Reliability analysis of wastewater treatment plants: Lesotho case study

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Abstract

Water is among one of the valuable resources that are now under threat due to human activities in the world exposing it to vulnerability to pollution. This study investigated the factors that affect the reliability of wastewater treatment plants in Lesotho and recommended strategies that can be used to improve the reliability of the wastewater treatment plants in Lesotho. Since the purpose of the research was not to generalize the findings but to gain an in-depth understanding, the X wastewater treatment plant was chosen as the case study with the questionnaire and secondary data as data collection methods. All sources identify operation and maintenance, health and safety risk, and human factors as factors influencing plant reliability. The study did not provide the evidence to conclude that policies and governance, vandalism, and theft had an impact on plant reliability, but corruption, design, and infrastructure inefficiencies were identified as areas that need to be investigated further. The following were found to be strategies that can be used to improve the reliability of the X wastewater treatment plant; Proper plant maintenance, policing, implementing health and safety systems, rehabilitation and upgrading of the wastewater treatment plant and employee focus.

Keywords

Wastewater, Wastewater treatment, Reliability, Factors, Strategies.

1. Introduction

Water is regarded as one of the most valuable resources in the world which is now under threat due to human activities exposing it to pollution (Majumder, et al., 2019). The fact that water is considered a valuable resource must be utilized efficiently to enable the next generation access to it and therefore it must be returned to the environment in a better state than before (Van, et al., 2011). This valuable resource must be prevented from pollution at all levels hence a need for treatment of wastewater before disposal into the environment. The need for wastewater treatment was influenced by John Snow to prove that the cholera outbreak that killed tens of thousands of people in London in the years 1832, 1849 and 1855 was caused by polluted water from Thames River (Angelakis and Snyder, 2015). Even though there had been a collection of wastewater back in the centuries but the treatment of wastewater dates back to 1800 and 1900 years (Dhote, Ingole and Chavhan, 2012).

Approximately 80% of wastewater is discharged into the environment without treatment and this is usually the root cause of waterborne diseases (Majumder, et al., 2019). In South America, 85% of wastewater is not treated, while in Venezuela only 3% of wastewater is centrally treated at the wastewater treatment plant and the rest is discharged untreated directly into the environment (Dhote, et al., 2012). Even in highly industrialized countries such as China, only 45% of its sewage goes through the treatment processes while the rest is discharged to the environment untreated (Dhote, et al., 2012). However, some countries and states take wastewater treatment and reuse seriously, for instance, California, Singapore and Spain (Angelakis and Snyder, 2015). Countries like South Africa are regarded as one of the countries having the facilities of wastewater treatment but aged infrastructure, overloading and improper maintenance have caused the treatment facilities to be as good as nothing thus posing serious health and socio-economic hazards to the dependents of such receiving water bodies (Dhote, et al., 2012).

For many years the reliability of wastewater treatment plants has attracted a lot of attention in the engineering and scientific world (Adraka, 2019). Reliability in the context of operational efficiency of wastewater treatment plants is one of the most important aspects in the field of the water sector and has driven technological innovation in today's

world (Majumder, et al., 2019). Reliability of a wastewater treatment plant is defined as the likelihood of adequate performance for a defined period under stated conditions (Taheriyoun and Moradinejad, 2015).

The reliability of a wastewater treatment plant is determined by the efficient solid-liquid separation which depends on biomass settling properties as well as the ability of the effluent to meet prescribed standards (Andraka, 2019). The capital city of Lesotho, Maseru is faced with the following challenges related to the performance of the wastewater treatment plants operating in Maseru; bad odour, water-borne diseases to the community living next to the wastewater treatment plants and polluted streams. As a result, this study was conducted to determine the factors that affect the reliability of wastewater treatment plants in Lesotho and to determine the strategies that can be used to improve the reliability of the wastewater treatment plants in Lesotho.

