade. However, the quality of the water in the dam increased by an order of magnitude over the same span of time. This is partly attributed to the rise in total dissolved solids (TDS) which has increased the flocculation of clay particles resulting in increased light penetration.

A variety of streams are present in the catchment area, along with elevated levels of compounds harmful to the natural aquatic ecosystem. These chemicals are predominantly metals and ammonia. Acid mine drainage linked with coal mining is mobilizing metals. Aluminium, iron and manganese are the primary metals of concern. Ammonia originally comes from wastewater effluent (Waters, Meiring and Barnard, 1993).

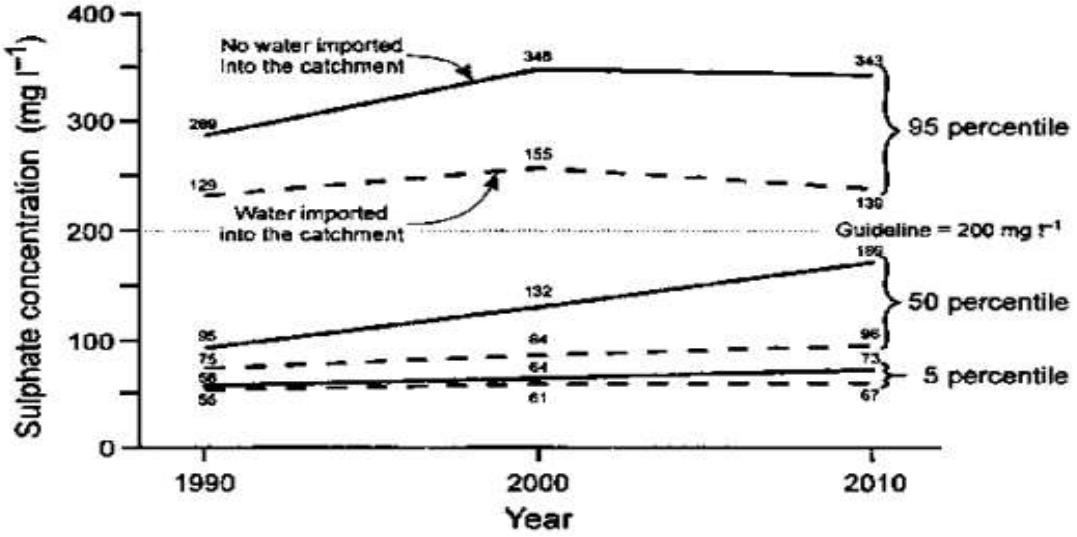

Figure 8: The present and predicted sulphate concentrations in Witbank Dam

3.4 Ethical concerns

The study ensured that all activities are conducted in an ethically comprehensive manner, from the study design to reporting of the final results. Apart from researcher's explanation. Informed approval was pursued from the participants. Before the approval was pursued the researcher provided details of the nature and purpose of the study, what is expected from participants, who are interested about the possible outcomes of the study. By this honour, completion and participation of the questionnaires by the participants was considered as giving permission to participate in the study and willing to be part of it.

A suitable time was given to Participants to respect and value their privacy and wiliness to participate. The residents urged not to give their actual names during this interviews but willing to participate without any hesitations. Therefore no names were recorded on the survey questionnaires.

Part 4: RESEARCH FINDING

4.1 Introduction

The result of the study will be well-defined in this chapter and is in line with the study research questions, the results of the key informative participant's interviews and residents. The result will briefly elaborate on the challenges leading to increase of high non-compliance quality at discharge into water resources, the impact of inadequate treated effluent, operational challenges and issues related to law-enforcement management for compliance and implementation. And the site visit observations of the plant operational system.

4.2 Sites visit and observation

Both Wastewater treatment plants operates 24 hours with two shift cycle. Sewage enters Inlet works where debris is removed either by mechanical screen or hand rake. During site visits a Process of debris removal was done to prevent the clogging of pumps. The removed debris were stored in the waste bin allocated, which is then removed by the municipal waste department and dumped at the municipal landfill.

Figure 9: Naauwpoort WWTP Inlet works

The pre-treated wastewater flows into primary clarifiers where bulk of suspended solids is removed and pumped into the 750m^3 volume digesters for fermenting of sludge. The primary clarifier is configured as a conventional circular clarifier with the wastewater feed into a central stilling well, a circular structure with a central sloping floor at a slop of 1.8, a central sludge hopper for sludge withdrawal, and a rotating sludge scraper with peripheral drive running on the outside wall. The primary clarifiers has 23m Diameter and side wall depth of 3.5m.

The primary effluent flows into the division box that directly feeds the BNR system. The anaerobic, anoxic and aerobic treatment processes takes place at the BNR at Naauwpoort WWTP, required oxygen is supplied by mechanical aerators at aerobic zone and while a combination of BNR and bio- filter treatment system at Riverview WWTP is used. Both WWTP have an internal recycling from aerobic zone back to anoxic zone, this allows flexibility in the routine operation of the BNR process. Mixed liquor is released to the secondary clarifier for further treatment, where the solids are settled at the bottom of the tank. The secondary clarifiers has a diameter of 16m and side wall depth of 4 m.

Effluent from Secondary clarifiers is then chlorinated with Hth (Calcium Hypochlorite) pills or chips. Final effluent is discharge to Olifants River and Naauwpoortspruit stream that feeds the Witbank dam.

Figure 10: Dosing chamber

The stabilised sludge at Naauwpoort plant is discharged to the drying beds and also to the existing beneficial land disposal site where kukuyu grass is cultivated. While Riverview plant discharge into the sludge drying beds and stock pile on site.

4.2.1 Operational Analysis Results

The operational analysis of inflow and outflow were carried out and analysed for the period of one month. Both study wastewater treatment plant use General Authorisation limits and are registered with DWS. For monthly compliance, municipality has appointed private lab to conduct sampling and analyses. The result below represent operational plants compliance. Palintest photometer wastewater test was use for operational analysis;

Figure 11: photometer 7500 Bluetooth –palintest

The Palintest Photometer 7500 Bluetooth is a direct reading, waterproof photometer used to determine key water quality parameters for drinking water, wastewater and process water samples. Optical absorbance techniques rely on the use of Palintest (spectro) photometric reagents, producing visible colours with complex reaction analysis. The strength of the emitted colour is measured with the Photometer 7500 and the data are measured against the stored calibration data to deliver the final result.

