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Assessment of Municipal Wastewater Treatment Plants in Addis Ababa: Operational Status, Challenges, and Technological Performance

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Abstract

Wastewater management in Addis Ababa faces critical challenges driven by rapid urbanization and population growth, resulting in the discharge of untreated wastewater into local water bodies. This pollution poses severe threats to aquatic ecosystems, diminishes biodiversity, and disrupts ecological balance. To address these issues, this study conducts a comprehensive assessment of the city's municipal wastewater treatment plants (WWTPs), with a focus on their operational status, factors influencing functionality, and the effectiveness of the employed treatment technologies.

The research adopts a structured methodology, employing both random and purposive sampling techniques to select 110 participants from a total population of 320, encompassing 11 WWTPs. Data were collected through structured questionnaires and semi-structured interviews, and analyzed using SPSS and Microsoft Excel. Results are presented using descriptive statistics, tables, and charts.

Preliminary findings reveal that out of the 11 WWTPs, only 10 are currently operational, while one remains non-functional. Key factors undermining technological efficiency include poor maintenance, limited budgets, outdated technologies, population pressures, frequent power outages, unavailability of spare parts, and low public awareness. Additional challenges involve odor control, insufficient staff training, sludge management difficulties, equipment failures, and *inadequate safety measures. The treatment infrastructure consists of two Up flow Anaerobic Sludge Blanket Reactors (UASBRs) and nine Membrane Bioreactors (MBRs), all operating at below 50% of their designed capacity.*

Keywords: Wastewater, Urbanization, Public Health, Wastewater Treatment, Wastewater Treatment Plants

Introduction

Pollution water bodies is largely caused by a lack of suitable wastewater treatment infrastructure, particularly in rapidly expanding urban areas (Baker et al., 2010). There is a growing interest in assessing the environmental impact of wastewater treatment plants (WWTPs) and improving their performance since proper wastewater treatment is essential for maintaining environmental sustainability and safeguarding human health (Molinos-Senante et al., 2010).

Problems with wastewater are becoming more widely recognized as a serious environmental danger to people (Mohammadi-Moghadam et al., 2015). Since the early 20th century, efforts have been made to prevent environmental contamination through the development and assessment of wastewater treatment technology (WWTT). Interest in developing WWTTs has grown even more since national and international rules were introduced with the goal of reducing wastewater impact (Molinos-Senante et al., 2015). In order to fulfill more stringent discharge limitations and increase reclamation efficiency, wastewater treatment facilities (WWTPs) are implementing innovative technology. As a result, not many WWTPs are include energy efficiency in their plans. However, this strategy is changing as a result of the European Union's framework for 2030–2050 Climate and Energy objectives. (Borzooei et al., 2020).

Access to universal sanitation and wastewater treatment is hampered in Africa by rising urbanization and budgetary limitations (World Bank, 2019). The infrastructure struggles to meet rising demands since it is frequently insufficient and poorly maintained (Zaware & Kumar, 2018).

Research on the operational difficulties, budgetary limitations, and institutional impediments that now operate treatment facilities is essential for shaping policy and directing capital expenditures in the future (N. Oti, 2018). Research shows that centralized wastewater treatment facilities, especially in developing nations, can be expensive and energy-intensive (Weerakoon & Thayaparan, 2024)

Protecting natural water supplies from pollution, abuse, and degradation is the goal of the Ethiopian Water Resources Management Proclamation (No. 197/2000). In order to effectively safeguard and manage Ethiopia's water resources and maximize their social and economic advantages, this legislation is crucial (Gazeta, 2000). In Ethiopia, wastewater treatment is a major concern, particularly in Addis Ababa, where population expansion and industry are expanding quickly (Gebreselassie, 2018). Comprehensive information about the city's municipal wastewater treatment facilities is lacking. (Alemayehu et al., 2020). To determine the obstacles impeding their efficacy and to evaluate their technical, operational, and financial feasibility, research is desperately needed (Y. Leta, 2018). Developing customized solutions and enhancing sustainable sanitation infrastructure require an understanding of Ethiopia's unique opportunities and challenges (Wolde, 2022). The study evaluates the technical efficiency, operational difficulties, and financial sustainability of Addis Ababa's municipal wastewater treatment plants in order to determine their viability. In order to help stakeholders such as AAWSA and plant staff make decisions, prioritize investments, and improve sustainable practices, it analyzes critical performance criteria and provides insights.

2. Methodology

2.1. Description of the study

The study area was on the municipal/condominium wastewater treatment plant in Addis Ababa city. Analysis of viability of municipal wastewater treatment plants in Addis Ababa, Ethiopia. The research has been more focused 11 municipal/condominiums wastewater treatment plant in Addis Ababa city (Fig 1).

All experimental/data collection procedures were conducted in strict accordance with relevant institutional guidelines and national regulations. The study protocol was reviewed and approved by the Kotebe University of Education Research Ethics Review committee, in accordance with the Ethiopia National Research Ethics Review Guideline (Fifth Edition).

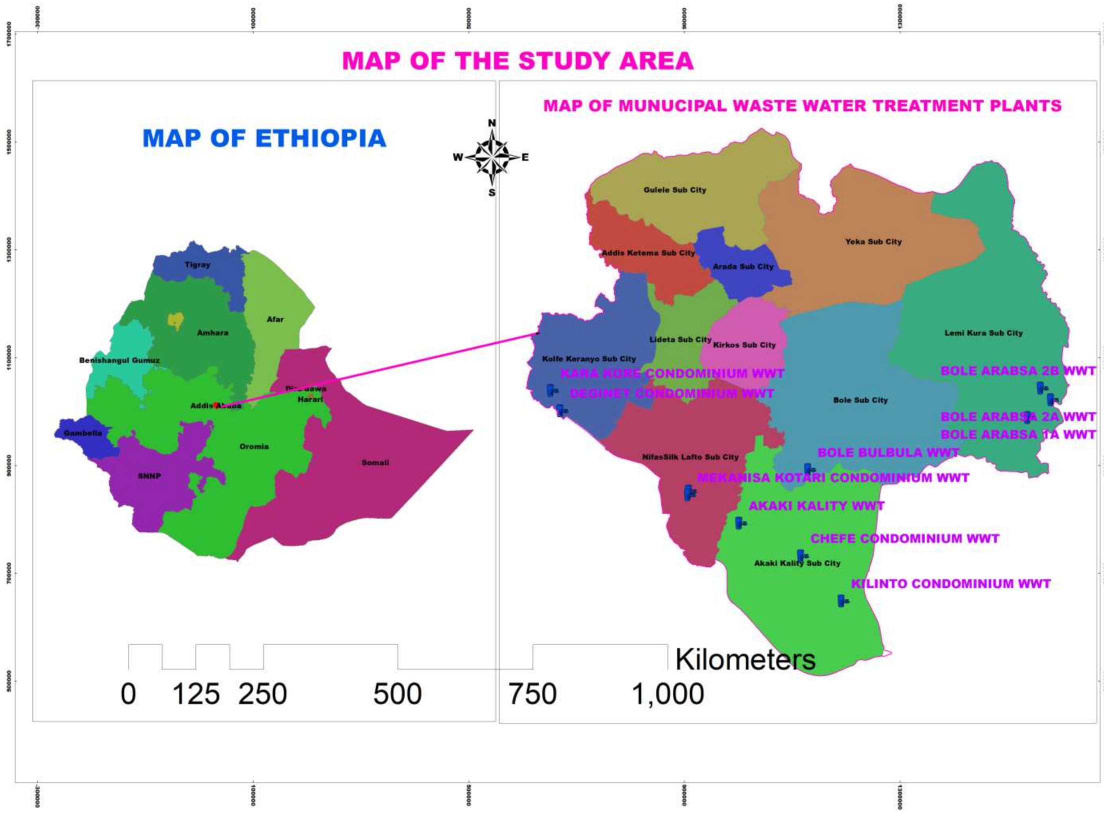

Figure 1. Analysis of viability of municipal wastewater treatment plants in Addis Ababa, Ethiopia

2.2.Research design

This study employed a descriptive research design, which is well-suited for systematically investigating and interpreting the characteristics, patterns, and associations among variables within a given context. Descriptive research enables the researcher to present an accurate profile of events, situations, or relationships as they occur in their natural setting, without manipulation of variables.

In this study, the descriptive approach allowed for the observation and documentation of key factors influencing the subject under investigation. It facilitated the examination of associations between multiple variables, helping to identify trends, correlations, and potential causal relationships, although no direct causation was implied.

The methodology was structured to ensure clarity, coherence, and logical flow in the data collection and analysis process. Quantitative and/or qualitative data were gathered through appropriate instruments, and the results were interpreted using relevant analytical tools.

The research design process and its components are illustrated in the (Fig2), which provides a visual representation of the steps and procedures followed throughout the study.