1.1 Objectives

The objectives of this research were:

1) To determine factors that affect the reliability of wastewater treatment plants in Lesotho
2) To recommend strategies that can be used to improve the reliability of wastewater treatment plants in Lesotho

2. Literature Review

Wastewater is defined as any water contaminated by human use and is composed of stormwater, sewage and industrial used water (Naidoo and Olaniran, 2013). Sewage and wastewater are usually used interchangeably even though the two words differ. The only difference between the two words is sewage is still wastewater while wastewater may or may not include sewage. Sewage is only composed of human excreta and not any other form of water used (Choi, et al., 2017). Domestic and industrial utilization of water contributes to many contaminants and pollutants to water (Anjum, et al., 2016). These pollutants have the potential of causing diseases and polluting receiving water bodies (Bugajski, et al., 2016). Domestic wastewater has contaminants in the water while industrial wastewater has both pollutants and contaminants (Abdel-Raouf, Maysour, Farag and Raheim, 2019). Industries use water for different purposes such as manufacturing of goods and services for example production of beverages, pharmaceuticals and agriculture (Grady, Daigger; Love and Felipe, 2011). All the water coming from these types of commercial sites is called industrial wastewater (Grady, et al., 2011). Many industries by law are mandated to pre-treat their industrial wastewater before discharge into the municipal sewerage systems due to their toxicity that cannot be handled by a normal wastewater treatment plant (Le-Clech, 2010).

2. 1 Impact of wastewater

Discharge of untreated wastewater into the environment results in increased concentration of ammonia, chlorine, organic compounds demanding high oxygen usage, poisonous substances and heavy metals (Anjum, et al., 2016). When pollutants or inadequately treated effluent is discharged into the environment there is an increase in organic load which results in oxygen deficiency in the receiving water body (Anjum, et al., 2016). Oxygen deficiency in the receiving water bodies adversely affects the aquatic ecosystem because its presence is important for the upkeep of biological life within the ecosystem (Andraka, 2019). Some plants and fish die while some are severely affected due to instabilities in their natural habitat (Edokpayi, et al., 2017).

Discharged wastewater into the environment becomes surface water which also turns out to be a source of potable water for many people especially in rural areas (Edokpayi, et al., 2017). The untreated wastewater is usually contaminated with pathogens and some toxic substances which cause diseases to humans (Holeton, et al., 2011). Besides the presence of pathogens, untreated wastewater is composed of nitrates which are dangerous to human health especially infants when consumed in large amounts (Akpor and Muchie, 2011). The disease caused by nitrates consumption to infants is called methemoglobinemia or blue babe syndrome (Akpor and Muchie, 2011). The very same water that has been used should not be discarded but should be taken back to the environment where it first originated so that it can be used again at low costs (Vouvoulis, 2018). While effluent discharged from a wastewater treatment plant is important for agriculture, but inadequately treated wastewater becomes a serious problem for the crops due to its potential to contain toxic substances (Liu, et al., 2018). The impact of wastewater necessitated an

academic study to uncover the factors affecting wastewater treatment reliability and recommend strategies to address those factors.

2.2 Reliability

Reliability is defined as the probability of an item to perform its function under defined conditions and specified time, reliability of any item is its likelihood of success while in the hands of the customer (Eliza and Simona, 2011). Reliability of any product is mostly regarded as the performance attribute of a product that has an impact on the function of the product as well as its maintenance and operating costs (Eliza and Simona, 2011). Reliability has an element of safety, and therefore reliable products rarely fail, and their chances of having defects that cause harm to operators are also reduced due to high reliability (Mrugalska and Tytyk, 2015). Reliability enables customers to plan maintenance and reduce maintenance and operation costs efficiently (Eliza and Simona, 2011).

2.3 Reliability in wastewater treatment plants

The reliability of a wastewater treatment plant is the ability of the plant to achieve the required effluent quality under variations in loads (Taheriyoun and Moradinejad, 2015). The reliable wastewater treatment plant is a sign of the level of commitment and development within the city and its public health (Naidoo and Olaniran, 2013).