Table 9: Operational analysis Naauwpoort WWTP

Parameters Monitored		PO_4 (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	CL_2 (mg/l)	pH
General limits		10	6	15	0.25	5.5-9.5
Naauwpoort WWTP August 2020						
Week 1	**Inflow**	84,2	5,8	9	**-**	7,7
	Outflow	1	0,2	0,05	**-**	7,5
Week 2	**Inflow**	13,8	34	0,8	-	6,98
	Outflow	6,56	35,5	0,7	0,2	7,17
Week 3	**Inflow**	18	0,2	1	-	6,98
	Outflow	20	0,06	0,7	0,33	7,23
Week 4	**Inflow**	28,25	76,7	0,8	-	7.3
	Outflow	14,29	23,9	0,4	-	7,46

Both Plants dose chlorine HTh, on week 1,2 and 3 it was not available. The safety of treated effluent at discharge on the receiving water resource was not guaranteed. It is also known that the wastewater is operating above design capacity during

summer, presumably due to the infiltration or inflow of storm water and developments around. This normally result in relatively low residual alkalinity remaining after insufficient treated effluent. Naauwpoort WWTP fails to remove Ammonia (NH_3) and Phosphates (PO_4) to the required standards.

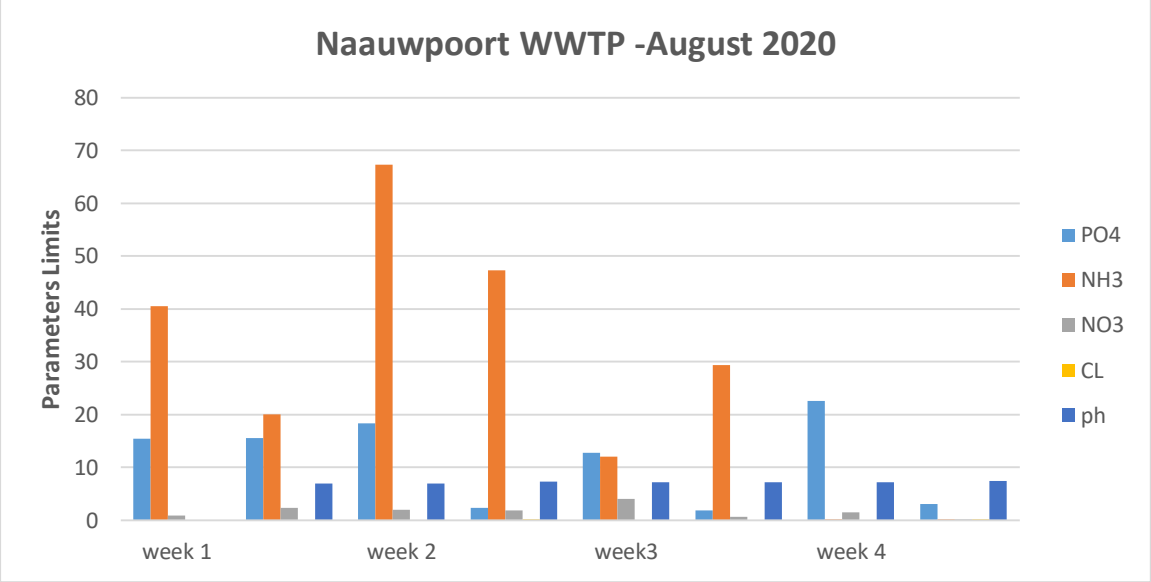

Figure 12: Naauwpoort WWTP compliance graph

Table 10: Riverview WWTP operational analysis

Parameters Monitored		PO_4 (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	CL_2 (mg/l)	pH
General limits		10	6	15	0.25	5.5-9.5
Riverview WWTP August 2020						
Week 1	**Inflow**	15,5	40,5	0,9	-	6.9
	Outflow	15,6	20	2,4	-	6,9
Week 2	**Inflow**	18,4	67,3	2	-	6,98
	Outflow	2,4	47,3	1,9	0,2	7,27
Week 3	**Inflow**	12,73	12,1	4		7,16
	Outflow	1,85	29,4	0,6	-	7,24
Week 4	**Inflow**	22,6	0,17	1,5		7,25
	Outflow	3,1	0,017	0,1	0,11	7,43

Riverview WWTP did not comply with Phosphates (PO_4) and Ammonia (NH_3) during analysis weeks. The concentrations of this two parameters was relatively high. Effluent is discharged into the Olifants River which is near the plant. The plant was also not dosing during week 1 and 3, chlorine Hth was not available. There was inflow containing oil getting into the plant, it was suspected it comes from the

industrial area. This plant is under pressure, due to developments in the area and is currently over capacitated and the treatment process retention time is not enough, resulting in poorly treated effluent at discharge.

