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ASSET MANAGEMENT IN THE WASTE TREATMENT ENVIRONMENT

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Abstract

The main aim of the research study was to determine what drives the asset management inadequacy in the waste-water treatment utilities, as to ascertain the main drivers of the equipment failures are, and whether the maintenance strategies respond or are adequate to deal with the failure rate of equipment in the waste-water treatment utilities. The environmental impact driven from the non-compliant final effluent discharged into the water resources in the country resulted from the equipment failures in the plant. The maintenance strategies, asset policy, asset management plan, including the rehabilitation programme and all statutory regulation compliance are evaluated and analysed to ensure they are responding or aligned to the growing challenges faced by the waste-water treatment environment. Using the quantitative approach, the three groups; the asset management team, quality and process team and operations team of participants were to be selected. A convenient approved sampling method, the survey questionnaire was electronically shared to respond to the Covid-19 restriction and the structure telephonic interview so ascertain the level of understanding of the current asset management strategies, policies and procedures, the equipment failures impact to the utilities compliance and the further corporate risk and environmental impact from inadequately manages waste-water treatment utilities. The findings confirms that there is indeed lack of the synergies in the waste treatment environment emanating from a few aspects i.e., lack of due diligent in the application of maintenance strategies in the waste treatment works, lack of in-depth understanding of the impact from equipment failures in the waste treatment process, and the misalignment of the rehabilitation program, leading to gross environmental impact and corporate

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risk. It was further recommended the collaborations in the maintenance strategies development and review process. The rehabilitation programme should be aligned to the requirements of the process

Keywords: *Asset management, waste-water treatment utility, water works, wastewater works, environmental impact, corporate risk, Rehabilitation programme, non-compliance*

1. Introduction

The urban water systems are the valuable part of the public infrastructure, worldwide utilities and municipalities are entrusted with the responsibility of managing and expanding them for current and future generation (Alegre and Coelho, 2013). Alegre and Coelho (2013) also state that, the infrastructure asset management of the urban infrastructure is the set of processes that utilities need to have in place in order to ensure the infrastructure performance corresponds to service targets over time. This is also done to ensure risk management, which ensures the cost correspondence to the lifetime cost perspective are as low as possible. The status of wastewater treatment plants all around the world is currently a challenge. An increasing number of studies are showing that lack of maintenance leads to progressive deterioration of equipment, leading to failures, environmental and social impacts (Hernández-Chover *et al*. 2019).

Many developed countries have shown an increasing concern about the condition of urban water infrastructures, and particularly wastewater treatment facilities. It has been observed that many of them exceed their useful life (Hernández-Chover *et al*. 2019). Wastewater treatment is essential to protect human health and ensure environmental sustainability (COI/UNESCO, 2011). The waste-water system does not develop linearly; rehabilitation may be necessary at earlier stages. Therefore, condition state is estimated to determine which parts of the waste-water network need rehabilitation (Giessler, 2017). The two key priorities need to be understood and addressed up-front by a municipality when creating infrastructure for supply services (Coetzee, 2011).

Wastewater treatment infrastructures are subject to a process of ageing and continuous deterioration (Hern´andez-Chover *et al.* 2019). The water sector demonstrates that more efforts are put in place in the provision of portable water infrastructure, thus ensuring water provision, but the whole value chain is incomplete until the same efforts are placed on the waste treatment thereof. According to CIRS (2019) the reasons for some of the works that are producing effluent that is little distinguishable from the raw sewage that flows into the works include one or more of gross under-budgeting by the municipality for wastewater maintenance and managers who have insufficient understanding of the technology of wastewater treatment.

The past neglect of a treatment works has in some cases been a primary contributor to current under-performance of some older works, but other relatively new works stated by CSIR and CIDB (2007).

CSIR and CIDB (2007) argue that although budgets remained inadequate, instances were found where it is appreciated that expenditure on infrastructure maintenance can save

other expenditure many times over (for example by reducing water losses), and can also reduce the risk of system failure Municipalities range from those that are facing up to the challenges of maintaining infrastructure in a transformational environment, to those that appear to be unable even to make the attempt, because of inadequate resources, or simply lack of will (CSIR, 2007). This study seeks to provide clarity to the research problem as the following research objectives has emerged to ascertain inadequacy in asset management of the waste treatment utilities, the main drivers to the challenge and the impact it has in the environment, human health and the corporate risk exposure of the organisation concerned.

The following were the research primary objectives of the study.

- ✓ To assess factors leading to inadequacy of maintenance in the waste-water treatment facilities.
- ✓ To evaluate the infrastructure rehabilitation strategies alignment to the asset failure rate of the waste treatment environment
- ✓ To evaluate the corporate risk and ensure priority alignment with regards to the waste treatment utilities

2. Literature review

2.1. Theoretical framework

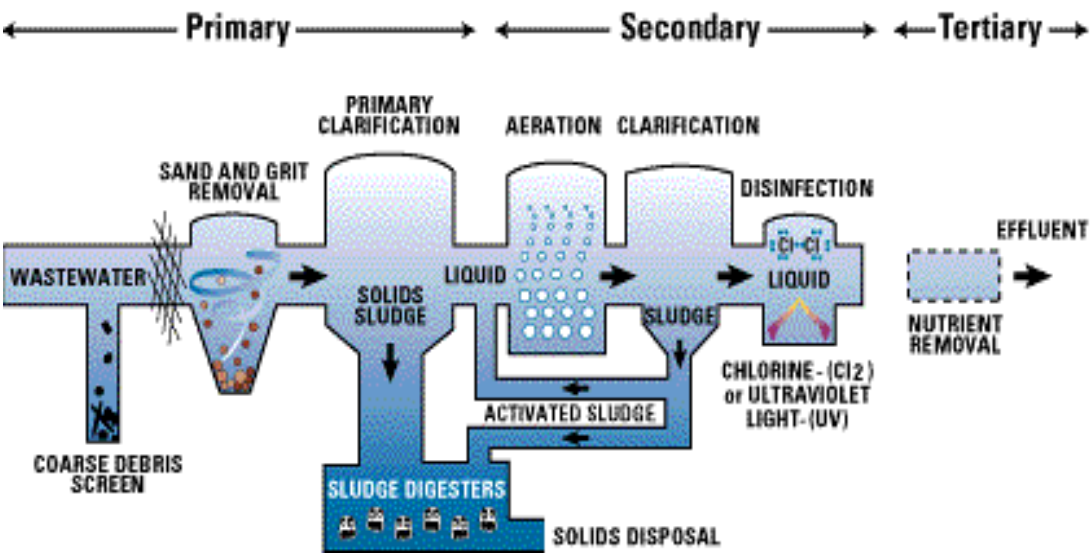
This section presents the discussion of the literature review with regards to the asset management in the wastewater treatment environment. It will also look at what led to inadequacy and mismanagement of the systems in the sector. There seems to be a growing concern in the state of the asset management for the wastewater treatment utilities. This growing trend has raised questions as to what leads to the noted inadequacy. Many researchers have tried to understand the concerned issue, due to the impact the phenomenon poses into the environment and the health especially in the urban society. This challenge has not yet been properly identified to the either infrastructure or the management strategies or even the skills capabilities employed in the system.

According to Vinz (2020) the theoretical framework defines the concept in the research, proposes relations between the concepts and discusses relevant theories based on the literature review. This chapter proposes a theoretical framework that serves as a base for the proposed research study. This framework is important as it is part descriptive for the quantitative case study to further assist the outline: theories, philosophies, and methodological techniques of the study (Thornburg, 2000).

Waste-water treatment process and related asset

According to Nicolette (2017) Wastewater treatment involves four main steps: Primary treatment, Secondary treatment, Anaerobic Digestion, and the Disinfection phase. The wastewater treatment process is outlined in Figure 1 below:

Figure 1: Wastewater treatment process (Picture by Nicolette. 2017)



Wiggam (2019) writes that wastewater treatment process begins at the head of the plant where the incoming wastewater from the city's sewer system is directed through the cylindrical fine screens. Wiggam (2019) further explains the link of asset to the process that the asset management comprises of five core components: Assets, Service level, Criticality, Life cycle and Funding. They further add in saying that the asset involves making a complete list of assets in the system and each asset to have documentation including name brand, serial number and models number, size pumps, horsepower motors and notes on replacement or maintenance on the asset.

Shaw *et al.* (2015) attest to this and say the wastewater reticulation network comprises of gravity sewer mains: manholes, customer literal connections, pump stations and associated rising mains with the inspection points. Dec.ny.gov. (2015) also add and say the municipality sewer consist of units' processes that have various pieces of equipment used to convey flows through the facility and aid in the removal of pollutions, and as mechanical equipment age and wear, it is increasingly prone to reduce performance and failures.