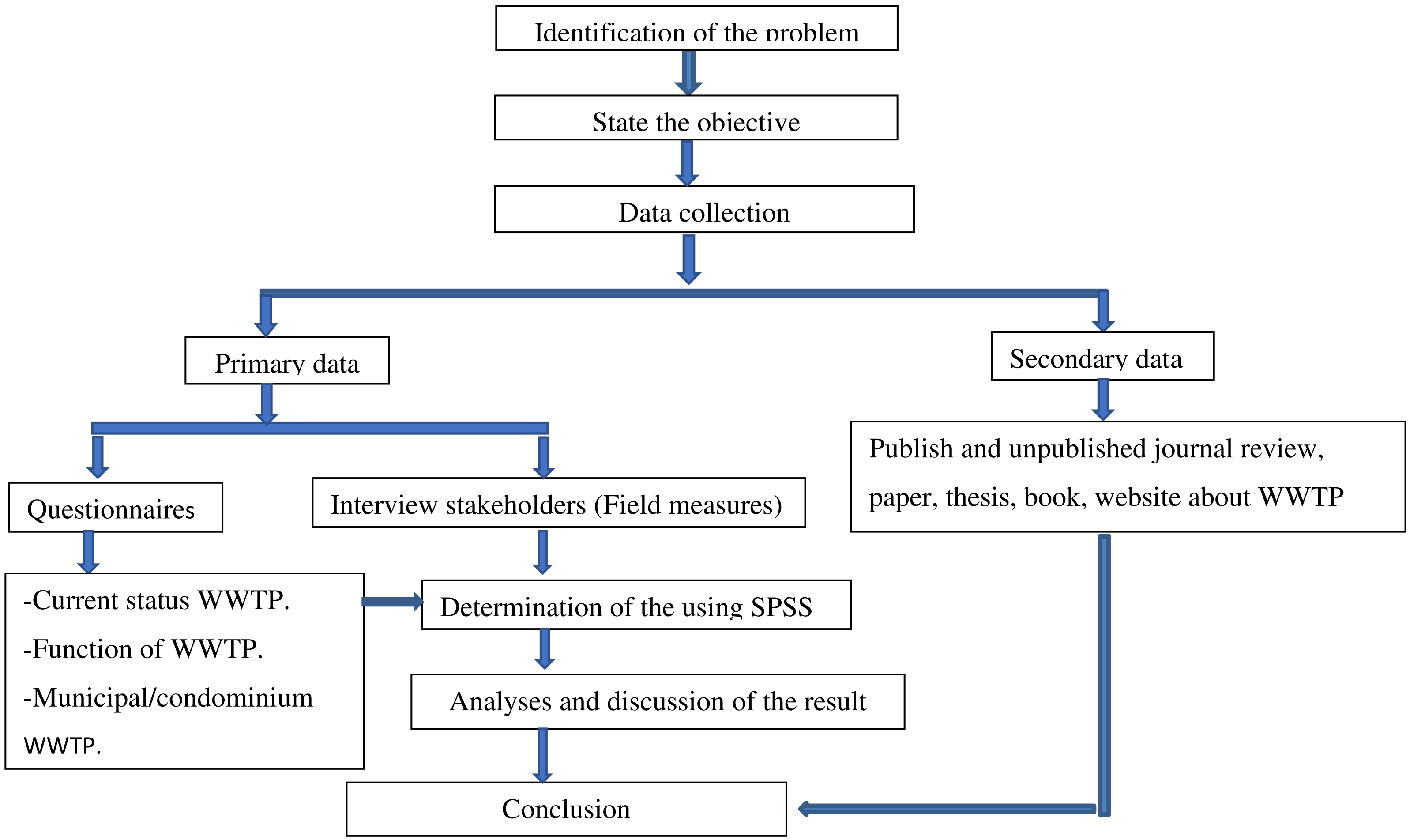

Figure 2. Research Design Diagram

2.3. Sampling techniques and sample size determination

Both probability and non-probability sampling methods were applied in this investigation to guarantee accurate results. While 110 employees of the Addis Ababa municipal wastewater treatment plant were chosen using probability sampling (random sampling, observation, and focus group discussion), purposeful sampling was utilized to collect general information from 11 municipal/condominium sites (Table 1).

Given the size of the population, demographic factors like age, gender, region, and several disciplines were taken into account while calculating the sample size. N > 10,000 was determined to be a representative sample using Cochran's equation (1963). A suitable and representative sample for proportions was guaranteed by this method.

$$n_o = \frac{z^2pq}{e^2}$$

Where, Z = standard variable error and its value that corresponds to 93% confidence interval and equals to 1.81. e =allowable error equal to about 7% of the mean (0.07) or the desired level of precision, p= is the estimated proportion of an attribute that is present in the population, and q is1-p (0.5, 0.5). In this case, the maximum sample size is estimated as follows

Sol. For population >10,000 $n_o = \frac{z^2pq}{e^2}$ n_o =3.2761(0.25)/0.0049= 167

The representative sample size was estimated using the following formula corrected for finite population.

If population <10,000

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

$$n = 167/1 + (\frac{167-1}{320}) = 110$$

Therefore n= 110

Table 1. List of Municipal Wastewater Treatment Plants in Addis Ababa City Administration

No	Name of WWTP	Type of WWTP	Technology used	Amount of lite/day	No of employers
1	Akaki Kality municipal WWTP	Municipal	UASBR	100000 l/d	100
2	Kality Chefe Condominium	Condominium	UASBR	25000 l/d	51
3	Kilinto Condominium	Condominium	MBR	4000 l/d	31
4	Bole Arabsa 1A Condominium	Condominium	MBR	2600 l/d	16
5	Bole Arabsa 2A Condominium	Condominium	MBR	3600 l/d	26
6	Bole Arabsa 2B Condominium	Condominium	MBR	4300 l/d	36
7	Bole Bulbula Condominium	Condominium	MBR	3000 l/d	21
8	Haile garment Oromia Condominium	Condominium	MBR	1200 l/d	9
9	Mekanisa Kotari condominium	Condominium	MBR	1700 l/d	10
10	Kara Kore Condominium	Condominium	MBR	1700 l/d	10
11	Degnet Condominium	Condominium	MBR	1700 l/d	10
	Total				**320**

2.4. Data Collection

The study used both primary and secondary data collection methods, with primary data coming from interviews and questionnaires at wastewater treatment facilities and secondary data coming from both published and unpublished documents. Both quantitative and qualitative methods were used to analyze the data.

2.5. Method of Data Analysis

A quantitative data analysis technique was applied to analyze the acquired data. Various software packages, including SPSS, Google Earth Pro, Microsoft Excel, Microsoft Office 2010, and GIS version 10.8, were utilized for data extraction and analysis.

3. Result and Discussion

3.1. Questionnaires return rate

As indicated in Table 2, 110 employees from 11 municipal and condominium wastewater treatment plants (WWTPs) completed the questionnaires, resulting in a 100% response rate. The respondents were distributed as follows: Akaki Kality Municipal (34), Chefe Genet Condominium (18), Kilinto Condominium (11), Bole Arabsa 1A Condominium (5), Bole Arabsa 2A Condominium (9), Bole Arabsa 2B Condominium (12), Bole Bulbula Condominium (7), Haile Garment Oromia Condominium (3), Mekanisa Kotari Condominium (3), Kara Kore Condominium (4), and Degenet Condominium (4).

Table 2. Level of respondents in Addis Ababa municipal/condominium WWTP

S/N	Municipal/condominium wwtp	Ni	n	N	Ni*n/N
1	Akaki Kality municipal wwtp	100	110	320	34
2	kality (Genet) Chefe Condominium	51	110	320	18
3	Kilinto Condominium	31	110	320	11
4	Bole Arabsa 1A Condominium	16	110	320	5
5	Bole Arabsa 2A Condominium	26	110	320	9
6	Bole Arabsa 2B Condominium	36	110	320	12
7	Bole Bulbula Condominium	21	110	320	7
8	Haile garment Oromia Condominium	9	110	320	3
9	Mekanisa Kotari condominium	10	110	320	3
10	Kara Kore Condominium	10	110	320	4
11	Degnet Condominium	10	110	320	4
Total		**320**			**110**

3.2. Characteristics of respondents

The gender composition of the respondents at the municipal/condominium wastewater treatment plant was notably imbalanced, with a male-to-female ratio of 83.6% to 16.4%, respectively (Fig 3). This significant disparity indicates that the study participants were predominantly male, highlighting a gender-skewed workforce or stakeholder representation within the wastewater treatment sector under investigation.

Such an uneven distribution may reflect broader structural or societal trends, including gender-based occupational roles, employment practices, or educational access in technical and engineering-related fields. It also suggests potential underrepresentation of women in the operational, administrative, or technical aspects of wastewater treatment facilities.

This imbalance is an important consideration when interpreting the findings of the study, as it may influence perspectives, experiences, and responses captured through the research process. It also points to the need for more inclusive engagement strategies in future studies and policy planning within the water and sanitation sector.