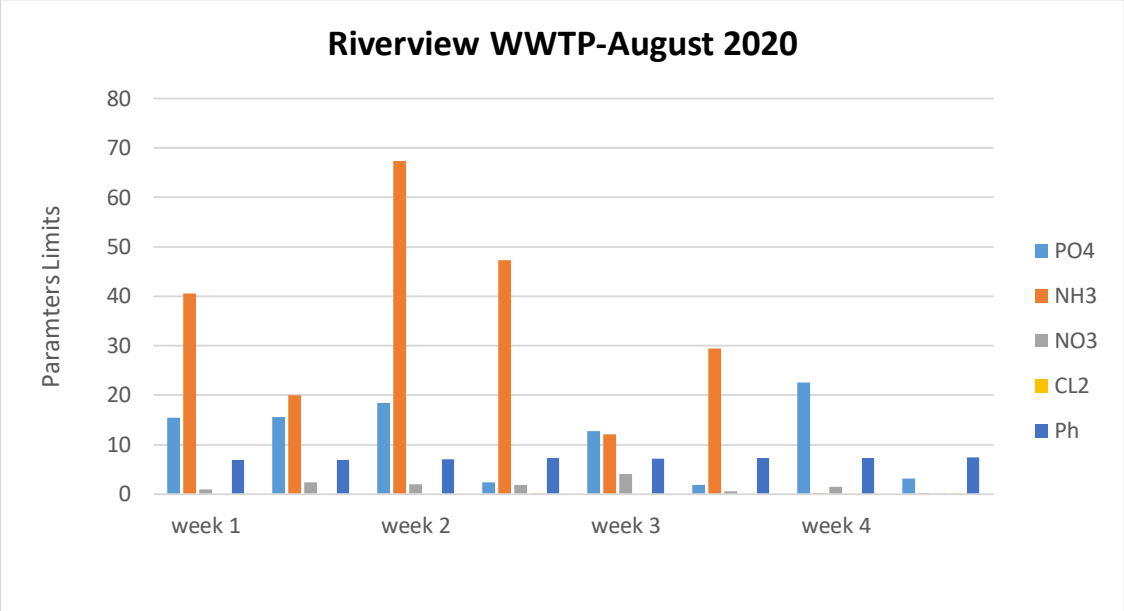

Figure 13: Riverview WWTP compliance graph

4.3 Research Question 1: What are the challenges leading to the increase of high non-compliance quality discharge into water resources?

South Africa has limited water and issue of water protection is well known. The state of municipal performance in water resources requires efforts to consider the potential risk to the nation's ability to secure water for sustainable development, as well as the efficiency of the resource itself. There are a variety of problems that underpin poor results when considering performance and compliance. The key problems are the shortage of qualified staff (skilled people), over capacitated plants, and inadequate maintenance. To date, this is a major challenge in all municipalities

Observing the data collected and reflection from this study, it can be concluded that there is a lack of commitment to comply with the Regulation 2834 for operation of wastewater treatment plant from the DWS. The municipal performance has proven this gap during both National Green drop assessments conducted in 2009 and 2011 as well in the 2014 wastewater progress assessment published reports. Below chart illustrate the performance;

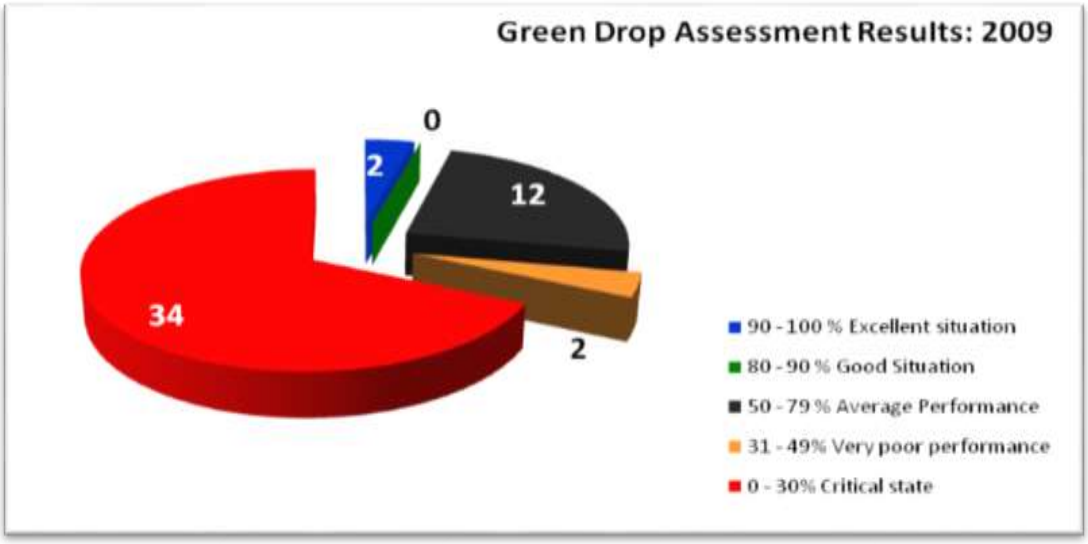

Figure 14: Mpumalanga Overall Green drop Assessment result, DWA-2009

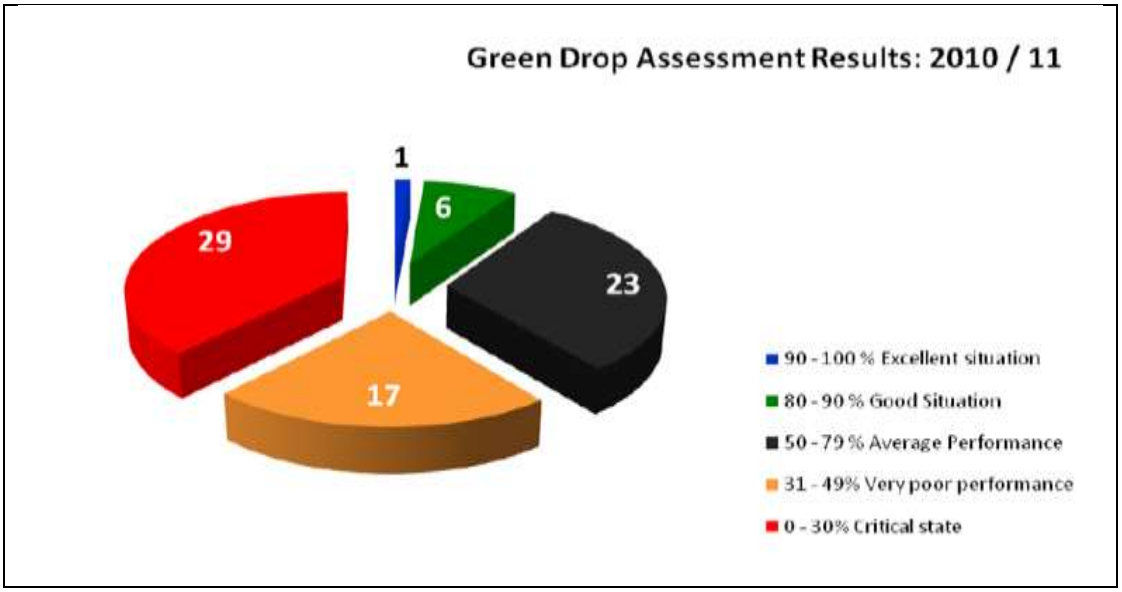

Figure 15: Mpumalanga Overall Green drop Assessment result, DWA-2011

eMalahleni local municipality WWTP's were at critical state in 2009 with 18% overall compliance and were place under supervisions in 2011 after poor performance of 45.6%. The municipality has performed unsatisfactory in both Green Drop tests, implying that the wastewater systems have not been operated in compliance with the expectations of the regulatory programme. The Green Drop criteria have not been met, in particular with regard to technical skills, reporting of performance, asset management and compliance with effluent quality.