Wastewater treatment plant asset may include the following equipment that may need maintenance, health, and upkeep: primary and secondary and tertiary treatment units, disinfection equipment, pumps, blowers, buildings, electronics components (control systems), equipment and materials (dec.ny.gov. 2015)

2.2. Empirical Framework

The key concepts or variables of the study are defined in this section below.

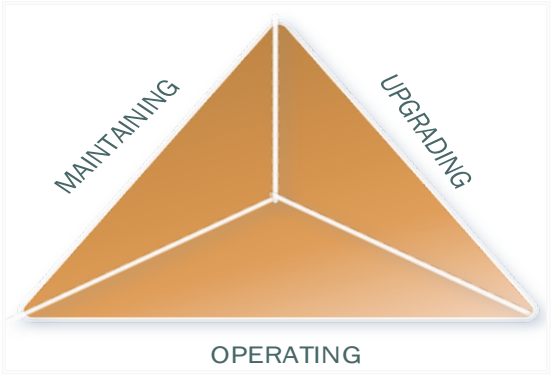
2.2.1. Inadequacy of infrastructure asset management in the wastewater treatment utilities.

EPA.gov. (2019) state that asset management is a process in the water and waste-water utilities that is used to make sure the planned maintenance can be conducted and capital asset (pumps, motor, pipes etc.) can be repaired, replaced, or upgraded on time. Komljenovel *et al*. (2016) attest to this, that the asset management strategy is composed of the array of interacting and interdependent activities and constituent elements within a multilevel structure. Komljenovel *et al*. (2016) continue in saying it is necessary to develop a holistic model for the asset management strategy that identifies and captures key consistent elements and influential factors as well as their relationship.

Alegre and Coelho (2012) also add to this notion by defining the Infrastructure Asset Management (IAM) of the urban water and waste infrastructure being a process that the utilities need to have in place in order to ensure the infrastructure performance is in line with the targets. Amaral *et al*. (2017) share the same notions that advanced urban water infrastructure management such as asset management has been suggested as the key factor for achieving adequate and sustainable level of water service in the long run. Alegre and Coelho (2012) further elaborate that the urban water systems are the valuable part of the public infrastructure. Worldwide utilities and municipalities are entrusted with the responsibility of managing and expanding them for current and future generation.

This is the practice to manage the infrastructure capital assets that minimize the total cost of owning and operation of the assets while delivering the desired service levels, asset management to pursue and achieve sustainable infrastructure (EPA, gov. 2019). While Tafazzoli (2017) also adds that quality infrastructure is an indispensable element of development for all countries. Figure 2 below illustrate the three dimensions of asset management according to Tafazzoli, (2017).

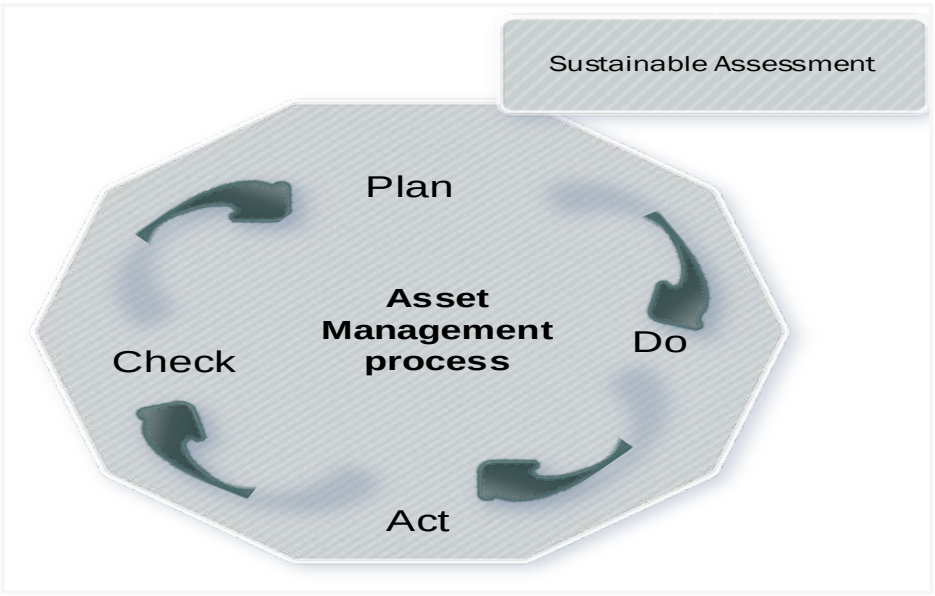
Figure 2. The three pillars of the asset management (Tafazzoli, (2017)



A quality asset management and maintenance program is a crucial part of the basic operation and maintenance needs of any facility regardless of the industry (Wiggins 2019). Mohammadifarli (2019) also notes that sustainability assessment tools are needed to project the performance of the assets onto their future life expectancy. Mohammadifarli (2019) outlines the sustainability assessment process for the

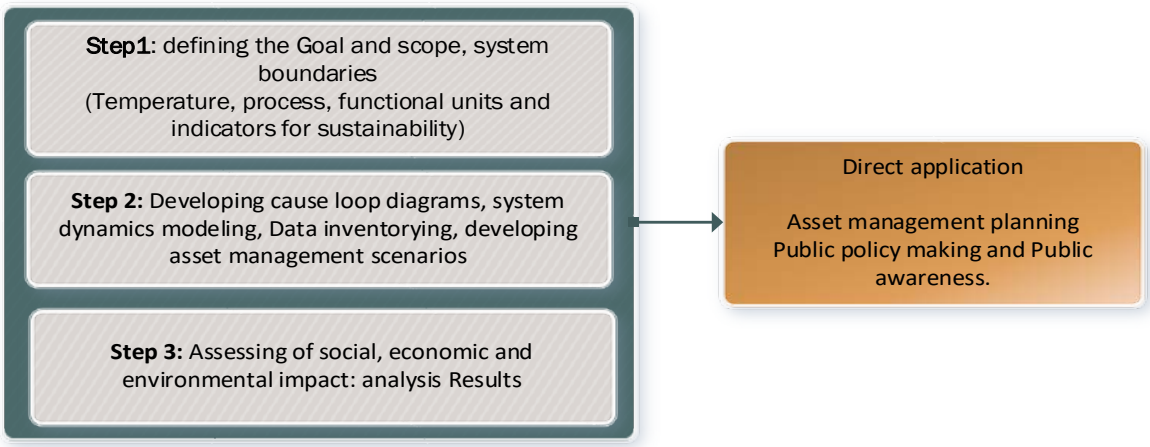
International Organization for Standardization (ISO) 55000 asset management framework, see Figure 3 below by Mohammadifarli (2019).

Figure 3: the proposed sustainability tool in ISO 55000 asset management framework (Mohammadifarli (2019)



Mohammadifarli (2019) further presents the conceptual framework below in Figure 4, for conducting the sustainability assessment of the water infrastructure asset management plans which consist of three iterative steps like those in ISO14040(2006).

Figure 4: Framework for the LCSA of water and wastewater asset. (Mohammadifarli 2019)



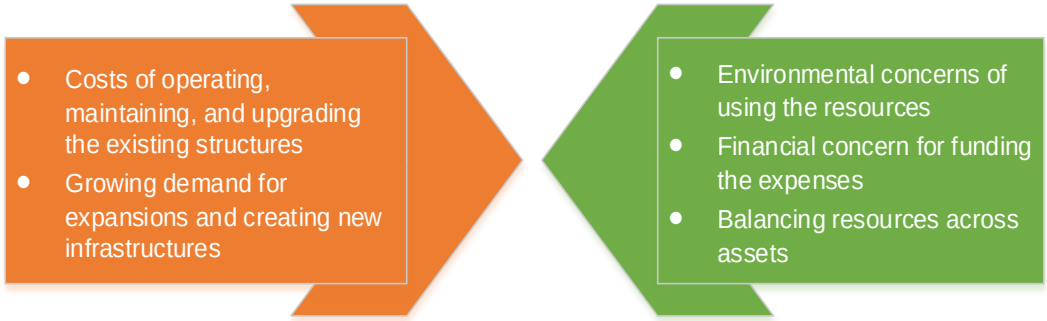
The above conceptual framework on Figure 4 would be adopted when conduction the asset inventory in the treatment utility for further analysis of the gaps in the asset management strategies, the asset care plans and maintenance schedules to deal with the inadequacy in the asset management for the wastewater systems.