2.4 Factors affecting the reliability of wastewater treatment plants

The following factors have been identified from the literature to be affecting the reliability of wastewater treatment plants:

Design and infrastructure inefficiencies- Design inefficiencies mean the plant cannot perform according to the requirements. This is caused by poor planning and incorrect data used during the design period (Mema, 2010). This later affects the reliability of the plant during the operation stage. Many wastewater treatment infrastructures have long been constructed and they are now old and cannot operate according to their design specification (Teklehaimanot, et al., 2015). Some can no longer accommodate the increased sewerage coverage caused by urbanization and population growth (Mema, 2010).

Operations and maintenance- High maintenance and operation costs limit many wastewater treatments plants to purchase critical components of the plant and thus affecting the reliability of the plant (Mema, 2010). As a result, failure to maintain and operate the plant has a direct impact on the reliability of the plant. Failure to operate the plant in alignment with design specifications also introduces foreign objects which affect the performance of the plant and thus the reliability of the plant (Ntombela, et al., 2016). Failure to maintain the plant does not only affect maintenance costs but also translates to reliability since maintenance is not planned even the plant's breakdown happens frequently such that planning becomes impossible (Taheriyoun and Moradinejad, 2015).

Human factors, errors and competency- Human factors include human behaviour and attitude at the workplace, this includes absence at work to perform operational duties and failure to monitor the process (Bugajski, et al., 2016). Stakeholders' ill bad practices such as flushing unwanted objects into sewer systems also harm the overall performance of the plant (Ntombela, et al., 2016). Lack of expertise and skill also affect the reliability of wastewater treatment plants (Taheriyoun and Moradinejad, 2015).

Corruption- Corruption practices on wastewater recruitments and licenses being awarded to incompetent individuals later have an effect on the poor operation and management of wastewater treatment plants thus contributing to poor reliability (Matsheza, et al., 2011).

Health and safety risks-Wastewater treatment plants are regarded as very hazardous places for employees. Hazards and risks can be caused by mechanical items, biological agents and toxic gases caused by wastewater. Injuries and illness contribute to absenteeism and later affects the performance of wastewater treatment plants and thus reliability (Malakahmad, et al., 2012).

Vandalism and theft-Mechanical and electrical components are usually stolen or vandalized at wastewater treatment plants and their absence affect the overall performance of the plant because they are the most critical components needed to run the plant (Ntombela, et al., 2016).

Lack of policies and governance- Lack of policies governing wastewater treatment plants results in a lack of rules and regulations monitoring the performance of wastewater treatment plants (Qadir, et al., 2010).

2.5 Strategies that can be used to improve the reliability of wastewater treatment plants

The following strategies were found to be useful to mitigate the factors affecting the reliability of wastewater treatment plants defined above.

Upgrading and rehabilitation- this was found to be a good strategy to mitigate the problem of design and infrastructure inefficiencies. Refurbishment and modification of existing infrastructure can be used to accommodate current and future wastewater treatment demands (Eggen, et al., 2014).

Proper plant maintenance and operations- This includes the application of reliability techniques such as critical component analysis (CCA), failure modes and effects analysis (FMEA), event tree analysis (ETA) and fault tree analysis to mechanical and electrical components of the plant (Alfiya, et al., 2013). Asset management can be used to reduce maintenance and operation costs (Senate-Molinos, et al., 2014). The adoption of benchmarking of cost reduction techniques can be utilized as a strategy for cost reduction (Afolalu, et al., 2018).

Employee focus- This strategy can be used to counteract human factors, errors and competency. Training of operators and management on the operation of the wastewater treatment plant. Training does not only enhance skill at workplaces, but it also indirectly increases morale, motivation and quality performance (Taheriyoun and Moradinejad, 2015). Process automation and supervision can also be used to counteract human factors and errors (Lynas and Horberry, 2011).

Policing- To control corruption, wastewater treatment plants can resort to training on anti-corruption policies (Lokaj, 2015). Introduction of incentives for reporting corruption and applying strict penalties on those found corrupt (Locatelli, et al., 2017).