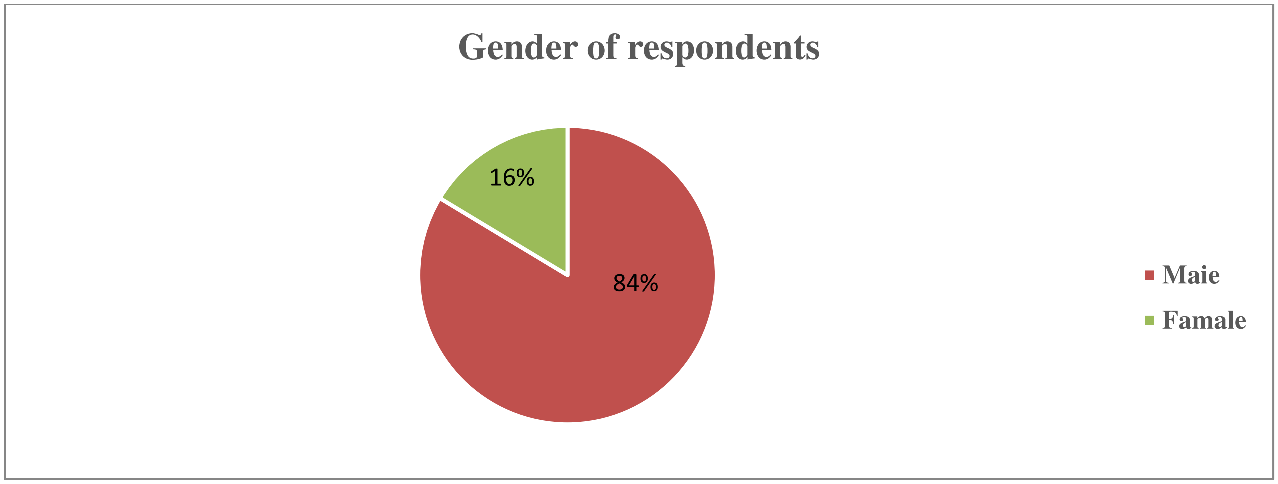

Figure 3. Gender of the respondents

Table 3. Age of respondents

Age	Frequency	Percent
18-28	20	18.2%
29-38	65	59.1%
39-48	24	21.8%
49-58	1	0.9%
Total	110	100%

As depicted in Table 3, with 59.1% of the sample as a whole, the age group with the largest percentage of responders was 29 to 38 years old. The age groups of 18 to 28 followed with 18.2% and 21.8%, respectively, followed by those aged 39 to 48. With no responders older than 49 to 58, this age group was the least represented, at 0.9%.

Table: 4. Level of education of respondents

Level of education	Frequency	Percent
TVET	39	35.5%
Diploma	20	18.2%
Degree and above	51	46.4%
Total	110	100%

The following is a summary of the staff members' educational backgrounds at the wastewater treatment facility: Every respondent had a high level of education. In particular, 46.4 % had a degree or higher, 18.2 % had a diploma, and 36.5 % had a Technical and Vocational Education and Training (TVET) certification. Interestingly, all WWTP personnel had finished at least a TVET program or earned a university degree in Ethiopia, as evidenced by the fact that none of the respondents lacked formal education (Table 4).

Table: 5. Distribution of level of experience of respondents

level of experience	Frequency	Percent
1-5	53	48.2%
6-10	53	48.2%
11-15	4	3.6%
Total	110	100%

In table 5, Out of the 110 people who answered the survey, 53 (48.2%) said they had between one and five years of experience, and none said they had less than a year. There were also 53 respondents (48.2%) who reported having 6–10 years of experience and 4 respondents (3.6%) who reported having 11–15 years. These results imply that workers at the wastewater treatment plant operated by the Addis Ababa Water and Sewerage Authority (AAWSA) lack sufficient experience in the sector, especially when compared to the experience needed for environmental management and wastewater treatment, particularly in developing nations (sign Frank Van Der Valk & Work, 2020).

Table 6. List of wastewater treatment plants in Addis Ababa

Name of wwtp	Frequency	Percent	Valid Percent	Cumulative Percent
Akaki kality municipal wwtp	34	30.9	30.9	30.9
Kality Chefe (Genet) condominium wwtp	18	16.4	16.4	47.3
Kilinto condominium wwtp	11	10.0	10.0	57.3
Bole arabsa 1A condominium wwtp	5	4.5	4.5	61.8
Bole arabsa 2A condominium wwtp	9	8.2	8.2	70.0
Bole arabsa 2B condominium wwtp	12	10.9	10.9	80.9
Bole bulbula condominium wwtp	7	6.4	6.4	87.3
Kara kore condominium wwtp	4	3.6	3.6	90.9
Degnet condominium wwtp	4	3.6	3.6	94.5
Haile garment Oromia condominium wwtp	3	2.7	2.7	97.3
Mekanisa kotari condominium wwtp	3	2.7	2.7	100.0
Total	110	100.0	100.0	

Response rates from 110 employees of 11 municipal/condominium WWTPs were gathered from the questionnaires that were distributed. 34 or 30.9% of respondents were from Akaki Kali Municipality; 18 or 16.4% were from Chefe (Genet) condominium; 11 or 10% were from Kilinto condominium; 5 or 4.5% were from Bole Arabsa 1A condominium; 9 or 8.2% were from Bole Arabsa 2A condominium; 7 or 6.4% were from Bole Bulula condominium; and Haile garment Mekanisa Kotari condominium 3 or 2.7%, Kara Kore condominium 4 or 3.6%, Degenet condominium 4 or 3.6%, and Oromia condominium 3 or 2.7% responses. Bole Arabsa 2B condominium 12, or 10.9%, of the respondents do not work here for a variety of reasons, including non-functional TP, according to the AAWSA (Table 6).

Table 7. The respondent's job position

S/N	Job position	Frequency	Percent	Valid Percent	Cumulative Percent
1	Plant manager	11	10.0	10.0	10.0
2	Operation supervisor	13	11.8	11.8	21.8
3	laboratories	20	18.2	18.2	40.0
4	Operator	45	40.9	40.9	80.9
5	EHS	5	4.5	4.5	85.5
6	Electromechanical	6	5.5	5.5	90.9
7	Mechanical	10	9.1	9.1	100.0
	Total	110	100.0	100.0	

There were responses to all 110 of the questionnaires that were issued, yielding a 100% response rate. From the 11 municipal/condominium wastewater treatment plant sites, the sample comprised 45 operators, 20 laboratory technicians, 13 operational supervisors or team leaders, 11 plant managers, 10 mechanics, 6 electromechanical engineers, and 5 environmental health and safety (EHS) specialists. Notably, 20 laboratory specialists work for the municipal and condominium wastewater treatment facilities in Kality and Chefe, performing water quality tests every 15 to 30 days (Table 7).

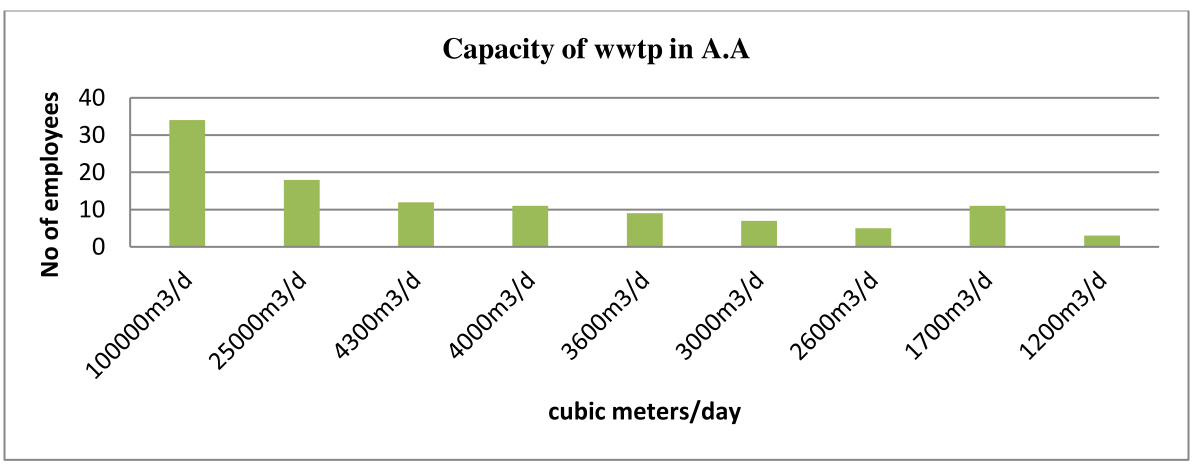

Figure 4. Standard capacity of WWTP

As indicated in Fig, 4, eleven wastewater treatment facilities (WWTPs) and their individual treatment capacity are included in the study based on the data gathered. The following are the presumed standard capacities: The combined capacity of the Mekanisa Kotari, Kara Kore, and

Deganet WWTPs is 1,700 m³/d. Kality WWTP has a capacity of 100,000 m³/d, Chefe WWTP has a capacity of 25,000 m³/d, Bole Arabsa 2B WWTP has a capacity of 4,300 m³/d, Kilinto WWTP has a capacity of 4,000 m³/d, Bole Arabsa 2A WWTP is 3,600 m³/d, Bole Bulbula WWTP is 3,000 m³/d, and Bole Arabsa 1A WWTP has a capacity of 2,600 m³/d. With a capacity of 1,200 m³/d, the Haile Garment Oromia WWTP has the smallest capacity. It's crucial to remember that not all plants are running at full capacity at the moment; Bole Arabsa 2B (4,300 m³/d) is not. Previous research have documented this reduction in therapeutic capacities.(Zhang et al., 2016).