2.3. Environmental and Social Impact

Edokpayi *et al*. (2016) explain that the surface water is one of the most influenced ecosystems on earth and surface water alterations have led to extensive ecological degradation such as a decline in water quality and availability. Water quality is affected by both natural processes and anthropogenic activities. They continue saying; in South Africa like most other developing countries in the world, surface water is usually used for domestic, recreational, and agricultural purposes mostly in the rural areas. Pollard *et al*. (2016) points out that without appropriate management, whether for municipalities supply, agriculture, industry, community development or maintenance of sustainable environment, we risk over-exploiting and contamination of our planet's most precious resources.

Bloganica (2017), further explains that treating wastewater is a process that helps protect our planet and all the creatures living in it. This is also supported by Hao *et al*. (2019) that the conventional wastewater cleans wastewater and minimizes water pollution, but on the other hand, there has been environmental impact that has been highlighted in the construction and operation of the WWTPs.

Figure 5: Demand for new infrastructure and challenges to meet them (Tafazzoli, (2017)



According to Wiggams (2019) without an established asset management and maintenance plan in place, organisations risk underutilizing their existing asset, overspending on maintenance and repair cost, and significantly reducing asset life expectancy. Wiggams (2019) also adds in stating that the United States Environmental Protection Agency (EPA) mentions that many utilities struggle to operate, maintain, and improve systems and infrastructure assets installed a decade ago. That uncertainty

about the location and condition of infrastructure asset and lack of comprehensive planning often led to a reactive approach to maintenance.

Kumar *et al*. (2017) note that India faces major environmental challenges associated with waste generation and inadequate waste collection, transportation, treatment and disposal. They further explain that the country's systems cannot cope with the volumes of waste generated by an increasing urban population, and this impacts on the environment and public health. Development of high-quality infrastructure that meet the needs of the people and protects the environment is fundamental to achieving effective economic growth.

2.4. Corporate Risk

Myers (2020) writes that corporate risk refers to the liability and danger that a corporation faces. Myers (2020) further states that the job of corporate risk management department is to identify the potential source of trouble, analyse them and then take the necessary steps to prevent losses. Risk management is the set of procedures that minimises the risk and cost for a business (Myers, 2020). Chen (2019) added that the company risk is the financial uncertainty faced by an investor who holds securities in a specific firm. Chen (2019) continues with the notion that risk takes many forms but is broadly categorised as the change in outcome or investment and actual returns will differ from expected outcome or return.

Hrudey *et al.* (2006) explain that risk need to be managed as managing risk is an essential business requirement across the process and utility sector, from embedding good corporate governance within the organisation through to the management of individual projects and asset. They continue and elaborate about the ability to understand and assess the risk and to implement preventative measures to improve control of risk. While Premanathan *et al.* (2018) believed that accelerated physical asset operations in organisations are necessitated in order to sustain within the competitive business environment. Hrudey *et al*. (2006) talks about the risk associated with water and say amongst other risk associated with drinking water is the environmental risk. That the equipment failure or human error can lead to adverse environmental impact including waste discharge to the atmosphere. Hrudey *et al.* (2006) continue and add that the benefits of good corporate risk management should achieve the preventative management of the said risk through the business.

Asset management practice leads to an overstatement of the company's asset value, not claiming as much depreciation as the company is entitled to and the company over-paying property taxes (Merna and Al-Thani, 2008). The steps involved in the defining and measuring the risk incudes; a) defining "Bad" by identifying the objectives of an organization and the resources that are threatened, b) Identifying scenarios whose occurrence can threaten the resources of value, c) Measure the severity or magnitude of impact.

Bowden (2002) notes that management of risk is a factor that is often overlooked in establishing sound fiscal procedure. He continues and argues that a strategic risk assessment, expressed in easily understood financial terms can be an effective tool when applied to cost effective management of asset.

Copperleaf (2017) supports the above and states that many utilities are looking to recent developments in asset management best practices, most notably the new ISO 55000 standard. They further explain that the essence of this standard is to ensure the right things are being done right thus further support the organizational strategies. Therefore, organisational hierarchy that exist even within the organisations requires that risk is actively managed at the strategic, programme and operational levels of the organisation (MacGillivra *et al*. 2006). Operational risk can result from unforeseen and/or negligent such as a breakdown in the supply chain or critical error overlooked in the manufacturing process (Chen, 2019).

2.5. Conceptual Framework

A conceptual framework is a structure which the researcher believes can best explain the natural progression of the phenomenon to be studied (Adam *et al*. 2018). Grant and Osanloo, (2014) adds to the notion and say the conceptual framework assists the researcher in identifying and constructing his/her worldview on the phenomenon to be investigated.

This study seeks to uncover the reasons behind inadequacy in the asset management of the waste treatment utilities. To understand the key drivers as to what variables, play a major role when decisions are made in terms of asset management in the wastewater utilities. The following variables will be analysed using the collected data to ascertain where the failures are, and where the gaps are in the process of asset management in the plants.

Asset strategies

- ✓ The inventory managements
- ✓ Risk assessment and management
- ✓ Rehabilitation and overhaul plans
- ✓ The asset policy
- ✓ The asset care plans

The three concept as covered under the theoretical framework will be closely looked at and further analysed to ensure the gaps are clearly understood and measures can be put in place to mitigate.

Umgeni Water asset management plan, (2019) avers that the physical asset policy framework also provides for a strategic and systemic approach to asset management that optimises service performance. It also provides for the useful life of an asset based on regularly maintaining assets to the asset management strategy and asset management plan.

Wastewater treatment effluent or discharge is the final product from a wastewater treatment plant. Due to the Federal Clean Water Act, the requirements for the treatment of the water are set on a plant-by-plant basis determined by the National Pollutant Discharge Elimination System (NPDES). Most of the effluent is discharged into a body of water, however, it also has its uses. There seems to be several factors starting from lack of skills in management of the utilities, lack of interest by the authorities and financial investment being channeled to the revenue generating businesses rather than environmental resource preservation.

3. Research Methodology

As indicated in the abstract, this research study to determine the reasons for inadequate asset management that exists in the waste treatment environment using a quantitative research approach. Jointly with the existing data in the form of past trends and asset care plans were acquired as secondary information, to further assess the level of planning towards the phenomenon. Quantitative research is expressed in numbers and graphs and analyzed through statistical methods (Bhandari, 2020).

Liberty (2019) further adds that quantitative data analysis deals with quantities and hard numbers and it relies on the ability to accurately count and interpret data based on hard facts. The author continued to explain that there are three types of data analysis method for the quantitative research: a) regression analysis, b) Hypothesis testing and c) Monte Carlo simulation. Therefore, the use of survey questionnaire as a technique to collect data from the correspondents were deployed to ascertain the view of responses as to may have led to the existing phenomenon in the water treatment environment. A minimum of two water boards and two water treatment service providers were approached for data collections using unstructured questionnaires. This enabled a better insight as to why there are inadequate asset management strategies when it comes to waste treatment utilities.

Furthermore, a combination of Hypothesis testing and Monte Carlo simulation were adopted. The survey questionnaire was designed to ensure relevant information is extracted. The data were then analyzed through textual analysis including both thematic analysis and to some extent the content analysis. Every secondary date was analyzed for legitimacy through confirmation and approvals, to ensure a clear understanding of the content is obtained. The data that were collected through secondary platforms were thoroughly analyzed for any missing text or content.

3.1. Ethical approach (Informed consent)

All research correspondents gave their permission to be part of this study and were given pertinent information to make an “informed” consent to be included in the study. In addition, all necessary forms were issued to all participants prior to any engagement to ensure they are fully aware of the topic and nature of the research.

The informed consent that was part of the participants group to this research study in the Umgeni Water were as follows

- ✓ Systems Managers for the Water treatment and Waste-water treatment plants
- ✓ Maintenance Engineer for the Water treatment and Waste Treatment plants
- ✓ Waste-water treatment Plants' Superintendents
- ✓ Water and waste-water maintenance Foreman
- ✓ Process and Quality manages
- ✓ Process and Quality Engineers

This research was treated as a private and confidential interaction; thus, all sensitive information was treated with extreme caution to ensure participants are not exposed to harm through the information shared. The research report is a controlled document to ensure ultimate access monitoring. It is imperative that the ethical considerations to human and social responsibility are exercised throughout the research. To further ensure compliance with university policies and procedures, an ethical clearance certificate was obtained from UNISA-SBL Ethics committee before or prior to all necessary data collection and use