Health and safety systems- This strategy can be used to control occupational health and safety risks (Malakahmad, et al., 2012).

Security- To control theft and vandalism by improving on security, control of inventory and making everyone accountable for damages and theft taking place at the plant. There should also be strict measures for those caught stealing and vandalizing, and again branding of company assets can be used to control theft at workplaces (Farinloye, et al., 2013).

Governance and policies development- There should be policies regulating the management of wastewater treatment plants and penalties imposed for non-compliance (Qadir, et al., 2010).

3. Methods

This study employed both qualitative and quantitative since the research questions focus was on factors that affect the reliability of wastewater treatment plants and from the literature, those factors can be investigated in a form of both explanatory and exploratory. Therefore, the two research methods were used in this particular study. The research is made up of two methods and those are deductive and inductive methods (Soiferman, 2010). Deductive methods are more concerned with testing the hypothesis while inductive methods aim at developing a theory (Soiferman, 2010). Apart from the framework created from the literature for the determination of reliability factors and the strategies, opinions from participants were also considered therefore both deductive and inductive methods were used to answer the research questions.

This study employed a case study method for the collection of data because an in-depth understanding of the subject was required. The case study method is usually a descriptive and exploratory type of research. It must be noted that results from a case study are not general, but the aim of this study is not to generalize the results but to gain an in-depth understanding of the factors that affect the reliability of a particular wastewater treatment plant found in Lesotho. This case study used a questionnaire, maintenance data, operational, health and safety data as units of analysis for the determination of the reliability factors and the strategies.

4. Data Collection

Data collection is defined as the method of assembling and evaluating the information on variables of interest in an organized orderly style that allows one to respond to defined study questions (Ajayi, 2017). Data collection is very important in research, and it consists of two classes, primary and secondary sources (Douglas, 2017). Primary data is the information that is collected for the first time, it is something not known but the research findings lead to it (Ajayi, 2017). Secondary data is the information that has been collected and produced by previous authors (Ajayi, 2017). This data can be published data, books, magazines, newspapers or even reports. For a collection of primary data, this study used a questionnaire approach. A designed questionnaire was sent to participants in sealed envelopes and out of 40 participants, 38 responded and dropped the questionnaire in a central box that was only accessed by the researcher after a week of distribution. To maintain anonymity, the participants were not allowed to write their names on the questionnaire and the rights of the participants were observed in alignment with the University of Johannesburg code of ethics. Collection of secondary data was basically through files checking of maintenance, operations, health and safety files to validate the primary data.

5. Results

This study relied on two data sources: a questionnaire and secondary data, as well as the assistance of employees in the case study setting. Sections 5.1 and 5.2 present information about the questionnaire, while Section 5.3 presents information about secondary data.

5.1 Demographic profiles

A questionnaire was distributed to forty (40) participants from the X wastewater treatment plant, including managers, engineers, supervisors, technicians, planners, officers, and operators. They were asked to comment on the plant's dependability as well as the proposed strategies. Thirty-eight (38) of the forty (40) participants completed the questionnaire and returned it, (95% response rate) (Table 1.). The majority (71%) of respondents were between the ages of 31 and 40, with the majority (58%) claiming NQF level 7 as their highest educational qualification. The participants had extensive experience in their field of study, with the majority (61%) having 6 to 10 years of experience. The demographic profiles demonstrated that the participants possessed the necessary characteristics to contribute meaningfully to the research.

Table 1. Demographic information (N= 38)

Variables	Count	Percentage
Age		
Less than 20 years	0	0%
20-30 years	3	8%
31-40 years	27	71%
41- 50 years	6	16%
More than 50 years	2	5%
Qualification		
Matric qualification (NQF 4)	0	0%
Certificate (1 -2 years) (NQF 5)	1	3%
National Diploma (NQF 6)	14	37%
Advanced Diploma, Degree, BTech (NQF level7)	22	58%
Honours Degree, (NQF 8)	0	0%
Master's Degree (NQF 9)	1	3%