Table 8. Current status of capacity WWTP in A.A

Cubic meter/day	Frequency	Percent	Valid Percent	Cumulative Percent
80000m3/d-70000m3/d	34	30.9	30.9	30.9
3000m3/d-2000m3d	18	16.4	16.4	47.3
2000m3/d-1000m3/d	27	24.5	24.5	71.8
1000m3/d-100m3/d	19	17.3	17.3	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

The 11 wastewater treatment plants (WWTPs) in the study area have a range of treatment capacity, according to the analysis of the questionnaire data that was gathered. The WWTPs are currently in the following operational state: Kality wwtp 80000m3-70000m3/d, Chefe wwtp 3000m3-2000m3/d Bole arabsa 2B wwtp not functional, Kilinto wwtp 2000m3-1000m3/d, Bole arabsa 2A wwtp 2000m3-1000m3/d, Bole bulbula 2000m3-1000m3/d, Bole arabsa 1A 1000m3-100m3/d, (Mekanisa Kotari, Kara Kore and Deganet wwtp) 1000m3-100m3/d and Haile garment Oromia wwtp 1000m3-100m3/d (Table 8). Notably, the Akaki Kality WWTP had the largest treatment capacity, with the remaining WWTPs having treatment capacities less than half of the maximum operational capacity of the Akaki Kality WWTP. Furthermore, the findings indicate that the Bole Arabsa 2B WWTP is not operational. These results are consistent with the suggestion of Onu *et al.,* (2023), which states that treatment capacity is positively correlated with a country's level of economic development.

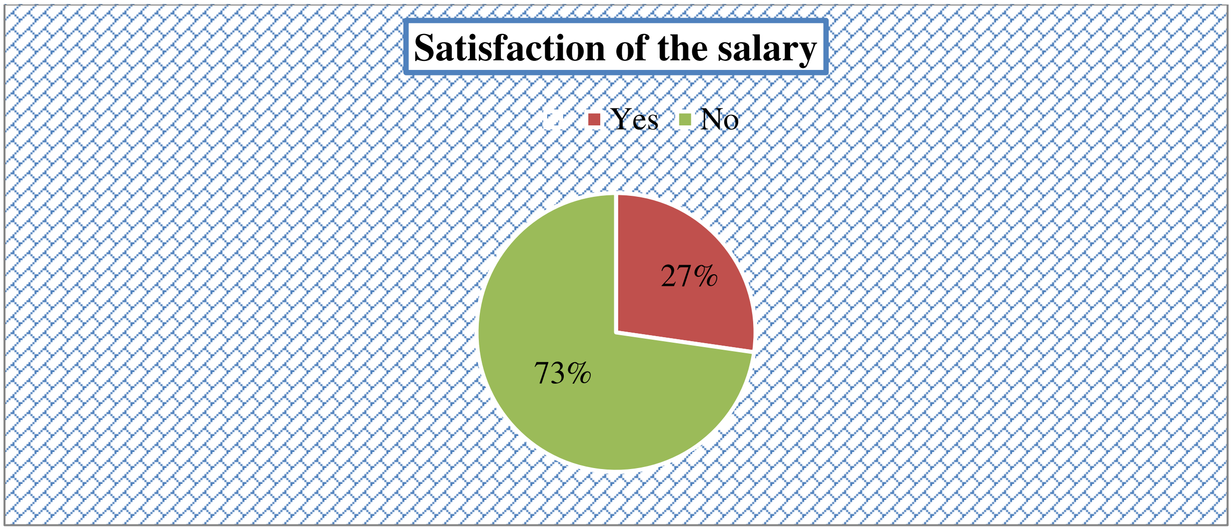

Figure 5. Satisfaction of salaries

Although pay at government offices are typically regarded as satisfactory, an analysis of the data gathered shows that they fall short of the present cost of living. Out of the 110 employees that participated in the study, 30 (27.3%) said they were satisfied with their pay, while 80 (72.7%) said they were not. This discrepancy raises the possibility that a sizable section of the workforce is unmotivated to carry out their jobs well. Such demotivation might have a negative impact on the wastewater treatment plant's operational effectiveness (Fig. 5).

Table 9. The pretreatment and primary treatment processes utilized

The pretreatment and primary treatment processes utilized					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	All	97	88.2	89.0	89.0
	Not function	12	10.9	11.0	100.0
	Total	109	99.1	100.0	
Missing	No answer	1	0.9		
Total		110	100.0		

In table 9, all respondents participated in the pretreatment and main procedures, according to data gathered from 110 employees at 11 wastewater treatment facilities. Among these, 97 workers (88.2%) stated that, aside from the Akaki Kality Wastewater Treatment Plant, their establishments did not use cutting-edge technology. Furthermore, 12 workers (10.9%) at the Bole Arabsa 2B treatment plant stated that their facility was not operating, while one worker did not respond.

Table 10. Secondary treatment process

Secondary process	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	98	89.1	89.1	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

Based on the information gathered, 110 workers from 11 wastewater treatment facilities participated in the survey. 98 (89.1%) of the respondents said they used secondary water treatment methods. But while some treatment facilities have state-of-the-art equipment, others are hampered by problems like outdated infrastructure and inadequate equipment, which make it difficult for them to provide efficient services. Key wastewater treatment systems are at serious risk of losing their effectiveness due to this lack of assistance. Furthermore, 12 (10.9%) of the workers at the Bole Arabsa 2B treatment plant reported that the facility was not operating. MBR systems integrate biological treatment with membrane filtration to produce high-quality effluent suitable for reuse by effectively removing suspended solids and microorganisms. Both Akaki Kality and Chefe Genet WWTPs employ MBR processes, while other plants, including Kilinto, Degenet, Kara Kore, Haile Garment Oromia, Mekanisa Kotari, Bole Bulbula, and Bole Arabsa (1A, 2A, 2B), also utilize similar systems (table 10). These secondary treatment processes are essential for meeting regulatory standards regarding wastewater quality, significantly reducing organic pollutants and pathogens before discharge or reuse, as highlighted by (Estrada et al., 2011), who noted their widespread adoption for emerging contaminants (ECs) removal globally

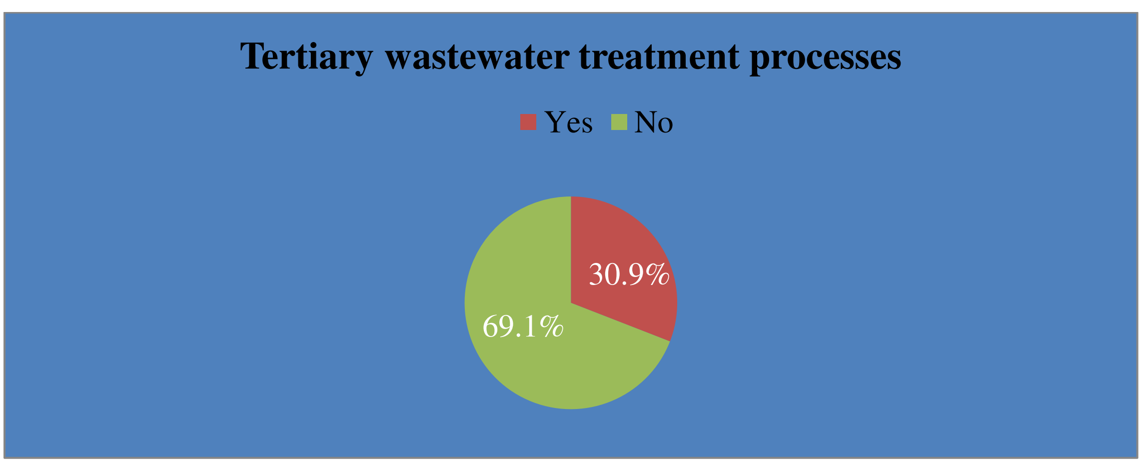

Figure 6. Tertiary wastewater treatment processes

As depicted in Fig. 6, Only 34 responders (30.9%) from the Akaki Kality treatment plant use tertiary wastewater treatment, according to data gathered from 11 municipal/condominium wastewater treatment plants (WWTPs). This system lacks sophisticated filtration techniques including reverse osmosis, ultrafiltration, microfiltration, and microfiltration, as well as disinfection and chlorination. Moreover, financial limitations impede additional purification initiatives. The other 10 WWTPs, on the other hand, had 76 respondents (69.1%) who said they lacked tertiary wastewater treatment systems. According to these results, the majority of respondents do not have access to tertiary treatment technologies, albeit a small percentage does. Tertiary wastewater treatment is advised in order to improve purification. Furthermore, it is important to monitor the amount and quality of wastewater released into adjacent rivers or open channels due to possible (Saraswati et al., 2021). More research may be done to determine the reasons behind the presence or absence of tertiary treatment processes and how they affect water quality and the ecosystem.