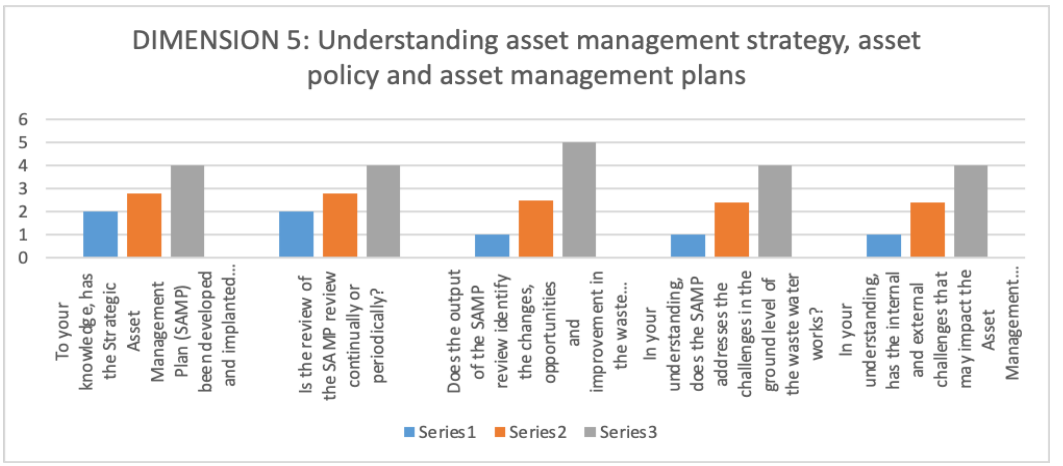
4. Discussion, Analysis and Conclusion

The main purpose of the study was to evaluate and analyse the reasons behind inadequacy of asset management in the waste treatment utilities. This section focuses on the presentation and discussion of the data collected through a circulated questionnaire and the waste-water plant performance indices trends.

4.1. Data Presentation

The figure below outlines the outcome of the questionnaire and interview under dimension 5 which was testing the maintenance strategies adequacy and relevancy to the waste-water treatment plants.

Figure 8: Dimention 5, Understanding asset management strategy, asset policy and asset management plans.



Infrastructure Rehabilitation Strategies and programme

Infrastructure Rehabilitation strategies

The asset renewal strategy forms about 30% of the asset management expenditure and this is set to increase to around 40% over the next 5 years primarily driven by condition of assets taken over from municipalities, asset age, utilisation, and finally the asset condition. The projects are initiated and implemented to improve and maximise organisation investment benefit, in particular the following:

- ✓ The quality of feasibility studies on rehabilitations and upgrades conducted to resolve business problems. This includes establishing a multidisciplinary evaluation panel;
- ✓ The quality of scope of works and specifications development and approval processes;
- ✓ Contract management during the implementation phase, quality control being the major area of focus; and
- ✓ Post project completion audits and closure processes

The Asset Management leadership will therefore enhance the core processes that help optimise expenditure in the renewals/rehabilitations areas over a given period to gain confident in resource allocation and supply stability to the customers. All the above is achieved by the continuous evolution of asset management reliability programmes.

Part of Asset management strategy is to conduct advanced condition assessments. The findings from this assessment are then evaluated for implementation strategy. One of the remedy implementation strategies is projects. This is when the cost for implementation exceeds a certain threshold or if the remedy indicates the end of equipment life and require technological advancement.

The structured advances condition assessment and the pre-approved schedule is included in this report. The segregation is done as per the equipment in both Water Work (WW) and Waste-water Work (WWW) and the schedule is pre- approved for budgeting purposes. Most of the enclosed assessment activities are outsourced, only the report is received from the specialist conducting the actual assessment.

These condition assessments are also pre-approved by the Municipality management as the owners as UW only has Operations and Maintenance (O&M) contract for most of the WWW.

The implementation strategy for the programme is through outsourcing. This includes procurement strategy and plant that is pre-approved by National treasury and a Public Finance Management Act, Act 1 of 1999 (PFM) requirement. The procument procedure of all these services included in the programme, goes through bid Committees process: Bid Specification Committee (BSC), Bid evaluation Committee (BEC) and Bid award committee (BAC). These committees are responsible for ensuring free, fair, and

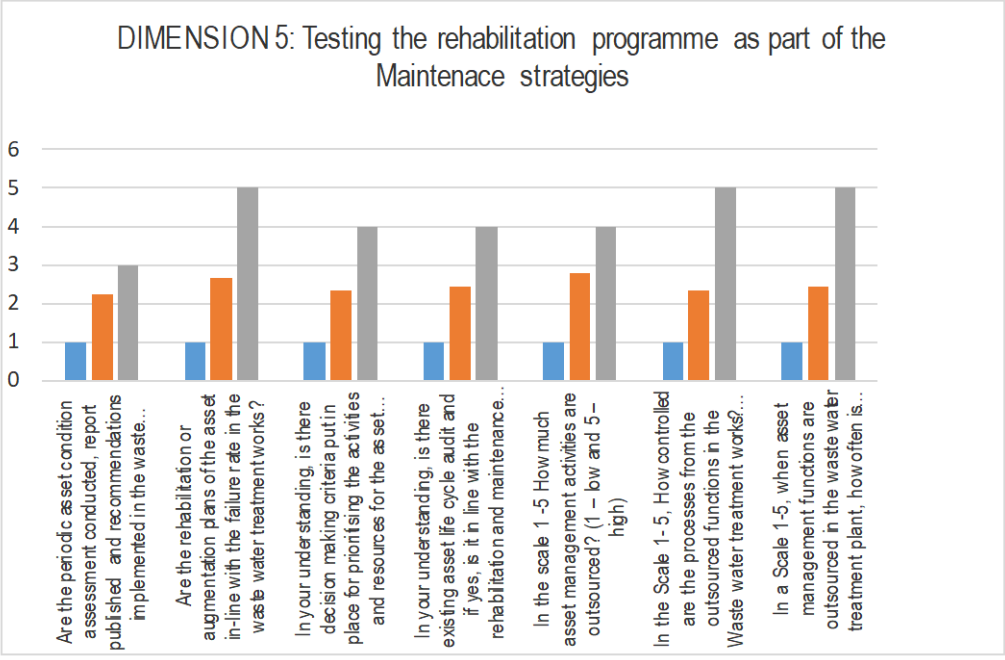
competitive procurement processes, and it is also a requirement as the government legislation and UW subscribe to the International Financial Reporting Standards (IFRS). The overage lead time for sourcing project of about R1 Million is not less than six months unless it is an emergency project.

More time is also required to source the Contract Participation Goal (CPG) partners on all projects that are more than R0.5 million. This is one of the interventions by the organisation to ensure that previously disadvantaged individuals achieve full participation and involvement in businesses that support UW in the supply of water services. The intervention also ensures the technical skills transfer, management, and entrepreneurial skills, thus ensuring the creation of sustainable large black enterprises is achieved.

The data collected through the survey questionnaire.

The chart in Figure 9 below outlines the response solicited from participants through the survey questionnaire. It evaluates the rehabilitation programme alignment to the failure rate in the waste-water treatment utility and ascertains the programme's turnaround time, prioritisation, and quality of workmanship of the external service sourced. The questionnaire outcome is also included in this report.

Figure 9: Infrastructure rehabilitation programme alignment evaluation



Several participants were asked the question as indicated in the chart. The blue bar represents the lowest scores, the orange bar represents the average scores and the grey being the maximum scores received in each aspect of the question with regards to the infrastructure rehabilitation program. The section aimed to test the awareness of the

programme, its development process, implementation strategy and prioritisation process.

As mentioned under data collection procedure above, the formation of the participants ranged from the asset management team, the operations team and process and quality team for collaboration purpose.

4.2.1. Corporate Risk Evaluation

One of the UW's commitments to safety are to ensure the discharge of the final effluent to the river meet and exceeds the requirement of all relevant legislation, such as local by-laws, special and general standards.

This section of data presentation focuses on the waste treatment plant compliance process, monitoring and reporting. UW SHEQ policy outlines the standards in which the organisation currently possesses the certifications or accreditations i.e., ISO 55000 and those that are in progress or working towards attaining i.e. PASS 55. Amongst other standards that focuses more on portable water and wastewater which are the SANS 0241, SANS 9001, SANS 17025, SANS 55001 and SANS 14001, there is also an internal process that evaluates the process requirement as per the legislations, Green Drop, and water discharge licence, which is Process Audit.

The Process Audit are conducted on a more frequent bases, looking at each WWW inflow, intermediate process, and final effluent quality. Over and above the later, the process audit tracks the disposal process of the inlet works also known as Head of Works screening, sludge disposal and air pollution (odour management).

Table 4 below outlines a summary of findings and the causes of failures with the required intervention to ensure non-conformance in the plant are mitigated, preventing inadequate final effluent discharge. This is included as a sample to indicate the impact of the equipment failure in the WWW to the environment.