Variables	Count	Percentage
Doctor of Philosophy (PhD) (NQF 10)	0	0%
Experience		
Less than 1 year	2	5%
1-2 years	1	3%
3-5 years	7	18%
6-10 years	23	61%
More than 10 years	5	13%

5.2 Factors affecting the reliability of wastewater treatment

Most of the measured variables have internal consistency ranging from 0.6 to 0.95, indicating that the variables' internal consistency was satisfactory and within the acceptable range (Sekaran and Bougie, 2013). Cronbach's alpha for health and safety risks was less than 0.6, indicating that respondents were inconsistent and that the issue of health and safety should be approached with extreme caution. Operations and maintenance (N=5; M = 3.3; STD =0.563; α= 0.653); health and safety risks (N=4; M = 3.2; STD =0.765; α= 0.513); and human factors (N=3; M = 3; STD =0.746; α = 0.639) all had an impact on the reliability of the X wastewater treatment plant (Table 2.). The mean score for corruption, design and infrastructure inefficiencies, policies and governance, vandalism and theft was less than 3, indicating that they were not among the factors affecting the plant reliability.

Table 2. Factors affecting the reliability of wastewater treatment

Variable	Number of items measured (N)	Weighted mean (M)	Standard deviation (STD)	Cronbach's Alpha (α)
Operations and maintenance	5	3.3	0.563	0.653
Health and safety risks	4	3.2	0.765	0.513
Human factors	4	3	0.746	0.639
Corruption	2	2.7	1.223	0.959
Design and infrastructure inefficiencies	3	2.4	1.123	0.739
Policies and governance	3	1.8	0.818	0.971
Vandalism and theft	2	1.2	1.070	0.628

The questionnaire was used once more to identify solutions for improving the X wastewater treatment plant's reliability. Table 3., shows the variables gleaned from the literature that are thought to affect wastewater treatment facility reliability. Employee attention (N=6; M = 4.6; STD =0.560; = 0.653); security (N=2; M = 4.2; STD =0.759; = 0.653); and governance and policies development (N=2; M = 4.1; STD =0.801; = 0.901) were identified as three techniques that the case study organization may utilize to increase wastewater treatment dependability.

Table 3. Variables mean, standard deviation and Cronbach's Alpha

Variable	Number of items measured (N)	Weighted mean (M)	Standard deviation (STD)	Cronbach's Alpha (α)
Employee focus	6	4.6	0.560	0.766
Security	2	4.2	0.759	0.814
Governance and policies development	2	4.1	0.801	0.901

5.3 Secondary data analysis

Secondary data included operational data, maintenance data, and health and safety data. To determine and confirm the items of interest, a checklist based on the literature was created for secondary data collection. Managers from maintenance, operations, and health and safety joined the research team to help find and confirm items of interest in maintenance, operations, and health and safety data. The primary researcher's main task was to mark the relevant boxes with an "X" to indicate the availability or unavailability of the item under investigation. The checklist that was generated to show the availability and unavailability of the items are shown in Table 4. The checklist included eight