4.3.1 Unavailability of skilled process controllers

The Green drop assessment report strongly highlighted that the shortage of process controllers is one of the factor and a requirement that subtracted scoring points on the two study works, they were under non-compliance. The National Water Act (Act 36 of 1998), Section 5 regulation requires the owner of the wastewater treatment

works to comply with the employment of the operators with expertise to manage, operate and control the waterworks. This must be done and be implemented from the date of commencement of its registration under regulation 3 of which the following must be employed;

- Supervisory process controller
- Process controllers, and as set out in schedule IV

Certificates of the staff needed for these functions shall be held by the owner of the waterworks and shall be available at all times for inspection by the competent authority.

The two study plants have 60 % of operators with no qualifications, non-registered to DWS and operates based only on experience. Lack of young people with relevant qualifications and expertise affects the compliance and operational efficiency of the plants.

In 2014, Rand Water Academy under the umbrella of Rand Water deployed qualified Process Controllers with class III, IV and Environmental scientist to assist the municipality for a period of 18 months. Municipality performance improved, however municipality could not retain the young professionals thereafter due to politics and other municipal issues.

The current operators cannot manage Green drop system in relation to updating of the plant analysis and information, taking operational analysis and optimise plant accordingly. As a result municipal continues to produce non-compliance water quality at discharge and receiving a Green drop compliance certificate will remain a dream should the programme resume.

4.3.2 The attitude and behaviour towards compliance

Attitude is characterized as a decided way of thinking about something, however scientifically it can be defined as;

A way to see life, a desire to know how and why things happen with an open mind, governed by truth. Scientific attitude is governed by factors such as intellectual integrity, collaborating and creativity.

The attitude of operators toward wastewater treatment processes and the need to comply is not their daily motivation. They do not seem to completely understand what needs to be done and what is reasonable and required to maintain an effective and consistent standard of quality. When asked, they don't know why certain treatment processes are part of the system, they only know what needs to be done about the procedure.

The nature and extent of operators" attitudes, largely, is understood easily by how they behave and act. Again the inappropriate technology and old infrastructure that is due for upgrade discourage operators and have attitude of “as long” sewage

comes in and out, which is the attitude of not caring. The attitude is again derived from the lack of training motivations from management and workshops on operational of sewage and protection of water resources.

4.3.3 Poor Maintenance and Management

Inadequate management and maintenance of wastewater and sewage treatment facilities is a serious concern in South Africa and leads to the contamination of the water supplies on which most rural areas rely for both their domestic and other activities. Currently this is becoming a huge problem even in urban areas where socio-economic is affected.

The deteriorating condition of municipal wastewater and sewage treatment facilities in South Africa is indeed one of the main contributors to the multiple contamination problems faced in most parts of the country and a significant contributor to health problems in poor communities, as evidenced by the recent Vaal sewage saga in 2019.

Plants ought to be monitored on a regular basis and changes need to be made where issues occur and repairs need to be made on an urgent basis. From the observations and remarks from the NGDA and plants operations there is an indication of lack of practice of good maintenance. All maintenance issues are reported by means of log call and by informing the superintendent of the WWTP. Challenges get resolved after few days and when it is beyond ability, municipalities outsource. This operational level of maintenance leads to poor end results, plant operations get affected and overall treatment processes then get compromised.

The NGDA 2011 report indicated that flow meters were not available to measure inflow and outflows, Therefore, the WWTP was unable to assess its load contribution to the receiving water resources, and where available were not calibrated to ensure correct flow recordings. It is a sign of ignorance from leadership and contribute to a plant treating an unknown flow.

Recommendation were outlined from the NGDA on both plants on the key performance areas that required immediate interventions, the implementation of the recommendation that require no budget (short term) were not considered, the medium and long term that required the budget were at least attended on the upgrade that resumed in 2013/2014. It was also noticed that the only criteria that municipality complied to satisfactory it was on the municipality by-laws.

The Green drop findings highlighted;

- Both studied WWTP had registered GDS data or could show any proof of submission of results to the Department of Water Affairs as obliged by legislation.
- Neither of the two systems have appropriate failure management response plans in place

- None of the structures have appropriate plans in place to construct or retain ample capacity in the collection and treatment systems.
- Ultimately, the implementation of standards and methodologies for asset management is not in place.

Naauwpoort WWTP was under renovation, which prevented a fair statement on the condition of the plant during the Green Drop assessment in 2011, and some negative results were concluded and reported during the assessment of the plant. Below are true evident of poor plant maintenance and management found;

- The inlet work was functional, but the screenings made their way into the biological nutrient removal plant.
- Grit removal was badly impaired by pump blockages (damages) and hardened grit accumulation visible in the grit canals, the Grit classifier was not working.
- Five aerators were not functioning at the Biological Nutrient Removal Facility.
- no process control available
- There poor sludge characteristics evident
- There was disinfection, but the effectiveness of disinfection was not verified
- Sludge drying beds have not been maintained and are not well managed for sludge disposal.

Figure 16: The condition of inlet area, Naauwpoort WWTP during 2010/2011 NGDA

From low scoring on fundamental green drop requirements, the condition in eMalahleni was deemed poor from a regulatory point of view as it proceeds to pose threats to human health and the environment. However, it was most promising to note that scientific (data) integrity and enforcement of the By-laws have been addressed and full credits were achieved.