Table 11. Factors affecting the functionality of wastewater treatment plan

Factors affecting the functionality of wastewater treatment plant					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Lack of proper maintenance	4	3.6	3.6	3.6
	Insufficient funding and resources	1	0.9	0.9	4.5
	Inadequate technology or outdated equipment	3	2.7	2.7	7.3
	Population growth	7	6.4	6.4	13.6
	Industrial pollution	5	4.5	4.5	18.2
	Community awareness	23	20.9	20.9	39.1
	9	7	6.4	6.4	45.5
	All	48	43.6	43.6	89.1
	Not functional	12	10.9	10.9	100.0
	Total	110	100.0	100.0	

Based on 110 participants' responses in table 11, the table lists the variables affecting wastewater treatment plants' operation. Interestingly, 48 respondents (43.6%) said that a variety of factors work together to affect plant operations, demonstrating how interconnected these issues are. Community awareness was mentioned by 23 respondents (20.9%) as a problem. Opposition to operations and insufficient funding for essential modifications might result from a lack of community awareness or support. Employees at the plant also mentioned that substantial operational difficulties are brought on by superfluous or solid waste donations from the neighborhood. Because growing populations result in increasing wastewater volumes, which put strain on the plant's treatment capacity, seven respondents (6.4%) cited population growth as a worry. Local farming operations use untreated water, which restricts the amount of wastewater that enters the treatment facility, according to seven respondents (6.4%). Five responders (4.5%) emphasized that industrial pollution frequently involves complex contaminants that call for more advanced treatment techniques. Inadequate maintenance was cited by 4 respondents (3.6%) as a contributing factor, leading to equipment malfunctions and reduced treatment effectiveness. Insufficient finance and resources were mentioned by one respondent (0.9%) as a hindrance to effective operations. Three responders (2.7%) mentioned problems resulting from antiquated machinery or insufficient technology that impairs plant operation. Furthermore, 12 respondents (10.9%) mentioned, without providing specifics, a variety of variables that negatively impact functionality. These results highlight how important it is to address maintenance procedures, financial constraints, technology advancements, and community involvement in order to improve wastewater treatment plant operational efficiency and guarantee adherence to environmental and health regulations. According to Japanese rules, when choosing treatment techniques, environmental conditions at the treatment location must be taken into account (Japan Sewage Works Association, 2013) and Waste effluent and emission impacts: The land, aquatic, and atmospheric impact of the selected odor-abatement technologies as a result of process operation was also assessed (Estrada et al., 2011).

Table 12. Wastewater treatment equipment malfunctioned or breakdowns

wastewater treatment equipment malfunctioned or breakdowns					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	84	76.4	76.4	76.4
	No	14	12.7	12.7	89.1
	Not functional	12	10.9	10.9	100.0
	Total	110	100.0	100.0	

An overview of the results in table 12, the study included 110 responders from 11 wastewater treatment plants (WWTPs). Their experiences with equipment malfunctions or breakdowns are summed up in the following results:

Equipment malfunctions or failures were reported by 84 respondents (76.4%), which could have resulted in inefficiencies, higher maintenance costs, and disruptions to the treatment process.

Due to properly maintained equipment or efficient treatment system operation, 14 respondents (12.7%) reported no experience with equipment malfunctions or breakdowns.

Implications: According to the research, equipment failures or malfunctions are a frequent problem in WWTPs. For treatment facilities to operate dependably and effectively, these problems must be addressed as soon as possible through routine maintenance and preventative actions (Zaware & Kumar, 2018). The current infrastructure is frequently insufficient, badly maintained, and unable to accommodate the demands of an expanding population.

Table 13. Challenges related to the disposal or management of treated wastewater effluent

Challenges related to the disposal or management of treated wastewater effluent					
Disposal challenge		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes, dewatering not function	68	61.8	66.7	66.7
	No	22	20.0	21.6	88.2
	Not functional	12	10.9	11.8	100.0
	Total	102	92.7	100.0	
Missing	No answer	8	7.3		
Total		110	100.0		

Based on responses from 110 participants at 11 wastewater treatment plants (WWTPs), the table shows information on the difficulties faced in the management and disposal of treated wastewater effluent. 68 (61.8%) of these respondents said they had encountered difficulties, mainly related to the dewatering procedure, which is necessary to remove surplus water from sludge or treated wastewater prior to disposal. Particularly in smaller communities, efficient dewatering technology is essential, and it should preferably be easy to operate. It is far more difficult to manage and dispose of treated wastewater when dewatering pumps are not operating (Wall, 2021). On the other hand, 22 respondents (20.0%) said they do not face these difficulties, which may imply that they have alternate disposal techniques or dependable dewatering systems in place. Furthermore, 12 respondents (10.9%) stated that they were unable to provide useful answers about disposal difficulties; however, it is unclear why this was the case. Additionally, it is unclear why 8 respondents (7.3%) chose not to react by not disclosing any information regarding their difficulties (table 13). After treating wastewater, certain treatment facilities encourage the use of dried sludge as fertilizer. After effluent processing, there were worries that some filtration stations would become contaminated by industrial contaminants.

Table 14. Concerns about the aging machine of the wastewater treatment plant

concerns about the aging machine of the wastewater treatment plant					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	82	74.5	75.2	75.2
	No	15	13.6	13.8	89.0
	Not functional	12	10.9	11.0	100.0
	Total	109	99.1	100.0	
Missing	No answer	1	0.9		
Total		110	100.0		

Data on issues with aging equipment at wastewater treatment facilities is shown in the table. 82 (74.5%) of the 110 respondents from 11 WWTPs voiced worries about aging equipment, which can lead to lower efficiency, more maintenance requirements, a higher chance of breakdown, and expensive repairs. However, 15 respondents (13.6%) said they had no worries, which might be because of their relatively new equipment or aggressive maintenance procedures. Furthermore, 1 respondent (0.9%) did not respond, and 12 respondents (10.9%) stated that their replies pertaining to aging machinery were non-functional (table 14). The significance of resolving these challenges to guarantee the dependability and effectiveness of plant operations is shown by the large number of respondents who expressed concern about aging gear. To lessen the effects of aging machinery, proactive maintenance, equipment upgrades, and strategic planning are essential. Future research should concentrate on particular aging-related issues that respondents mentioned as well as possible approaches to preserving plants' peak performance.

Table 15. Challenges faced in the day-to-day operation of the treatment plant

	Challenges faced in the day-to-day operation of the treatment plant			
Challenges day to day	Frequency	Percent	Valid Percent	Cumulative Percent
Equipment malfunctions	2	1.8	1.8	1.8
Sludge management	6	5.5	5.5	7.3
Energy consumption	3	2.7	2.7	10.0
Odor challenge	8	7.3	7.3	17.3
Aging infrastructure	2	1.8	1.8	19.1
Spare part	5	4.5	4.5	23.6
All	72	65.5	65.5	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

As depicted in table 15 above, the difficulties encountered in day-to-day operations were determined by analyzing data from 110 respondents in 11 WWTPs. interestingly, 72 respondents (65.5%) said they had experienced more than one problem. Odor control (7.3%), sludge management (5.5%), trouble finding replacement parts (4.5%), energy consumption problems (2.7%), and broken equipment (1.8%) were among the specific difficulties. Furthermore, 2 respondents (1.8%) mentioned problems with aging infrastructure, while 12 respondents (10.9%) said that operational and monitoring systems were non-functional. It was observed that a lack of specific knowledge for maintaining particular technologies, like MBR installations and dewatering systems, is the root cause of some serious issues.

Table 16. Wastewater treatment plant affected by fluctuations of wastewater flow rates

wastewater treatment plant affected by fluctuations of wastewater flow rates					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	95	86.4	88.8	88.8
	Not functional	12	10.9	11.2	100.0
	Total	107	97.3	100.0	
Missing	No answer	3	2.7		
Total		110	100.0		

Data on the effects of variations in wastewater flow rates on treatment facilities are included in the table. 95 (86.4%) of the 110 respondents from 11 wastewater treatment facilities (WWTP) stated that plant operations are impacted by variations in flow rates. These variations have the potential to impair treatment effectiveness, call for operational modifications, and result in overburdening or underutilization of treatment facilities. Three respondents (2.7%) did not respond to the question, and twelve respondents (10.9%) said their estimates of the effects of flow rate were not functional (Table 16). Overall, a sizable majority of respondents said that WWTPs face difficulties due to flow rate changes. Maintaining treatment performance, dependability, and regulatory compliance requires effective control of these changes. Specific tactics used by responders to lessen the effects of flow rate fluctuations on plant operations could be the subject of future research.