Table 4. Checklist for determination of secondary data

Variables	Item	Compliance levels				Remarks
		Yes	No	Yes%	No%	
Maintenance	Asset management policy		X	(37.5%) 3	(62.5%) 5	The maintenance manager could not produce the asset maintenance policy for the research team.
	Maintenance policy	X				There is a maintenance policy developed for the plant but during the investigation, the policy was not yet approved by the authorities. Therefore, the policy was not yet operational even though consultations with relevant stakeholders was done during policy development.
	Records of meetings between maintenance and operations team	X				There were records of meetings between operations and maintenance divisions even though there were inconsistencies in how frequent the said meetings are held.
	Maintenance budget	X				The maintenance manager was able to present to the research team proof of the annual maintenance budget but claimed that there had been cut off maintenance budgets in the previous year's thus making the budget insufficient for maintenance activities.
	Maintenance plan schedule		X			There was no maintenance plan schedule presented to the research team. The maintenance manager also claimed that even if the planning team could develop the plan but due to budget constraints and unavailability of spare parts the maintenance schedule ended up not being adhered to.
	Adherence to the maintenance schedule		X			Adherence to the maintenance schedule was not possible because of delays in the supply chain and budget constraints.
	Records of periodic wastewater structural assessments		X			The maintenance manager could not present to the research team any records of wastewater treatment plant structural assessments carried by professional structural experts.
	Records of machinery inspections		X			There were no inspections carried out on the machinery to ensure smooth operation and prevention of unplanned machinery breakdown.
Employee focus	Proof of training program		X	(38.5%) 5	(61.5%) 8	The operations manager could not present the training program to the research team. However, there were training needs submitted to human resources for consideration but had to be cut due to budget constraints.
	Proof of competence training conducted		X			There was no proof of competence training conducted for operations and maintenance staff.
	Human resource welfare policy		X			The human resource welfare policy was available but not operational.
	Records of theft and vandalism		X			There were no records of theft and vandalism at the wastewater treatment plant. However, the operations manager claimed that there had been few minor reports of theft and vandalism at workplaces even though those incidents were not formally recorded.
	Security contract personnel in place	X				At the time of collection of data, there was a private security company engaged at the plant with a valid contract.
	Supply chain management policy		X			At the time of collecting data, there was no supply chain management policy presented to the research team.
	Human resources policy	X				The human resource policy was presented to the research team.

Variables	Item	Compliance levels				Remarks
		Yes	No	Yes%	No%	
	Wastewater treatment plant standard operating procedure		X			There was no standard operating procedure developed for the entire X wastewater treatment plant. The only standard operating procedure developed about the X wastewater treatment plant was the monitoring of vacuum sewage tankers.
	Risk management policy		X			There was no risk management policy presented to the research team
	Performance management system	X				The performance management system was presented to the research team, it was operational and the reviews were done quarterly.
	Records of performance rewards		X			There were no records of rewards for outstanding performance and conduct.
	Records of quality assurance for effluent disposal	X				There were records of quality assurance communicated to relevant stakeholders weekly.
	Reports of wastewater quality	X				There were reports of the weekly and monthly performance of a wastewater treatment plant.
Health and Safety	Records of risk assessments		X	(33.3%) 4	(66.7%) 8	There were no records of risk assessments at the plant.
	Records of incidents, near miss and hazards, reporting		X			There were no records of incidents, near misses, or hazards presented to the research team.
	Records of toolbox talks	X				Records of toolbox talks were presented to the research but there have been inconsistencies in how the toolbox talks should be conducted.
	Records of Incident investigations		X			There were no cases of reported incidents and investigations.
	Records of issuance of personal protective equipment (PPE)	X				Personal protective equipment records were available but were not sufficient for the whole staff. Some staff were not provided with PPE
	Records of health and safety training program		X			The health and safety manager could not present to the research team records to health and safety training programs
	Records of drills conducted for substance abuse		X			There were no records of safety drills conducted to staff to ensure their readiness in the case of emergencies
	Records of periodic medical examinations	X				There were records of annual medical examinations conducted to wastewater treatment plant operators. However, there were no annual medical examinations conducted for the rest of the staff who were directly or indirectly involved in the day-to-day operation of the plant.
	Health and safety policy	X				There was a health and safety policy presented to the research team that was aligned with the labour code of Lesotho.
	Records of health and safety audits		X			There were no records of health and safety periodic audits presented to the research team.
	Records of safety inspections		X			There were no records of safety inspections conducted either on the machinery or the overall operation of the plant.
	Records of tests on substance abuse		X			There were no records of tests on substance abuse presented to the research team.

items to evaluate the effectiveness of the wastewater treatment plant's maintenance. The research team discovered evidence on three of the eight items (Maintenance policy, Records of maintenance and operations team meetings, and Maintenance budget), resulting in 37.5 percent compliance with maintenance requirements. The employee focus consisted of 13 items, and the research team confirmed the evidence of 5 of them, accounting for 38.5 percent compliance. The checklist included 12 items related to health and safety, and the research team confirmed evidence on 33.3 percent of the items; there was no data to claim the practice on 66.7% of the items.