4.3.4 Political interferences

The upgrade of the wastewater generally requires funding and people with expertise, this means the standard requirements must be met. As a result, sound decision of management is essential to improved municipal service delivery and, eventually, effective local governance. However, political infighting and related conflicts between the political and management elements of local government in South Africa have affected the delivery of municipal services. In eMalahleni it is very common and is a matter of concern. Contractors are then forced to work with community members regardless of the required experience.

This affects the project timeframe and delay the completion of projects. eMalahleni local municipality failed to absorb the graduates from Rand Water in 2015 after having them for a period of 18 months. Internal politics interfered the process and all was in vain.

4.4 Research Question 2: what is the impact of non- compliance effluent to water resource from wastewater treatment works?

The issue of water resource water quality weakening and polluted over inadequate treated effluent from wastewater treatment plant, and sewage spillage that finds its way into water resource is no longer a surprise. The prevention of these pollution needs to be a priority for water service providers and the society at large.

The non-compliance water problem in eMalahleni affects the community life and wellbeing. Social life and commercial growth (businesses) has been negatively impacted by the polluted water in town. The National News (2014) reported that the Naauwpoort sewerage plant in eMalahleni (Witbank) had not worked, and that was the explanation for the raw sewerage flowing into the Witbank Dam. I quote “There was a sewerage spilling into a stream that runs into Witbank Dam. The smell of sewerage is unbearable when visiting the dam”. Mobilitate.co.za has reported on record saying that not one of the Witbank sewage plants is in working order. As a result, the raw sewage overflows and ultimately flows into the Witbank Dam.

The residents of Duvha Park and Naauwpoort have also complained about stench and dirty water in recent years. A resident of Naauwpoort and a member of the Naauwpoort 2 Community Police Forum (CPF) said they had identified raw sewers on different occasions to various departments within the municipality and to councillors but had received no feedback.

"The stench is unbearable, and because Naauwpoort borders on the Witbank Dam we do water sports but it is too dangerous because of the contaminated water," she said. It also is feared that the effect of raw sewerage on fish and ecological systems would be irreversible.

The two hotels in the coal mining town have told their guests not to use tap water due to its metal and faecal contamination. Both the Protea Hotel in Jellicoe Street, on

the suburbs of Witbank, and the Protea Highveld Hotel, in the city centre, gave notices reading: "Due to the state of eMalahleni water, it is recommended you do not drink the water from the taps in the hotel or anywhere in the city. Enjoy your stay!" this was issues in Witbank news, 2014.

And, as per Protea Hotels Managing Director Mr Derick Tait, the hotel chain gave notices after carrying out tests on the water found that it was "not safe to drink." The findings revealed that the water was extremely acidic, with a pH of 2. The hotel hired a private consultant to test the water.

Residents even took the matter into their own hands and began a social media awareness on Facebook, where they posted a picture of the brown water flowing from the taps, which was met with a massive response from the residents. When Hannes Olivier's statement brings a bit of humour to the situation, “Some people pay R1 000’s for a mud bath, be grateful”. Edward van Rensburg suggested that residents should add a bubble bath, and then they won't see the brown bathwater. But Antoinette de Villiers Naude was not persuaded that this would succeed and said that the bubbles did not even cover the colour of brown.

The effect on resident’s life was totally shut down with no hope. As the annual Green Drop reports, released by the water and sanitation department, also listed most of the plants along the Olifants as being in a poor or “critical” state. This means there were high release polluted and inadequate treated effluent water more often not meeting the standard of operations.

Figure 17 : This is a picture regularly seen, white foam coming from Riverview wastewater treatment works and running into Olifants River. (Witbank News, August 13, 2014)

- **Community awareness and participation**

Only one time residents did not have to drink polluted water was when they had money to buy bottled water. Otherwise, before drinking, they had to boil tap water, the residents said. Another said they have a lot of problems around eMalahleni, and nothing has been said or done about it. The water problem has been around for a long time, and some people were reported sick because of it.

99% of the residents within the study area expressed that the issue of sewage and unsafe drinking water affected their life in a negatively way, this is evident buy the large number of respondents who strongly indicated their disappointments towards the brown water and lack of responds and action from the municipality. The overall findings on impact is clear that most residents are negatively affected and that the situations needs money to have clean water while majority of the community members are not employed .This leads to several protest and non-paying of municipal services due to lack of improvement.