Table 17. Safety and health assurance

Safety and health assurance				
Safety assurance	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	31	28.2	28.2	28.2
No	67	60.9	60.9	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

In table 17, data on safety assurance procedures was supplied by 110 respondents from 11 wastewater treatment plants (WWTPs). Sixty-seven (60.9%) of them said there were no safety assurance mechanisms in place. On the other hand, 31 respondents, or 28.2%, said that safety assurance protocols were in existence. Remarkably, 12 Bole Arabsa 2B WWTP respondents

(10.9%) said that the current safety protocols were ineffective. Given the hazardous nature of the workplace, concerns were voiced about the lack of focus on employee health and safety. This implies that a tiny minority of respondents acknowledged the existence of safety measures, but their poor implementation, while the majority indicated a lack of safety guarantee. The results point to important areas where the facility's safety procedures need to be improved in order to safeguard worker welfare and guarantee adherence to safety rules. To determine the reasons behind the lack of efficient safety assurance procedures and to create plans for raising workplace safety standards, more research is necessary.

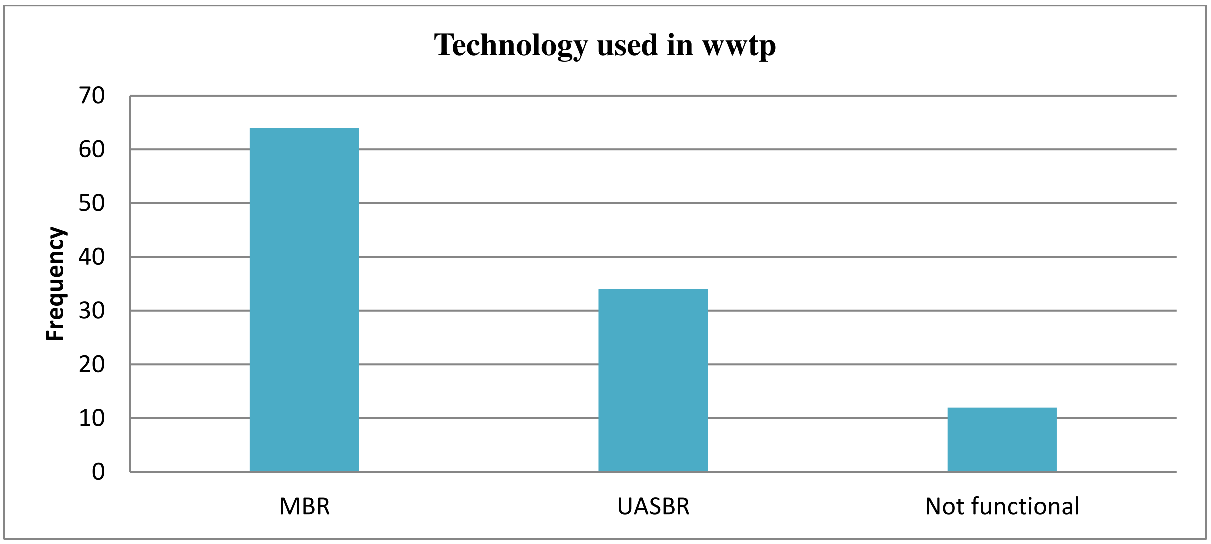

Figure 1 Technology used in WWTP

As indicated in Fig. 7 above, the technologies used in wastewater treatment facilities (WWTPs) are shown in the table. Sixty-four (58.2%) of the 110 respondents, who represented 11 WWTPs, reported deploying Membrane Bioreactor (MBR) technology in nine different facilities. Drive, Moore, (2021) claim that MBR systems combine membrane filtration and biological treatment to effectively remove pollutants and produce high-quality effluent. 34 respondents, or 30.9%, however, stated that their WWTPs used Up Flow Anaerobic Sludge Blanket Reactor (UASBR) technology. Anaerobic reactors known as UASBRs treat wastewater by using microbial activity to break down organic matter without oxygen. This process produces less sludge and uses less energy (Francisco de Assis Martins Ponce et al., 2018). All things considered, the statistics show that MBR is the more commonly used technology, while UASBR is the secondary technology used in the WWTPs surveyed. By offering practical and efficient wastewater treatment options, these technologies support public health and environmental preservation.

Table 18. Concerns about the capacity or efficiency of wastewater treatment processes to meet current or future demand

concerns about the capacity or efficiency of wastewater treatment processes to meet current or future demand					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	71	64.5	67.0	67.0
	No	23	20.9	21.7	88.7
	Not functional	12	10.9	11.3	100.0
	Total	106	96.4	100.0	
Missing	No answer	4	3.6		
Total		110	100.0		

Table 18 above, presents data on concerns regarding the capacity and efficiency of wastewater treatment processes in relation to current and anticipated demand. Among the 110 respondents from 11 wastewater treatment plants (WWTPs), 71 respondents (64.5%) expressed apprehensions about their treatment facilities' ability to manage increasing wastewater volumes and comply with regulatory standards. This indicates a significant majority of respondents are worried about the adequacy of their facilities. In contrast, 23 respondents (20.9%) reported they do not have concerns, suggesting confidence in the capabilities of their treatment plants to meet present and future requirements. Additionally, 12 respondents (10.9%) provided non-functional responses regarding concerns about capacity and efficiency, although the reasons for this are unclear. Four respondents (3.6%) did not answer this question, and their rationale also remains unknown. The data highlights a critical issue, as substantial concern exists about the capacity and efficiency of wastewater treatment processes. Factors contributing to these apprehensions may include population growth, industrial expansion, aging infrastructure, and evolving regulatory standards. Addressing these concerns is vital for ensuring that wastewater treatment facilities can effectively manage effluent and safeguard public health and environmental integrity. Further investigation should focus on strategies for upgrading or expanding facilities to mitigate these capacity and efficiency challenges, thus better meeting future demands (Narayan & Charles, 2017). Rapid urbanization often strains sanitation infrastructure, underscoring the urgency of addressing these issues.

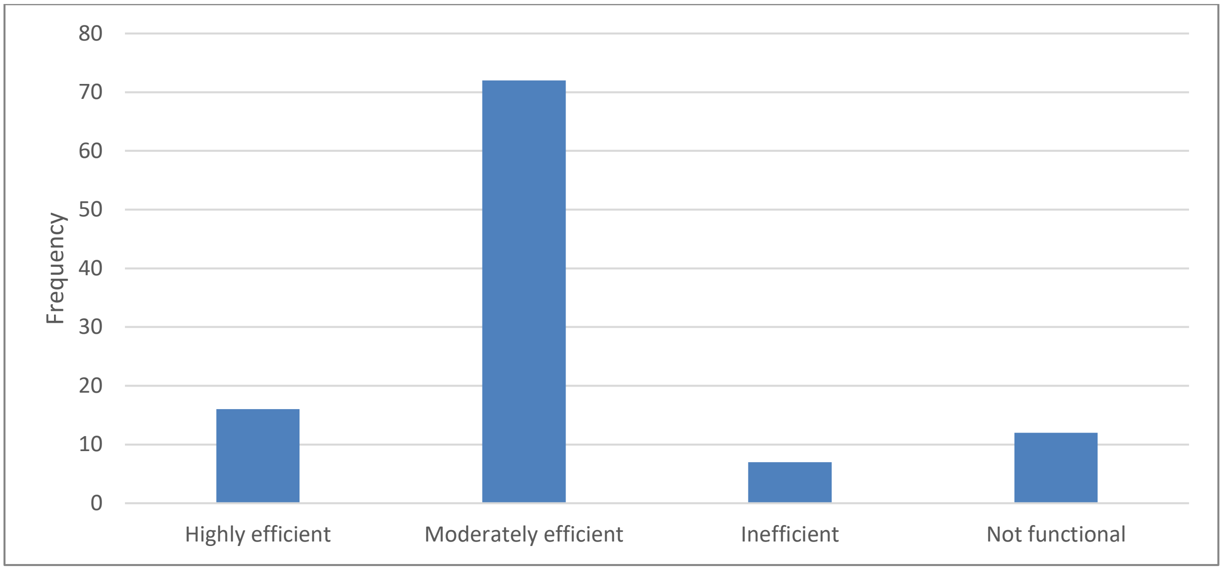

Figure 2. Rate of the efficiency of wastewater treatment plants in treating wastewater

As displayed in Fig 8, information based on 110 respondents' opinions about the effectiveness of Addis Ababa's wastewater treatment plants (WWTPs). 72 respondents (65.5%) rated these facilities' efficiency as "Moderately efficient," suggesting that most people think the treatment procedures are sufficient, though there may be room for improvement. On the other hand, 16 respondents (14.5%) gave the WWTPs a rating of "Highly efficient," indicating that this group believes the plants are capable of continuously producing high-quality wastewater. In contrast, 12 respondents (10.9%) declined to provide a functional rating, presumably because of the operational status of the WWTPs or the lack of information, and 7 respondents (6.4%) characterized the WWTPs as "Inefficient," expressing concerns about the efficacy of these facilities in carrying out their treatment responsibilities and complying with regulatory standards. Overall, the predominant perception among respondents is that WWTPs in Addis Ababa operate at a moderate level of efficiency. Further research is warranted to investigate the specific factors influencing these perceptions and to identify potential improvements in treatment plant performance.