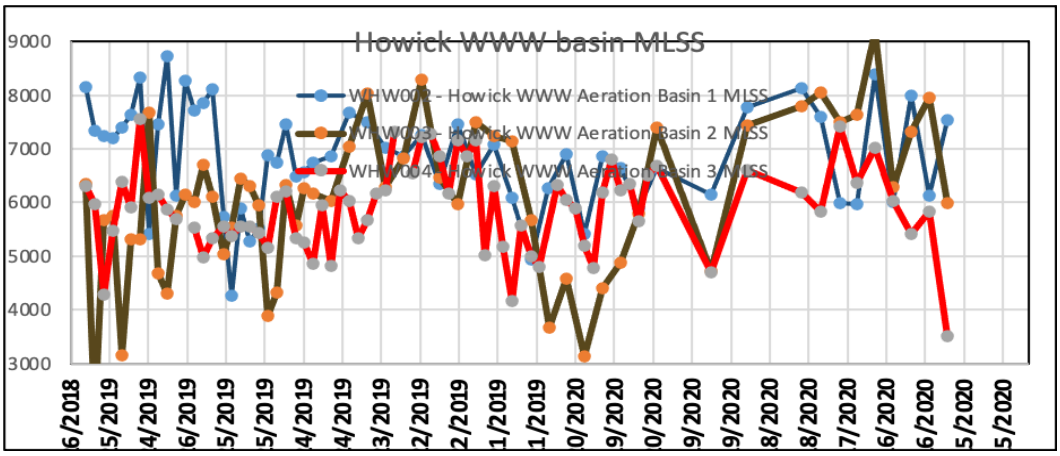
Summary of finding	Recommendation by auditor	Management comment	Corrective & Preventative action	Accountable	Responsible person
FINDINGS					
Solids loading rates (MLSS) exceeded the recommended range of 3500 – 5000 mg/l on the day of the audit). - Excessive foaming in aerobic zone, solids build-up in anoxic and anaerobic zones and solids/scum carryover to downstream	Drying equipment to be upgraded to maximise the wasting of the sludge	Dewatering units' upgrade project is in place, the units has been bought. Project Manager will provide a date of project commissioning	New CPG has been appointed to design, fabricate and install the new electric panel. The contract has been signed and the project will soon start.	Operations	Asset management

processes					
The thin sludge pump tripped frequently. This leads to reduced wasting capacity as there was only one screw press working	A job card should be generated and the pump repaired to full functionality.	The pump has been repaired. Both units are working	Job Notification was generated. Pump has been fixed.	Operations	Asset management
No inflow meter at Head of Works. The disposal licence states clearly that daily records shall be kept of the inflow metering.	The installation of an inflow measuring meter must be incorporated in the upgrade of the splitter box	Head of works upgrade is in-progress. Inflow will be measured.	Project to deal with the inlet channel in progress	Operations	Asset Management
The mechanical screen at the head of works was offline since the screw press shaft was broken. Inflow to the reactors which has not been screened may lead to increased frequency of cleaning of tanks (i.e. reactors, clarifiers, etc.) and possible pipes and pumps blockages.	A job card should be generated and the screw press be repaired.	The mechanical screen is working	Job Notification was generated. Screen was repaired. New project for replacing screen with automated screen underway.	Operations	Asset management
OBSERVATIONS					
Head of Works: The bypass channel that is used when the inlet works is cleaned was full of sewage	The bypass channel must be regularly cleaned and be kept in good condition when not in use.	The channel has been cleaned	done	Operations	Operations
One of the pumps at Mpophomeni Pump Station has a huge leak.	A job card should be generated and the pump repaired	Gland packing seals needed a replacement	Job Notification was generated. Assets Management is attending the problem	Operations	Asset management
Thick scum was observed in the Anoxic tanks	The cause of scum to be investigated and measures to mitigate must be put in	An investigation is being conducted by Process Services	The investigation has been done and Report No. 2019/32 is available on the intranet.	Operations	Asset management

	place.				
The rubber seal on the MD100 chlorine vial was missing.	Replace the vials	The function of rubber seals will be investigated and corrective action will be taken.	New vials and rubber seals have been purchased and the old ones were replaced.	Operations	Asset management
Flow to Clarifier no.1 was restricted due to a high sludge blanket level visible in the clarifier.	Desludging of clarifiers should be conducted more frequently. Dewatering equipment and drying bed should be operated and used respectively at maximum capacity.	This is related to the desludging issues and the high flows	Desludging issues will be resolved once the dewatering unit's project is completed.	Operations	Asset management
Contact tanks had surface scum.	Desludging of clarifiers should be conducted more frequently. Dewatering equipment and drying bed should be operated and used respectively at maximum capacity.	Too much scum formation upstream. Dairy discharges / COD influent loading rate too high	Desludging issues will be resolved once the dewatering units' project is completed.	Operations	Asset management
The emergency shower was not operational since the water supply source was changed	A job card should be generated and the emergency shower should be connected to the new water source		The emergency shower is now connected to the water source and can be used anytime.	Operations	Operations
The staffing is non-compliant with Regulation 17*	Staff must be trained to meet or surpass Regulation 17 requirements.	The staff member is correctly doing N3.	Extended for September 2019.	Operations	Operations

The table 4 above outlined the amount of asset related finding during process audit which has a direct impact to the plant performance and imposed limitations to the compliance as indicated in Figure 10 below.

Figure 10: Howick trends and performance by Steve Terry



The picture in Figure 10 above indicates the instability that has been observed in the past two years due to numerous projects, i.e., the 11 Aerator gearbox sets replacement project that was implemented over a period of two years, replacement of 12 anaerobic mixers that also was implemented over a long period of time, and the delayed Dewatering units' replacement projects. These projects were a major contributor to the non-compliant of the entire plant for over two years.

4.2. Waste-water treatment performance trends.

There is a team in the organisation that is responsible for external water resource tracking. It also ensures the organisation does not contribute to the natural resource pollution through illegal dumping of both waste and inadequate effluent from the failed WWWs.

Each WWW has onsite, the laboratory that monitors all these apparatus/parameters to ensure proper actions are taken in terms of chemical dosing and equipment optimisation to further minimise deviation and non-conformances. The quality of raw inflow influences the chemical dosage level, and it also assist in ensuring the equipment optimisation is implemented to ensure final products comply with the required standards. This is why all apparatus are checked as indicated in the tables below.

Table 5 below represents the apparatus that are measured daily based on the inflow to each plant, included as a sample.

Table 5: Inflow raw data into Howick WWW

Raw Inflow data																		
Sample Point	Sample Date	Al (AE)	Alkalinity	BOD	COD	Color	Cond	NH3	NO2	NO3	pH OS	SRP	SS	Temp	TKN	TOC	TP
		µg Al/L	mg CaCO3 / L	mg O2/L	mg O2/L	mg Pt-Co/L	mS/m	mg N/L	mg N/L	mg N/L	-	ug P/L	mg /L	°C	mg N/L	mg C/L	ug P/L
WHW001 - Howick WWW Influent	2020-09-07		173	84,8	1023		81,4	18,9	<0.50	<0.50	7,9	8006	418	17,8	111		11762
	2020-09-21		187		628		50,6	25,6			7,8	2421	215	16,3			
	2020-10-05		193		1166		49,2	19,2			9,1	2393	308	17,3			
	2020-10-19		151	224	921		41,6	10,1	<0.50	<0.50	8,7	1562	155	19	33,6		5546
	2020-11-02		93,6		361		42,9	8,28			7,6	890	152	17,2			
	2020-11-09																

The highlighted red numbers in Table 5 indicate non-conformance to the set standards or a deviation. The above and below limits this information influence what optimisation is required in the plant.

The Table 7 below outlines the parameters that are continually monitored at the final effluent of the waste treatment work, to confirm the level of compliance on the discharge to the environment or nearby stream, or water table.