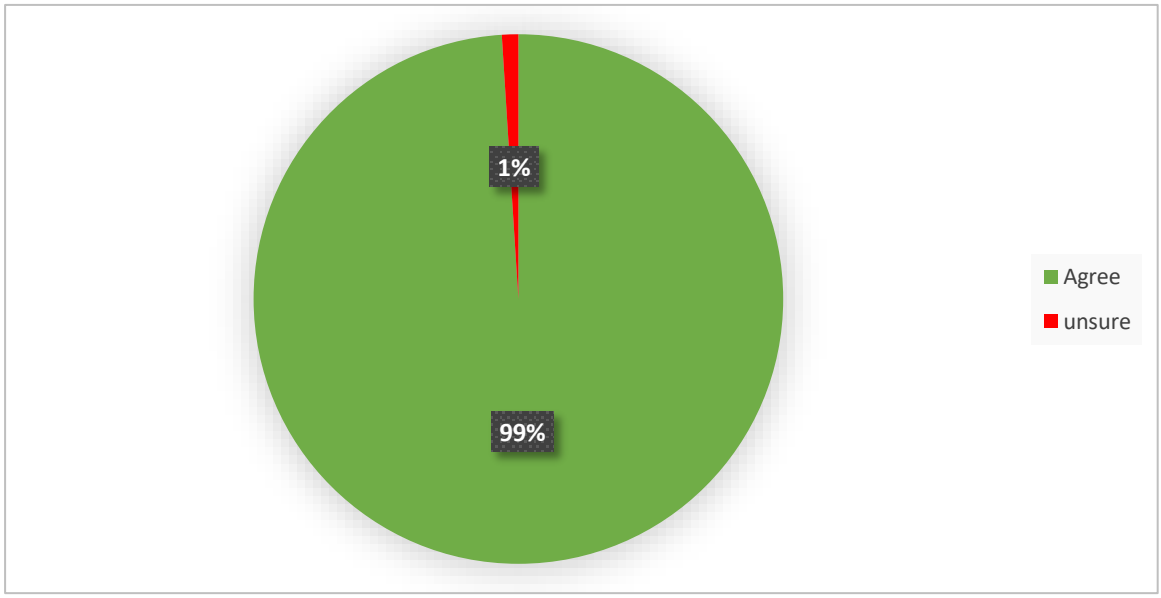

Figure 18 : General understanding of protection of water resource

In general effluent with high sewage concentration leads to Eutrophication on dams when it finds its way into the water resource. Eutrophication is the process of enrichment of nutrients and the subsequent excessive growth of plants in water bodies. It is part of the normal aging process of the lakes and accelerates human impacts. High concentrations of nutrients are the product of cultural and natural nutrient inflows. If the situation in eMalahleni is not controlled, Witbank dam will become suffocated by nutrients and result in Eutrophication.

4.5 Research Question 3: What are the challenges and issues related to law-enforcement management for effluent compliance and implementation?

The Department of Water and Sanitation is the main regulator and responsible for the administration of legislation providing for the control, management, use and conservation of water resources. Water services in South Africa is advocated by the National Water Act 36 of 1998 and Water Services Act 30 of 2004.

The regulatory department also use the National Green Drop assessment programme and Regulation 2834 that sets out compliance standards requirement for safety operations of wastewater treatment works. It ensures that society makes the best use of water resources and administers legislation on the basis of reasonable standards that are public, open, equitable and able to be enforced uniformly across a wide range of circumstances.

The legislation lays down the basis on which water is distributed for use, security and management by means of licenses that are compatible with the best interests of the country as a whole.

The objectives of the department's compliance and enforcement policy are to:

- Ensure proper control of the country's water supplies for the good of all users and of the country as a whole;
- Support and promote the conservation of water supplies and the water-dependent environment;
- include support structures to facilitate self-regulation by licensees in accordance with the conditions of the Water Resources License
- include effective and meaningful guidance for stakeholders and the broader community;
- maintain public confidence in how the state's water resources are managed
- strengthen the security of water entitlements
- Maintain continuity and transparency through the publication of the National Green Drop Assessment of Wastewater Works

4.5.1 Compliance and enforcement challenges

The word "compliance" refers to compliance with legislation and/or licensing requirements, while regulation refers to the use of legislative powers to ensure compliance with the law (Commercial law, 2016). The studied municipality showed that budget and lack of commitment are the major factors amongst others things that hinder compliance and implementation. The collected data from the national assessment (NGRA) outlined areas which required immediate intervention, however the municipality failed to comply.

There are several mechanism in place from the legislative that are made public and available to all municipalities and relevant stakeholders to ensure efficient and acceptable approaches to compliance and regulation which assist to enable on most

appropriate response in a situations where water resources is being polluted and degraded. The following mechanism are being used to promote compliance with regulations or conditions of license, including but not limited to;

- General information about legislation
- Formal Warning
- Informal warning
- Issuing of fines
- Directing compliance and prosecutions
- Cooperative assistance and collaboration

Above all this mechanism is totally ignored by the municipality, and most plants including those of this study were found in critical condition and needed serious intervention from the management to implement all the recommendations made during assessments. The Study Plants performed poorly on the criteria of the Green Drop Certification Program during tests and audits. The municipality had scored very low and the assessment regulatory Impression endorsed the Municipality performance unsatisfactory during the Green Drop evaluation, showing that the wastewater facilities are not handled in compliance with the expectations of the regulatory programme. A dedicated team of management is required to enforce the laws, standards and other major decisions that needs serious interventions.

4.6 Residents Questionnaire

Interviews were conducted using a house to house strategy by the researcher, to residents who reside close to the study wastewater treatment works in eMalahleni. 20 residents participated and requested to be interviewed in the comfort of their own homes. This sampling population method was used to get close response to determine the impact, see below table;

Table 11: sampling population for questioners

Age group	25-30	31-37	38-43	43-50+	Total
Female	3	3	6	1	13
Male	1	3	1	2	7
Total	4	6	7	3	20

The above residents gave the researcher a close response of the impact and the water situation of eMalahleni. Below is a summary of the close responses and questionnaires

Table 12: The interview questions

Questions	Yes	No	Not sure
1. Do you know of raw sewage spillage into the Witbank dam?	12	2	6
2. Has the brown water affected living set up?	20	0	0
3. Can you consider water condition bad in eMalahleni?	20	0	0
4. Do you think the sewage spillage is caused by the old pipelines and infrastructure?	9	11	0

4.7 Conclusion

The Green Drop requirements are not met by both wastewater treatment works, In particular, with terms of the technical skills, submission of results, asset management and compliance with effluent quality. A significant reference point for eMalahleni Green Drop scores is noticed when compare with the 2009 GDS status and 2011 GDS. Despite positive developments in the upgrade of the Naauwpoort WWTW plant, the situation in eMalahleni is considered to be unstable from a regulatory point of view as it continues to pose risks to public health and the environment (reference: unacceptable conditions found during site inspections , NGDA;DWA 2014).

The Municipality found that it was not able to stop and correct the possible risks at studied wastewater treatment plants in the overall evaluation of the Municipality. Both plants were in high-risk positions and were expected to move into critical risk areas during the next Green Drop cycle, if decisive action and appropriate resources are not applied to specific issues affecting performance.

Both studied plants surpass the design capability, which has an impact on the plant's ability to meet the effluent quality discharge requirements. When treatment works operates above the capacity, retention time is likely to be low therefore settlements on treatment processes is not occurring properly, and result in inadequate treated effluent.