Table 19. Frequently WWTP operate and monitor

Frequently is the wastewater treatment plant operated and monitored				
Frequently operate and monitor	Frequency	Percent	Valid Percent	Cumulative Percent
Continuous operation	32	29.1	29.1	29.1
Daily operation	27	24.5	24.5	53.6
Regular maintenance	10	9.1	9.1	62.7
Continuous monitoring	5	4.5	4.5	67.3
Emergency response	19	17.3	17.3	84.5
All	5	4.5	4.5	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

The operational frequencies of wastewater treatment plants (WWTPs) were assessed among 110 respondents from 11 WWTPs. The results indicated that 29.1% (n = 32) of respondents reported continuous operation, while 24.5% (n = 27) and 17.3% (n = 19) reported daily and emergency response operations, respectively. Additionally, 9.1% (n = 10) and 4.5% (n = 5) of respondents reported regular maintenance activities and continuous monitoring, respectively. Notably, 4.5% (n = 5) of respondents reported that their WWTPs operated at all of the mentioned frequencies.

However, 10.9% (n = 12) of respondents from the Bole Arabsa 2B WWTP reported that their operation and monitoring systems were non-functional(Table 19). These findings suggest that WWTPs exhibit a range of operational frequencies, with daily and continuous operation being the most common. The high prevalence of emergency response activities highlights the importance of preparedness for unexpected events. Furthermore, the reported non-functionality of operation and monitoring systems at some WWTPs underscores the need for improved plant management and maintenance. Future studies should investigate the underlying reasons for the observed frequency ranges and evaluate their effectiveness in ensuring the efficient operation of WWTPs.

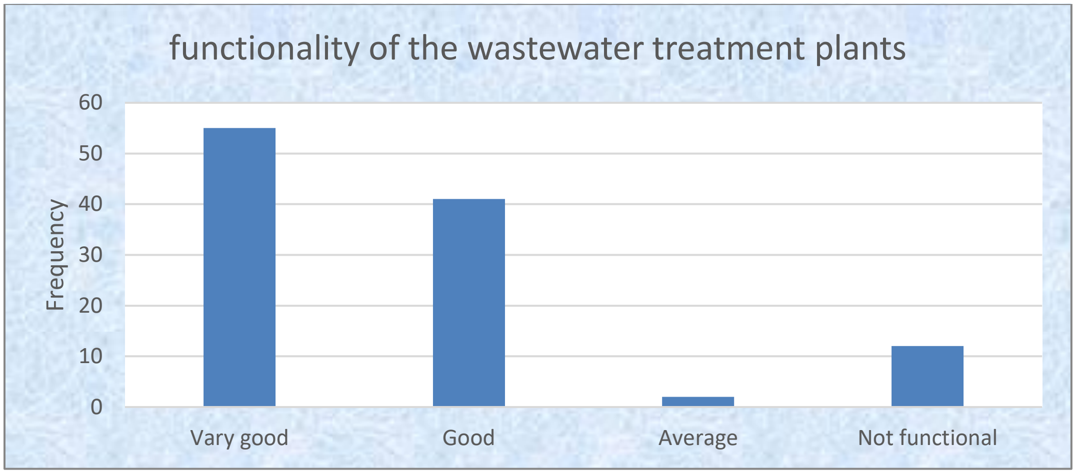

Figure 3. Functionality of the wastewater treatment plants

Fig. 9 above provides data based on 110 how respondents 11 WWTP would rate the overall functionality of the wastewater treatment plants they have visited. 55 respondents (50.0%) rated the overall functionality of the wastewater treatment plants they have visited as "Very good." This suggests that a majority of respondents found the treatment plants they visited to be highly effective and efficient in their operations. 41 respondents (37.3%) rated the overall functionality of the treatment plants as "Good." This indicates that a significant portion of respondents considered the treatment plants to be performing well, although perhaps with some room for improvement. 2 respondents (1.8%) rated the overall functionality of the treatment plants as "Average." This suggests that a small minority of respondents perceived the treatment plants they visited to have moderate performance, neither exceptional nor poor. 12 respondents (10.9%) indicated that their responses regarding the overall functionality of the treatment plants were not functional. It's unclear why these respondents provided this response, but it may indicate that they did not have sufficient information to provide a rating or that the treatment plants they visited were not operational.

The majority of respondents had positive perceptions of the overall functionality of the wastewater treatment plants they have visited, with a significant portion rating them as "Very good" or "Good." However, there is a small minority of respondents who rated the functionality as "Average" or indicated that the plants were not functional.

Table 20. Ensure compliance with environmental regulations and standards

	Ensure compliance with environmental regulations and standards			
Environmental regulation and	Frequency	Percent	Valid Percent	Cumulative Percent

standard				
Regulatory knowledge and awareness	34	30.9	30.9	30.9
Monitoring and reporting	41	37.3	37.3	68.2
Emergency preparedness and response	23	20.9	20.9	89.1
Not functional	12	10.9	10.9	100.0
Total	110	100.0	100.0	

As seen in table 20, Out of 110 responses collected from 11 wastewater treatment plants (WWTPs), 41 respondents (37.3%) indicated that they implemented reporting and monitoring actions to ensure regulatory compliance. This underscores the critical importance of regular oversight of plant operations and the submission of pertinent reports to regulatory authorities as a means of demonstrating adherence to environmental standards. Furthermore, 34 participants (30.9%) acknowledged their awareness and understanding of relevant regulations, suggesting that a significant proportion of respondents rely on ongoing education and awareness of legislative frameworks to maintain compliance. Additionally, 23 respondents (20.9%) reported having emergency response and preparedness strategies in place, indicating that some facilities prioritize proactive measures to anticipate and manage potential environmental issues in order to uphold regulatory standards. This assertion is supported by previous research (Rajaona et al., 2023), which emphasizes the vital role of wastewater treatment plants in promoting sustainable development and safeguarding environmental integrity.

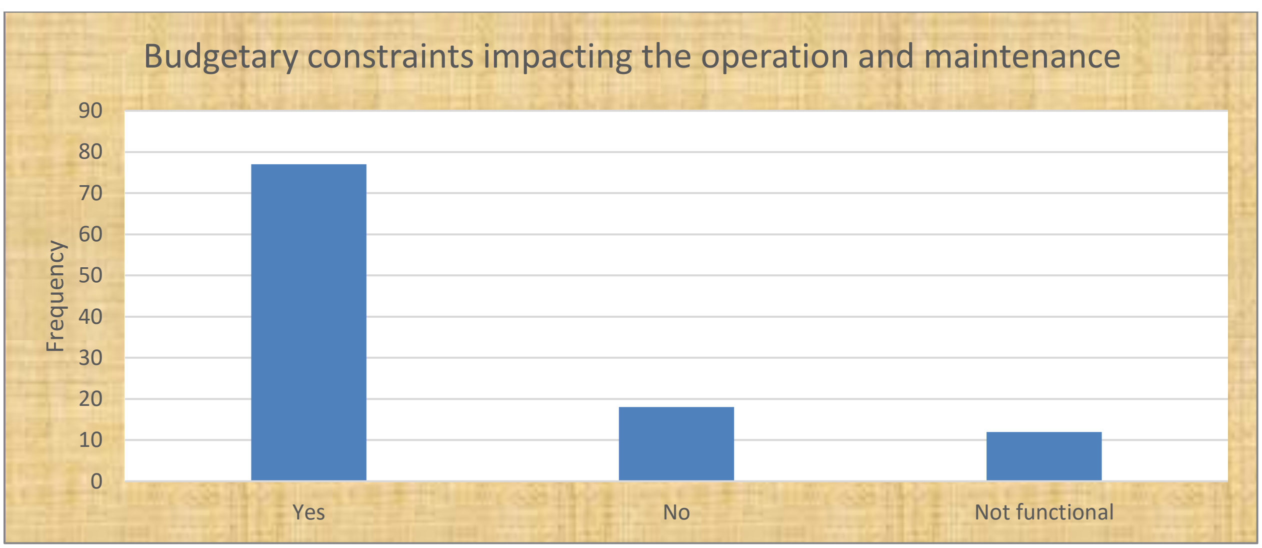

Figure 10. Budgetary constraints impacting the operation and maintenance

Fig.10 above, illustrates data collected from 110 participants regarding the financial constraints impacting the maintenance and operation of wastewater treatment plants (WWTPs). Of the respondents, 77 individuals (70.0%) indicated that budgetary limitations significantly influenced the upkeep and functionality of their respective WWTPs. This finding suggests that a substantial proportion of participant's experience financial restrictions which adversely affect the maintenance and operational efficiency of their facilities. In contrast, 18 respondents (16.4%) reported that their budgetary constraints did not impede the upkeep and functioning of the WWTP. Additionally, 12 respondents (10.9%) expressed that their insights regarding fiscal limitations were not applicable, although the rationale for their responses remains ambiguous. Furthermore, 3 respondents (2.7%) did not provide a definitive answer concerning financial constraints. As noted by (Castellet & Molinos-Senante, 2016), it is essential to recognize that wastewater treatment services are funded by citizens through water tariffs, and enhancing the efficiency of WWTPs yields significant societal benefits.