5.3 Proposed Improvements

The reliability of X wastewater treatment plant is influenced by operations and maintenance, health and safety risks, and human factors. Aligning operational goals, maintenance strategies, and business strategies is one strategy for improving plant reliability (Ntombela, et al., 2016). It was suggested that the X wastewater treatment plant defines its goal, review current plant realities, and determine the gap between the current state and the desired state. The current organizational culture, employee skills, and level of regulatory compliance should all be examined. The senior management team should take the lead, advocate for improvement, involve employees in planning and decision-making, allocate resources, and monitor progress toward the desired goals regularly. Based on the responses and the literature, it was determined that benchmarking of maintenance and operation can be used as another strategy to mitigate the problem of operations and maintenance issues.

5.4 Validation

The study used a variety of validation methods, including face validation during the development of the questionnaire, an audit trail during secondary data collection, and triangulation during data analysis (Table 5.). The Cronbach's alpha provided the ability to assess internal consistency or item reliability, and the majority of the variables met the cutoff point, while those that did not meet the lower threshold were treated with caution. Table 5 shows the similarities and differences between primary and secondary data where '' ✓ '' shows that the factor was determined to be affecting the reliability of the plant and '' × '' means that there was no evidence indicating that the variable had the impact on the reliability of the plant. Both sources identify operation and maintenance, health and safety risk, and human factors as factors influencing plant reliability. There was no evidence to conclude that policies and governance; vandalism and theft affected plant reliability, while corruption; design and infrastructure inefficiencies were identified as areas that require further investigation. We concluded that the study had both reliability and validity based on the similarities between the two data sources and Cronbach's alpha results.

Table 5. Triangulation

Variable	Questionnaire	Secondary data
Operations and maintenance	✓	✓
Health and safety risks	✓	✓
Human factors	✓	✓
Corruption	✓	×
Design and infrastructure inefficiencies	✓	×
Policies and governance	×	×
Vandalism and theft	×	×

6. Conclusion

The study investigated the factors that affect the reliability of wastewater treatment plants in Lesotho and recommended strategies that can be used to improve the reliability of the wastewater treatment plants in Lesotho. Since the purpose of the study was not to generalize the findings but to gain an in-depth understanding of the factors and the subject, the X wastewater treatment plant was therefore chosen as the case study for this research. The study used a questionnaire approach for the collection of primary data and operational data for a collection of secondary data and the two data sets were compared to conclude factors affecting the reliability of the X wastewater treatment plant. The nine factors identified from the literature were investigated as factors that affect the reliability of the X

wastewater treatment plant: corruption, human factors, errors and competency, operations and maintenance issues, health and safety, design and infrastructure inefficiencies.

Both sources identify operation and maintenance, health and safety risk, and human factors as factors influencing plant reliability. There was no evidence to conclude that policies and governance; vandalism and theft affected plant reliability, while corruption; design and infrastructure inefficiencies were identified as areas that require further investigation. However, even though policies were found to be having no impact on the reliability of the X wastewater treatment plant there were very important missing policies such as asset management, supply chain management, maintenance, and risk management policies. The unavailability of these policies may later have an impact on the reliability of the X wastewater treatment plant. Vandalism and theft were also not found to be a problem that may have an impact on the reliability of the plant but for the fact that a minority of the respondents mentioned it, it cannot be overlooked and needs investigations.

It was determined from the respondents and the literature that proper plant maintenance and operations, as well as the adoption of best maintenance and operation best practices, can be used as a strategy to mitigate the problem of operations and maintenance issues. Rehabilitation and upgrading of the wastewater treatment plant were also identified as a strategy to improve the reliability of the wastewater treatment in cases where design and infrastructure inefficiencies affect the reliability of the plant. Last but not least employee focus was found to be a very good strategy in controlling human factors, errors and competency at the workplace. All the above-mentioned strategies can be used to improve the reliability of the X wastewater treatment plant.

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