The impact of the quality of the partially treated water affects everyone within and around the community, water resource protection is then compromised and unsafe drinking water is provided to the society. The residents are not happy with the condition of the water crisis in eMalahleni, the responds from the residents shows the loss of hope and that they take each day as it is than to dwell in the water problem situation. It also became clear that resident’s attitudes towards water resource protection are governed by ecocentric environmental values. The poor management approach within the municipality affects the success of the plants.

PART 5: DISCUSSION

5.1 Wastewater treatment plant operations

The wastewater treatment plants are situated in eMalahleni Local Municipality, they are both managed and operated by the municipality. These wastewater treatment plants are operating over the design capacity and are Biological nutrients removal treatment process that removes Ammonia (NH_3-N), Phosphate (PO_4) and Nitrates (NO_3-N) and generate sludge that require disposal of and maintained well. The final treated effluent is then discharged into streams that feeds water resources on both plants. Produced sludge is desludged to drying beds and later re-used as lawn compost to farmers and other is stock piled at the plant.

- **Treatment processes**

Treatment processes require three phases of primary, secondary and tertiary treatment. The primary treatment consists of keeping the sewage temporarily in a quiet reservoir where heavy solids can settle down to the bottom while oil, grease and lighter solids float to the surface and the sludge is removed to the digesters.

The secondary treatment occurs at the BNR which consist of three compartments namely, Anaerobic, anoxic and aeration zone. This is the process of removal of nutrients that pose negative impact to the water resource when discharged at high concentration. Nitrification and Denitrification process take place in this treatment stage, where Ammonia is converted to Nitrite later into Nitrate and Nitrate to Nitrogen gas that is later released to air. There are bacteria at each compartments that perform the conversion.

Effluent from secondary settling tanks is disinfected before discharge, the municipal use chlorine chips as disinfectant. This occurs at tertiary treatment process.

- **Water Quality Monitoring**

As a requirement from the regulator in charge for every wastewater treatment plant to monitor, record and update the water quality produced. Naauwpoort and Riverview wastewater treatment works has two monitoring programmes, operational and monthly quality compliance. Operational monitoring is done on selected treatment processes to monitor the operational efficiency of the plant, while monthly monitoring is for overall treatment works compliance. Effluent from inlet and effluent are collected once a month and are sent to an accredited laboratory for analysis. Parameters monitored is Ammonia, Phosphates, Nitrates, COD, pH, Electrical Conductivity, Suspended Solids and Chlorine.

This two plants further partake in the PAT assessment conducted by the regulator department where physical and conditional of the treatment works are evaluated along with the quality of the treated effluent. This exercise from Department of Water

and Sanitation is mainly conducted to encourage the municipality to comply and meet the standard operation requirement of Green drop.

5.2 Challenges Revealed

Several challenges were exposed during the study, moreover presented from the National Green drop assessments and PAT assessments conducted at this two study treatment works, as well from the current plant conditions. Below are the challenges found;

- Unavailability of process controllers with expertise
- Flow measurement not available and where available are not calibrated for accurate readings
- Lack of Green drop requirements enforcement
- Poor housekeeping
- Poor maintenance
- Non-compliance of effluent
- Lack of commitment
- Non-registered operators with the Department of Water and Sanitation
- Plants operating over design capacity
- Budget
- Exposure to risk

5.3 Resident participation and concerns

The residents were welcoming and assisted the researcher during the household interviews, majority indicated that they are totally not pleased with the condition of water in eMalahleni. They also highlighted that they can no longer enjoy being in Witbank dam due to pollution rising from inadequate treated Wastewater treatment effluent and spillage of sewage that finds its way into the dam.

They indicated to have more concerned on the business I quote “the issue of water is affecting local businesses, hotels around are affected due to customers not having safe drinking water during their stay” they believed that the water problem would have been better should the municipality contained the deployed water specialist from Rand water in 2014.

This issue is not unique, eMalahleni residents are still getting unclean water on a daily basis "Most people are unemployed and have to surrender and consume the water and use it for their daily house chores." said one of the resident.

It is also noted the brown water colour is causing a huge financial stress to residents as they believe to bath with lots of foam bath to cover the brown colour, however it is something that not all residents believe can solve and avoid the problem, once more not every household can afford. They further indicated that the water protection awareness campaign to residents can assist in educating on water pollution

prevention and care for water as a whole. Ms Clarissa du Plessis, who resides on the banks of the Olifants River, decided to make her voice heard in an effort to save the water resource. She orchestrated meetings and got several role players around the table to discuss and debate the fate of the river. The Department of Environmental Affairs were amongst the roles players on these meetings and she pointed out that the culprit was the Riverview Waste Water Treatment Works upstream of R555 Bridge (Witbank News, 2014)

5.4 Conclusion

The study was conducted and limited to eMalahleni local municipality, two wastewater treatment plants were selected and they are both discharging into water resource and cause pollution. The bottom line is that compliance stand as a huge challenge in all municipality and eMalahleni is one of them. National green drop assessment and the condition assessment of this study indicates same challenges that requires immediate interventions by the municipality. The pollution is no longer only the problem of eMalahleni residents but of the nation as one has to rethink when being and want to visit the coal town on their water status.

PART 6: Conclusions and Recommendations

The study results revealed municipality is not keen to adhere to the green drop requirements of safe operation of sewage works, the conditions of the two study wastewater treatment works has certified it. Section 24 of the National constitution states that “everyone has a right to the environment that is safe to their health and wellbeing and to protect environment that is beneficial for present and future”. The surrounding environment is polluted, the water is not in a healthy condition people and aquatic life to consume or use, therefore this section is violated.

Water consumption has grown more than twice the rate of population growth in the last century and the demand for it is high. Thus it becomes everyone’s responsibility to conserve this limited resource in order to control pollution and protect our ecosystems. The law requires water users (this includes farmers, communities, companies, and businesses, water users associations, water services providers) to register with the responsible authority(DWA) and release clean water that must comply with given license wastewater limit values before release into water resources .