Table 7: Darvill WWW final effluent data

Sample Point	Sample Date	Cl2 (T) OS	COD	Conductivity	E.coli	NH3	NO2	NO3	pH OS	SRP	SS
		mg Cl2/L	mg O2/L	mS/m	MPN/ 100mL	mg N/L	mg N/L	mg N/L	-	ug P/L	mg /L
WDV020 - Darvill final effluent	**2020-10-01**	**0.20**	**37.2**	**55.4**	**12**	0.63	<0.50	6.76	7.40	353	22.0
	2020-10-02	**0.20**	**40.5**	**53.4**	**78**	<0.50	<0.50	8.82	7.30	336	20.0
	2020-10-05	0.25	42.9	50.6	35	0.92	<0.50	8.70	7.20	474	30.0
	2020-10-06	0.20	29.9	53.6	6	1.84	<0.50	3.28	7.34	555	16.0
	2020-10-07	0.20	48.3	52.8	8	1.98	<0.50	1.18	7.40	720	31.0
	2020-10-08	0.20	98.7	59.9	5794	5.85	<0.50	<0.50	7.21	1426	54.0

	2020-10-09	0.50	45.7	53.9	200	1.70	<0.50	<0.50	7.20	765	29.0
	2020-10-12	0.05	75.4	47.3	1046	1.28	<0.50	4.67	7.20	561	24.0
	2020-10-13	0.10	39.5	49.4	770	1.29	<0.50	1.92	7.40	569	55.0
	2020-10-14	1.20	86.6	58.9	50	7.45	<0.50	<0.50	7.60	1152	52.0
	2020-10-15	0.20	55.2	56.2	201	1.41	3.77	1.36	7.80	811	25.0
	2020-10-16	<0.05	58.2	58.2	12033	2.57	3.04	2.52	7.70	1211	45.0
	2020-10-19	<0.05	76.1	50.2	1553	1.18	0.90	2.47	7.40	591	51.0
	2020-10-20	<0.05	59.5	50.2	689	1.59	<0.50	4.08	7.80	467	26.0
	2020-10-21	<0.05	34.5	51.5	517	1.45	<0.50	4.67	7.10	434	29.0
	2020-10-22	<0.05	71.0	53.9	298700	1.15	<0.50	4.08	7.70	941	85.0
	2020-10-23	0.10	382	60.4	10900	0.84	<0.50	6.46	7.40	648	316
	2020-10-26	0.05	76.5	62.0	1120	0.68	<0.50	6.34	7.30	304	45.0
	2020-10-27	<0.05	151	63.2	988	2.41	<0.50	4.17	7.40	525	129
	2020-10-28	0.10	46.7	64.8	51	2.68	<0.50	0.59	7.70	852	37.0
	2020-10-29	0.05	24.6	64.5	96	1.53	<0.50	2.57	7.30	412	19.0
	2020-10-30	0.30	62.6	66.0	38	2.51	<0.50	0.54	7.40	740	
Limit / Range		*0.3 mg/l*	*75 mg/l*	*85 mS/m*	*500 counts/100ml*	*6 mg/l*	*15 mg/l*	*15 mg/l*	*5.5 - 9.5*	*1000 ug/l*	***25 mg/l***
No of Analyses		22	22	22	22	22	22	22	22	22	21
No of non-compliant		2	5	0	11	1	0	0	0	3	**13**
% Compliance		91%	77%	100%	50%	95%	100%	100%	100 %	86%	38%
% Non-compliance		9%	23%	0%	50%	5%	0%	0%	0%	14%	62%

The above data is collected from the biggest waste treatment plant the organisation owns. The plant is currently under upgrade since financial year 2018 to 2021. Half of the plant is under construction by an external service provider. All the non-conformances were pre-submitted to the department of environmental affairs for approval, and the system is also closely monitored to ensure the final discharge is within the approved limits for the period of construction.

The initial contractor went under business rescue while still in progress with construction. This led to another year's delay while the dispute and reappointment had to be made for completion of work. The WWW is being upgraded from 75 ML/d, operated at about 100ML/d, which was way above its design capacity and currently being upgraded to 200ML/day (more than double its capacity).

The Table 7 below outlines the comparison in terms of the plant performance against

Compliance % 2020-2021	License	License	GA limits	GA limits	GA limits	GA limits	Howick's License	GA limits
	Darvill	Howick	Ixopo	Lynnfield	Albert falls South	Albert falls North	Mpofana	Camperdown
Jul-20	85,00	86,42	95,00	75,00	100,00	100,00	86,67	100,00
Aug-20	80,93	93,48	82,00	90,00	100,00	100,00	90,00	100,00
Sep-20	93,72	93,48	100,00	100,00	100,00	100,00	85,00	83,30
Oct-20	84,3	98,78	55,00	100,00	100,00	100,00	90,00	83,30
Av. year to date	86,00	93,08	87,50	95,10	100,00	100,00	87,78	91,67
Min Required Compliance	75,55	90,00	95,00	95,00	95,00	95,00	75,00	95,00
2019-2020								
	Darvill	Howick	Ixopo	Lynnfield	Albert falls South	Albert falls North	Mpofana	Camperdown
Jul-20	64	5,3	0,43	0,22			2,60	0,07
Aug-20	60,42	4,6	0,15	0,22			2,88	0,04
Sep-20	64,57	4,89	0,06	0,17			2,61	0,10
Oct-20	62,03	5,95	0,13	0,15			4,02	0,10
Design Capacity (ML/d)	75,00	6,80	1,00	0,50	0,04	0,055	3,40	0,50

the approved license over a period of three months around the same time in the two years.

Table 7: Multiple plant compliance comparison

The above was conducted to track the significant of failures and the direct linked to the outcome in the waste treatment utility.

The data collected through the survey questionnaire.

Figure 11 below outlines the responses from the survey conducted through the circulated questionnaire and interviews.

Figure 11: Understanding of the process requirement in the WWW

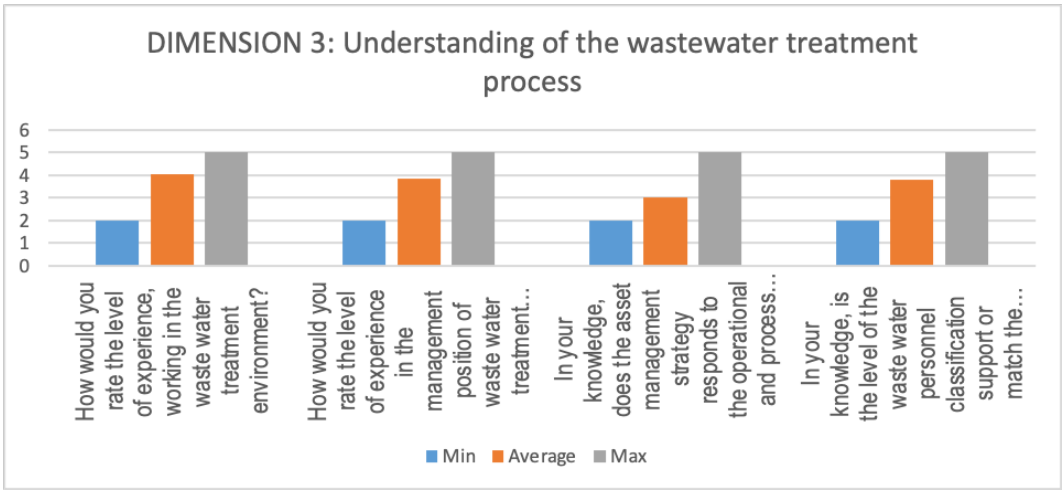
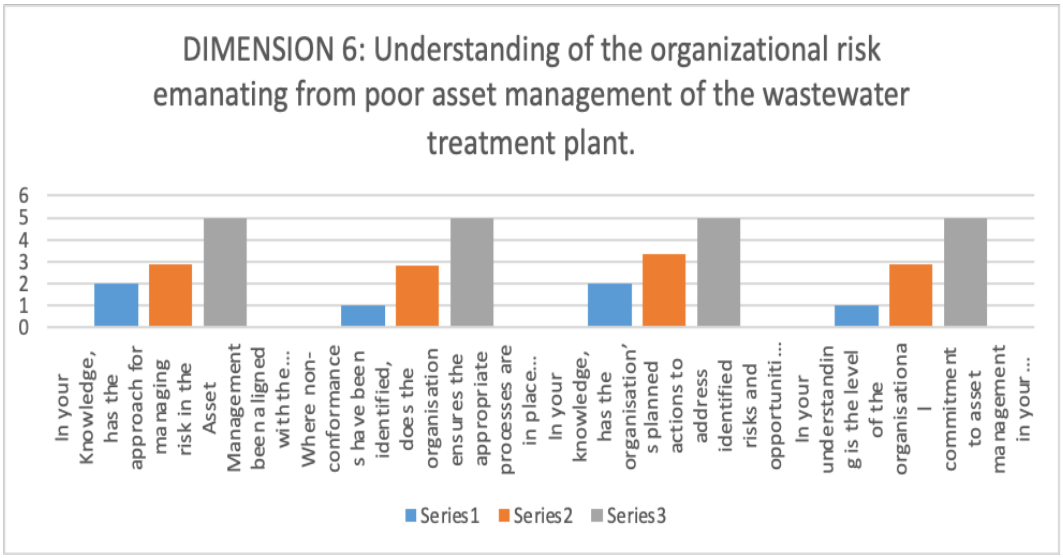


Figure 12 below outlines the data collected through questionnaire and interview to test the level of responsibilty by the organisation into the legislation compliance in the waste-water treatment works.

Figure 12: Dimention 6, The Organisational Risk testing



The same group was asked the above questions to ascertain the level of impact and corporate risk from the inadequately managed treatment utility, and to the company's reputation. The same colour coding is observed for the scores attained.

5. Discussion and Literature Review Evaluation

5.1. Maintenance Strategies adequacy or inadequacy

The organisation has been in existence for over five decades. The mission and vision have always been about providing sustainable and quality portable water to the local

municipality in the region. The focus has always been about expanding the boundaries to ensure quality and quantity is met as the demand grows.

The maintenance strategies have been developed as indicated under section 4.1.1. above from the asset policy and procedures in ensuring asset management sustainability for future growth and compliance to the organisation mission statement is met. This is evident by the four pillars as indicated on the asset management, which are Asset Policy, Strategy, Detailed Annual Plan, and Implementation Control. The organisation strategies are the best in the country and well implemented by the asset management team, as a result the product is of excellent quality year in, and this is also supported by the number of certifications (ISO 55001) and awards the organisation has achieved/attained in the years.

It has been cited above, in accordance with Wiggam (2019), the link of asset to the process that the asset management comprises of five core components: Assets, Service level, Criticality, Life Cycle and Funding. They further add in saying that the asset involves making a complete list of assets in the system and each asset to have documentation including name brand, serial number and models number, size pumps, horsepower motors and notes on replacement or maintenance on the asset.

The organisation has invested more on ensuring the asset register is well developed and is monitored closely. This is to ensure adequacy for the abstraction, the water treatment works, and waste-water treatment works, distribution, and storage facility.

Cardoso *et al*. (2012) above also add on the same note that they rate the water supply and waste-water infrastructure asset management as a key in achieving adequate levels of service in the future particularly with regards to reliable and high-quality drinking water supply. The organisation's current asset policy and strategy presented above does indicate the level of commitment to ensuring its infrastructure asset management is taken as key by the maintenance schedules, plan, and monitoring framework in place.

The predictive/proactive maintenance strategy, schedule condition assessment, corrective maintenance are the main key drivers of excellence in the asset maintenance strategies that are in place for the organisation or division.

The asset management objective presented above talks directly to the organisational output and to further drive excellence. However, the strategy for the WWW is yet to be confirmed as it may have been a cut and paste situation where the organisation rolled out to taking on the sanitation aspect of the business.

5.2. Rehabilitation programme alignment

The Umgeni Water footprint is quite large, this is since the organisation was established many years ago, solely for portable purification and distribution to the Municipalities and other consumers. This has a significant influence on the culture, mind set and behaviours of staff. This also does not only affect the staff's behaviour, but most strategies still favour the old model. The sanitations part of the mission was added in the

last decade, due to the organisation's capabilities, commitment, and contribution to the social services of the community it operates on.

Giessler (2017) writes that the waste-water system does not develop linearly; rehabilitation may be necessary at earlier stages. Therefore, condition state is estimated to determine which parts of the waste-water network that need rehabilitation. Coetzee (2011) also attested to this, that the two key priorities need to be understood and addressed up-front by a municipality when creating infrastructure for supply services. Looking at the rehabilitation program, it is noted that bulk of the resources are invested in the Water Works (WW) compared to the WWW. Over 60% of the funds are allocated for the Portable plant's processes, distribution network and building facilities.

It is also noted that bulk of the budget even in the WWWs is allocated for building, fencing and access roads facilities then the actual process failures. This may also be since majority of these waste-water treatment utilities have just been taken over from the Municipalities to try and uplift the condition as part of the O&M contracts. The condition of asset at the takeover was all below the acceptable level and slowly, the organisation is trying to resuscitate the infrastructure.

The rehabilitation programme is implemented over a long period of time; this causes prolonged system failures while awaiting the completion of work. During that time there is no backup plan in ensuring the work does not affect the plants performance. It is also noted that through the rehabilitation programme, the organisation is in participation on the CPG partnership intervention that is to uplift the skills and competencies in the country. Whilst this is an excellent intervention, it also possesses other challenges in terms of project delays.

Amongst other challenges that have been presented by the research study through the questionnaire, the confident from the operation and process team is very low rated. This is due to several aspects, ranging from not understanding the programme development process, lack of prioritisation criterion, lack of funds in the waste-water treatment plants (Funded by the Municipalities) and sourcing strategies. They understand the process to be tedious and frustrating, due to lack of understanding the impact of equipment failures to the process and the need to fast track replacement.

As cited under literature; CSIR and CIDB (2007) argued that although budgets remained inadequate, instances were found where it is appreciated that expenditure on infrastructure maintenance can save other expenditure many times over (for example by reducing water losses) and can also reduce the risk of system failure. The equipment failure rate from the operations and process team point of view is the major link to plant performance, which attest to this view. The team complains that the WWW equipment failure cannot be dealt with at the same pace as in the portable water treatment plants due to different environmental exposure and its high failure rate.

5.3. Corporate risk evaluation

Whist Pollard *et al.* (2016) explained in chapter 2, that without appropriate management, whether for municipalities supply, agriculture, industry, community development or maintenance of sustainable environment, we risk over-exploiting and contamination of our planet's most precious resources. This is the very reason the organisation adopted all the standards outlined under collected data. The process audits and SANS compliance confirms that the organisation has positioned itself in line with compliance requirement to manage risk.

However, it is noted through the data presented above that there are still a lot of challenges in achieving the said outcomes. The tables presented above indicate that there are several non-conformances that are recorded through the equipment failures. The data is recorded and reported on a set frequency, but this has not yielded changes in strategies employed in the WWW systems. The same strategy applied in the potable water is applied while the environment and the situations are completely different.

This is evident from the outcome of the results of the questionnaire from the asset management team point of view. Majority of the asset team focuses on equipment repair, maintenance, and replacement without really understanding the actual impact it poses on the process. This also supported by the number of failures recorded by the process audit as indicated in above. Although the operations team fully understands the consequences of the prolonged lead-times in the equipment replacement process, the same cannot be said about the Asset Management team.

The Darvill system has continued to underperform over a period of two years due to the ongoing project. This means the utility has been discharging the final effluent that is non complaint for over 24months, but because the non-conformances are pre-approved the latter is allowed.

Figure 10 above shows the Howick WWW's poor and fluctuating inflow quality into the system, but the situation is aggravated by the long-standing failure of the sludge removal machines, leading to a complete process failure. The scum formation, odour and excusive field that follow the poor disposal process have direct environmental impact, leading to poor final effluent discharge. This has led to several communities complains, rending the organisation reputation damage.

Table 7 and Figure 10 above indicate the out of ranges in the MLSS tracking, this is contributed by the long ineffective and repeat failures of the aeration basin. Almost every month there is one or two gearboxes that are not working, while waiting for repairs and the aerator replacement project still at procurement stage.

The trending of the measured apparatus is submitted for the re-evaluation for Green Drop and in this case a continuous failure is achieved due to the out of ranges.

6. Findings and Recommendations

6.2.1. Maintenance strategies adequacy

Whilst the maintenance strategies as per the asset policy, strategy, implementation control are in place, the organisation has invested much in ensuring the systems are developed and continully reviewed inline with the latest standards for Asset management. The factors challenging the relevency to the WWW are still in question.

The strategies need to be relevent to the plant in which it is implemented, it can not be one size fit all. The waste treatment facility environmnt is harsh, the equipment failure rate is also high meaning, the maintenance schedule must be fit for this aspect. As indicated from the literature, the asset failure rate in the waste-water treatment works is about 75% higher than in the portable water treatment works, this has to be considered during the maintenance strategic reviews.

The other aspect is the asset managemet team knowlegde of the equipment use impact. The response to the failures in the WWW is treated in the same way as in the WW. Meanwhile the WW has a redundancy operating philosophy and environment, with spare capacity and redundancy. The WWW is always operated at capacity or above, which means any faiures do not have backup.

The skills set in the operations team was noted as a challenge through the process audits. Some of the plants are non compliant in terms of the operators qualifications and clasification requirement. This affects the response actions needed for the process which further has a direct impact on the equipment failure.

The waste-water treatment utilities are normally operated as part of the social responsibility, meaning there is no revenue derived from these utilities. This could be another source of problems in terms of organisational commitment by all.

6.2.2. Rehabilitation programme alignment

Whilst the programme has been developed and currently being implemented as part of the asset management strategies and asset pholicy, there is still an element of poor investment in the WWW. This could be contributed by the fact that there is no revenue derived from the investment.

The condition assessment in the WWW is not conducted as frequently as in the WW. These condition assessments are only conducted once in three years, while in the WW the frequenvy is much higher. This is due to the fact that the organisation charges the Municipality monthly for the operation and maintenance conducted. This output always takes a back sit as the Municipality will not view it as critical. The organisation will fund its own plants, excluding the WWWs, whilst these assessments are a major contributor or feeder to the rehabilitation programme but are often delayed or skipped..

The other major impact on the success of the rehabilitation programme is funding. WWW projects are aften delayed or cancelled due to lack of funds. When the report

from condition assessment is concluded, the submitted programme requires approval by the owner of the utility. In this case, the Municipality and this process is often delayed.