The following recommendations are stimulated from the findings and challenges of the study as well the recommendations from the residents. They need to be adhered, considered and implemented for the wastewater treatment plants to comply and meet the standard requirements;

- An upgrade of both wastewater treatment work to capacitate the current flow
- Registering of operators with the Department of Water and Sanitation for process controller classification. This is one of the standard requirement from Regulation 2834 that all personnel operating wastewater treatment works must be registered and their certificate must be displayed on the open space for regulator to see during the assessment period.
- Installation of flow measurements on both inlet and outlet channel, for accurate flow measurements.
- Employment of process controllers with expertise to operate and manage the plants.
- Constant update of monthly analysis result on Green drop system
- Effective monitoring and maintenance of the wastewater plants, this will assist in good operation and operational efficiency of the works.
- Community awareness of wastewater and impact on water resource, this can be exercise quarterly to residents, and can help to develop duty to care perspective over clean running water from burst pipes and spillage of sewage on street. Residents will have more understanding of water protection as a whole.
- Annual update of Asset management, W_2WRAP and Operational Manual documents of plants.
- Implementation of maintenance logbook

- Implementation of operational weekly meetings and monthly compliance meetings.
- Wastewater treatment training courses for current operators to enhance the knowledge of operational processes.
- Implementation of Quarterly municipal water and wastewater quality update on Witbank News to provide the residents with status.

The following **overall Risk management process** must be implemented for effective operations;

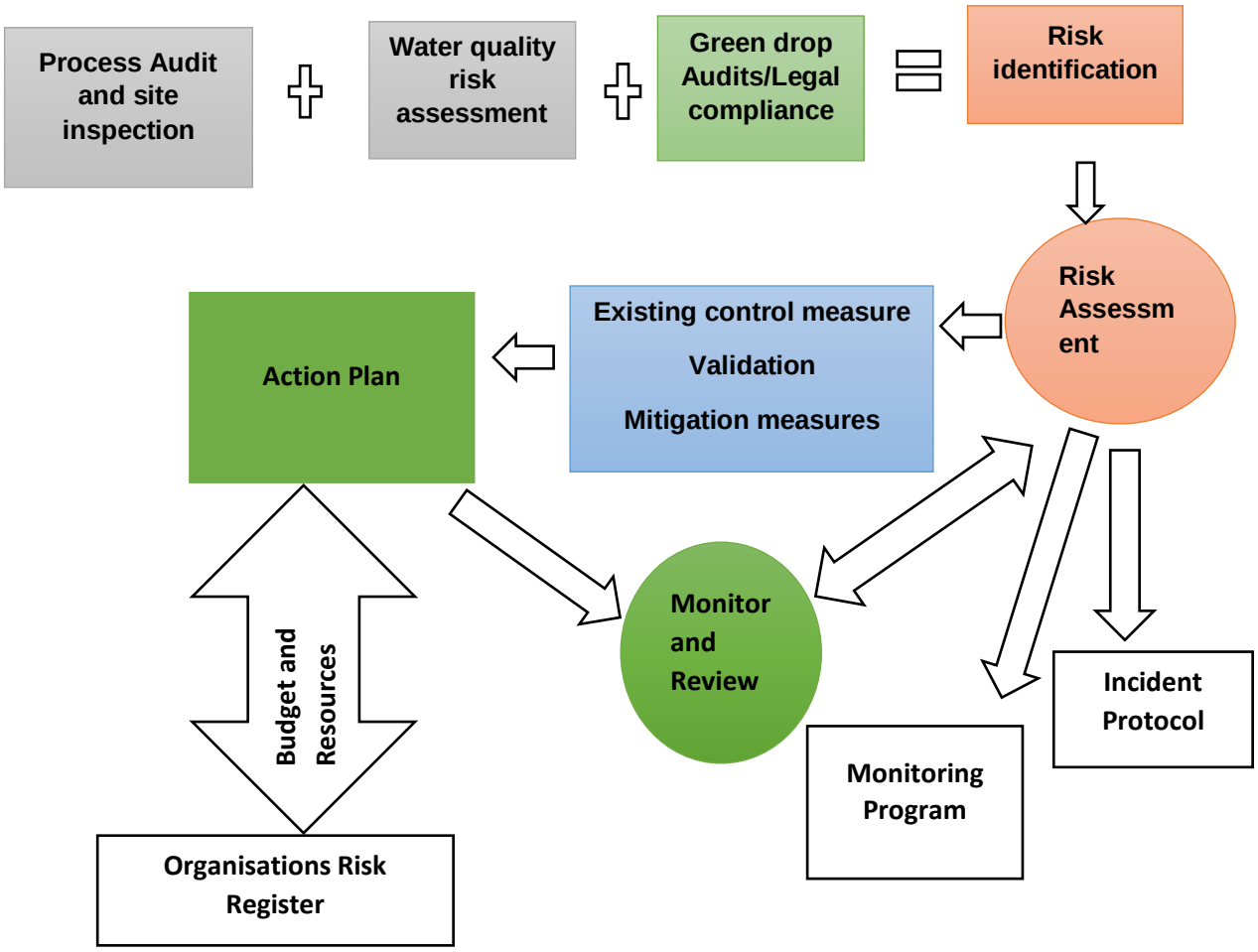

Figure 19: Risk assessment flow diagram

Should the above overall risk management process not be implemented and not considered and the non- employment of people with right expertise, together with monitoring and maintenance of the wastewater plants amongst other required factors persist and without effective motivation, complying effluent at discharge will not be successful and will remain a dream.

A Failure to take care of the environment, affects water resources, the biodiversity within and the human being. It is an offense and directives can be awarded to the Municipality.

In closure, water is a natural resource that needs to be managed, conserved, and controlled for current and future generations. Everything and everyone needs water.

The world water is divided as follows, is 97% saline, and 3% is fresh water, South Africa is a water scarce country and availability and quality of this resource is deteriorating rapidly. The South African government had to sign international agreement with Lesotho to bring water into the Vaal Dam, therefore protection and prevention of water must be fully practice.

The failure of municipality sewage works on compliance pollute the water resources and affect water quality , a negative impact to residents is occurring , should the non-compliance continue and the recommendations not done as stipulated from the Green drop assessment and residents a significant threat to public health will be experienced. The above recommendation are important and will assist municipality wastewater treatment works to comply and water situation in eMalahleni can improve.

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