The procument process is another challenge during the rehabilitation programme implementation. This could emanate from poor planning or just long processes that need to be followed. This includes all the Bid committees, the CPG negotiation and other compliance requirement by the PFMA or national treasury.

6.2.3. Environmental impact and Corporate risk

The organisation is well aligned in terms of the monitering framework for the plant management. The systems are in place and are currently being used. The major challenge in this aspect is the working in silos of the three teams that are responsible for the perfomance of the plant. The operation team manages their aspect and do not really participate in what the asset management team is doing.

The collaboration and the understanding of outputs are not synchronised in the system. This was evidence through the questionnare that was shared. Operations scored high on the process understanding and its capabilities but the asset management team scored high on both the rehabilitation programm and the asset management strategies understanding and implementation in the plants. The operations team does not know of the SAMP, and the Asset team continues to under perform throughout the process audit.

The plant performance trends are available on the organisation intranet but the link to equipment failure is always in question. This mean the asset management team is not intouch with the pictures displayed on the plant key perfomance indicators (KPI) dashboards.

- ✓ The continual review of maintenance strategies for proper alignment to waste environment.

  While it has been determined through the literature that the failure rate is higher in the waste-water environment, it is critical that the continual review focuses on the ever-changing environment and technologies for the waste treatment facilities. This will ensure proper alignment to the requirement and its harshness.

  Adequate implementation of the maintenance strategies, the SOPs, job plan and work schedule should be reviewed to be directly linked to the failure rate of the equipment in the waste treatment works, thus mitigate the risk exposure downstream of the treatment utilities.

- ✓ Review process of the SAMP

  The review sessions for the SAMP must include all stakeholders. The survey indicated that there is a gap between the process knowledge in the strategy compared between the teams. This suggests that the teams are working in silos, leading the teams to pull in differentials. The process team has limited knowledge of what the asset management

team is doing or even supposed to do. Some of the team members do not know if it even exists, leading to inadequate failure of the monitored outcome. There should be a workshop conducted after every review and the document should be made public.

The maintenance manuals are handed over to the asset management team after construction to maintain the equipment and this process does not include the process and operations team, leading to them not knowing what is expected from asset management in terms of the equipment maintenance perspectives.

- ✓ The asset management strategic alignment to the organisational objectives.

The output is well covered on the SAMP but there is still more focus required on the revenue driven mission as to the social driven stream. There is still a lot required to be done to change the culture and the mind-set of the environment. The organisation has embarked on the water and sanitation in the last decade, this means getting involved in more interventions that will help community and the environment it operates in, and not only be driven by revenue. Waste-water treatment utilities deal more with this aspect of business, as it serves to preserve the environment and the communities downstream.

- ✓ Run to failure replacement strategy in the asset management strategies.

The run to failure strategy that is adopted in most of the equipment in the waste-water treatment plant seems to be a source of some challenges, as there are delays and inefficiencies with regards to the replacement process.

References

Adom, D. Kamil, E. and Adu-Agyem J, 2018. *Theoretical and conceptual framework, mandatory ingredients of a quality research,* viewed 24 August 2020. Available on < www.researchgate.net>

Albrecht, C. Kullashi, S. Armato, E. 2017. *Difference between quantitative and qualitative research,* Published October 2017. Publisher market research overview available on <www.iff-international.com>

Alegre, H. and Coelho, S.T. 2012. *Infrastructure asset management of the urban water systems*. Published December, 2012.

André Queirós, Daniel Faria, Fernando Almeida, (2017*). Strengths and Limitations of Qualitative and Quantitative research method,* published by European Journal of education studies, Vol 3 No. 9

Bloganica, 2017. *What are the effects of wastewater on the environment*? 2017, viewed on the 26 July 2020, available on https://www.organicawater .com

Bowden, A.2002*. risk management key to cost effective asset management,* published by waterworld, 2002, viewed 29 July 2020.*https://www.waterworld .com*

Bhandari, P. 2020*. A step by step guide to data collection, viewed on the 26 August 2020, available on www.scribbr.com*

Bhat, A. 2020. The ultimate guide to great questionnaire, available on www.questionpro.com

Cardoso, M.A. Silver, M.S. Coelho, S.T. and Almeida, M.C. 2012. *Urban water infrastructure asset management – a structural approach in four water utilities,* viewed on 22 July 2020, available on www.researchgate.com

Chen J, 2019. *Company Risk*, published by Investopedia viewed on the 26 July 2019, available on www.investopedia.com.

Cook N, Sarver E and Krometis LA, 2015. *Putting corporate social responsibility to work in mining communities: exploring community need for central Appalachian Wastewater treatment.* Viewed 26 July 2020. Available on https://www.mdpi.com

Copperleaf, 2017. *Value-based Decision Making: A Best Practice of ISO 55000,* available on < https://www.copperleaf.com/>

Deloitte, 2015. *Asset management: a risk based approach, energy and resources benchmark*,

Department of environmental conversation (DEC) (2015) *Municipal sewer system asset management guide*, viewed 23 August 2020. Available on <www1.dec.state.ny.us

Durcevic, S. 2020. *Your modern business guide to data analysis method and techniques*, available on < www.datapine.co

Edokpayi J.N., Odiyo J.O., and Durowoju O.S., 2016. *Impact of Wastewater on Surface Water Quality in Developing Countries: A Case Study of South Africa.* Published: January 18th 2017 viewed on 28 July 2020. Available on https://www.intechopen.com/books/water-quality/impact-of-wastewater-on-surface-water-quality-in-developing-countries-a-case-study-of-south-africa

EPA.gov, 2019. *Sustainable water infrastructure, Asset Management for water and wastewater utilities.* Available on *https://www.cbd.int*

Giessler, M. 2017. *A combined model to assess technical and economic consequences of changing conditions and management options for wastewater utilities*. Journal of Environmental Management 207 (2018) 51-59

Han, S. Hwang, H. Kim, S and Baek G.S. 2015. *Sustainable water infrastructure asset management: A gap analysis of customer and service provider perspective.* Published June, 2015https://www.cbd.int

Hussain, D. 2019. *How do you write the validity section of the research proposal for master's level,* <https://www.researchgate.net>

Hrudey, S.E. Hrudey, E.J. and Pollard, S.J.T. 2006. *Risk management for assuring safe drinking water*, Vol 32, Issue 8, Page 948-957. https:// www.sciencedirect.com

Hydro-comp enterprise LTD, 2020*. Asset Management on infrastructure planning system,* Viewed 29 June 202, <www.edams.com>

Kemm, J. 2004. *What is health impact assessment and what can it learn from EIA*? Environmental Impact Assessment Review, 24(2), pp.131-134.

Klipper, H. 2008. *The qualitative research proposal*. Publisher curations, 2008. Viewed 02 July 2020, available on <https://curation.org.za>

Market research, 2018. *Qualitative research: A guide to research methodology*, Published by Editorial team, viewed 15 July 2020

Mathew, G. and Medearis, T. 2019. *Modern technique of prioritizing asset Rehabilitation and capital plans*, Journal of Florida water resource, available on
www.innovyze.com

McCombes, S. 2019. *How to write Research methodology*, published scrubbr, viewed on 06 July 2020 <www.scribbr.com>

McMenemy, I. 2019. *Strategies for Corporate Risk Management*. Viewed 15 May 2020: https://insight.digent.com

Merna, T. and Al-Thani, F.F. 2008. *Corporate Risk management*, 2nd ed, Publisher John Wiley and Sons Ltd, 2012.

Rouse, M. 2020. *Risk management***,** Viewed 07 December 2020, available on https://searchcompliance.techtarget.com/definition/risk-management.

Sage, 2020, *Corporate risk*, published by Sage, 2020, viewed 28 July 2020. Available on www.sage.com

Shaw, N. Thompson, N. Charteris, M. (2015) Wastewater asset management plan, viewed 20 August 2020, available on www.hauraki-dc.govet.nz

SkillsYouNeed (2011 - 2020). *Writing your Dissertation: Methodology,* viewed 03 July 2020, available on <https://www.skillsyouneed.com/learn/dissertation-methodology.html>

Swaen, B. 2015. *Conceptual framework: control variable,* available on www.scribbr.com

Tafazzoli, M. 2017. *Strategizing sustainable infrastructure asset management in developing countries, Viewed on available on* <www. ascekibrary.org>

Umgeni Water. Operations, 2019. *Asset management Plan.* Viewed on 05 December 2020, Available on Umgeni water intranet.

Wiggam, L.B. 2019. *Asset Management Plan Development for a Wastewater Treatment Plant,* viewed on 23 August 2020, available on *www.scholarworks.iupui.edu*