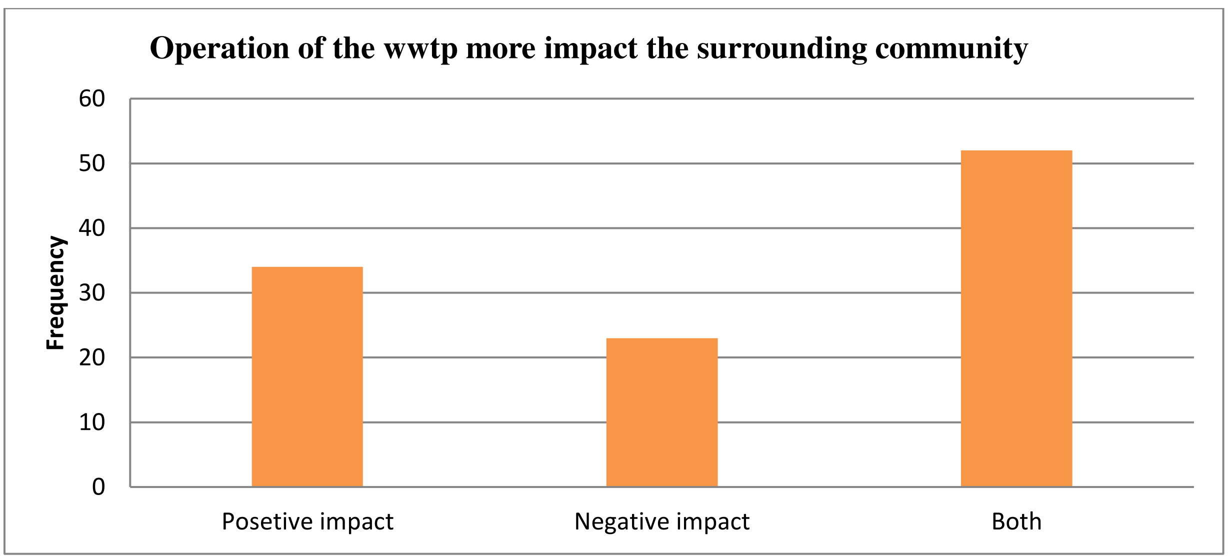

Figure 11. Operation of the WWTP more impact the surrounding community

Based on data gathered from 110 respondents associated with 10 wastewater treatment plants (WWTPs), 34 respondents (30.9%) reported that the operation of their respective WWTP has a positive impact on the surrounding community. This indicates that these facilities may enhance community welfare in several ways, including improvements in water quality, reductions in environmental pollution, and the creation of employment opportunities for local residents. In contrast, 23 respondents (20.9%) indicated that the operation of the WWTP had a negative impact on the surrounding community. Such negative effects could encompass issues such as odorous emissions, noise pollution, and visual disturbances that may adversely affect the quality of life and health of nearby residents. Notably, in instances where WWTPs are no longer functional, as exemplified by the Bole Arabsa 2B site, a more pronounced negative impact was reported, with 12 respondents (10.9%) acknowledging adverse effects on the community. A significant portion of the respondents, 52 individuals (47.3%), indicated that the operation of the WWTP presented both positive and negative impacts on the community. Additionally, one respondent (0.9%) did not provide a response (Fig.11). This signifies that the effects of WWTP operations are multifaceted, with some community members experiencing benefits while others encounter challenges, depending on various factors such as location and timing of the impacts. Municipal wastewater discharge arises from households within the community, which is conveyed through a network of pipes and manholes to the treatment facility (Saraswati et al., 2021). Overall, these findings underscore the complex dynamics of wastewater treatment operations and their differential impacts on community members.

Table 21. Complaints or concerns lift up by residents regarding the treatment plant

Complaints or concerns lift up by residents regarding the treatment plant					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Odor	60	54.5	54.5	54.5
	Untreated discharge WW	10	9.1	9.1	63.6
	Noise pollution	3	2.7	2.7	66.4
	Sludge discharge	25	22.7	22.7	89.1
	Not functional	12	10.9	10.9	100.0
	Total	110	100.0	100.0	

As depicted in able 21 above, a survey of 110 residents revealed that odor emissions from wastewater treatment processes (WWTPs) were a significant concern for nearby residents, as reported by 60 respondents (54.5%). The potential environmental contamination and odor associated with sludge discharge also garnered attention from 25 respondents (22.7%).

Additionally, 10 respondents (9.1%) raised concerns about the untreated discharge of wastewater, highlighting the need for effective treatment plant operations to prevent environmental and health impacts. Furthermore, 3 respondents (2.7%) mentioned noise pollution as a concern, emphasizing the disruption to the peaceful environment caused by treatment plant noise. The concerns expressed by the community underscore the importance of addressing these issues to maintain positive relations and ensure the sustainable operation of the WWTP. Notably, a study by (Saeidi et al., 2017) highlighted the challenges of municipal WWTPs in meeting increasing demands due to population growth, environmental pollutants, and water scarcity, particularly in warm and dry areas.

Table 22: Specific challenges or limitations you have observed regarding the technology or efficiency of WWTP

Specific challenges or limitations you have observed regarding the technology or efficiency of wwtp

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	92	83.6	83.6	83.6
	No	6	5.5	5.5	89.1
	Not functional	12	10.9	10.9	100.0
	Total	110	100.0	100.0	

Based on 110 participants from 11 WWTP, the study examined obstacles or constraints on efficiency 92 respondents, or 83.6 percent, said they have seen particular difficulties or restrictions with the technology or effectiveness of WWTPs (table 22). This indicates that a significant proportion of participants have recognized concerns with technology or operational effectiveness, which might potentially affect the effectiveness of wastewater treatment procedures. Furthermore, 12 respondents (10.9%) said that the answers they provided on the difficulties or constraints they faced were ineffective. The reason for these respondents' reaction is unclear. No Obstacles or Restrictions: 6 respondents (5.5%) said they had not seen any particular difficulties or restrictions with relation to the efficiency or technology of WWTPs. It's probable that these individuals haven't run upon or recognized any problems specific to their situation.

The data suggests that many respondents and (Drive, Moore, 2021) similar to have identified challenges or limitations regarding the technology or efficiency of WWTPs. These challenges may include issues such as outdated equipment, technological limitations, inadequate treatment capacity, or inefficiencies in treatment processes. Addressing these challenges is essential for optimizing the performance and effectiveness of WWTPs in treating wastewater and protecting the environment and public health.

3.3. Focal Group Discussion (FGD)

During discussions with key informants, several insights were articulated concerning the wastewater treatment plant managed by the Addis Ababa Water and Sewerage Authority (AAWSA). The first point of discussion focused on the primary challenges faced by wastewater treatment facilities in effectively processing wastewater, emphasizing the significance of comprehensively understanding these obstacles to optimize plant operations. Furthermore, participants acknowledged the pivotal role these plants play in ensuring water quality. Another theme raised was the environmental impact of wastewater treatment plants, which is contingent upon several factors, including plant design, operational protocols, and adherence to regulatory standards. Participants emphasized the importance of collaboration with the AAWSA and other relevant stakeholders to enhance the technological efficiency of the treatment processes. It was noted that community engagement with the Addis Ababa Water and Sewerage Authority is vital for identifying areas requiring improvement and for implementing solutions to address these deficiencies. Moreover, the necessity of obtaining managerial and stakeholder feedback was highlighted to better grasp their needs and concerns.

The discourse also encompassed the environmental implications associated with wastewater treatment, underscoring its relevance to public health and overall quality of life. Participants stressed that the enterprise must prioritize public health considerations and community preferences when designing wastewater treatment facilities. Furthermore, the integration of stakeholder feedback was emphasized as a mechanism for identifying areas for enhancement and instituting relevant modifications. Factors influencing the technological efficiency of wastewater treatment in Addis Ababa were examined. Participants identified key impediments such as the unavailability of spare parts, insufficient infrastructure, inadequate regulatory enforcement, and limited funding for maintenance and expansion as significant barriers affecting operational efficiency.

To bolster water quality, safeguard public health, and ensure environmental integrity, participants proposed delineating the roles of various stakeholders. This included the government's responsibility to establish and enforce rigorous regulations and standards for wastewater treatment, the private sector's role in collaborating with government agencies to invest in wastewater infrastructure through public-private partnerships, and the community's role in promoting awareness regarding the significance of proper wastewater disposal and the effects of pollution on public health and the environment. Lastly, the participants deliberated potential solutions to mitigate the challenges associated with the current state of technology and the factors influencing its efficiency. Recommendations included increasing funding for maintenance and expansion initiatives, forming partnerships with the private sector to enhance service quality and infrastructure, rigorously enforcing regulations to promote safety and environmental compliance, and exploring innovative responses to existing challenges. Consequently, the discussions suggest that a feasibility assessment of the current status of wastewater treatment facilities is essential for safeguarding environmental impacts, aligning with the findings of the study.

Conclusion

In summary, the viability of wastewater treatment in Addis Ababa is contingent upon a multifaceted approach that includes the modernization of aging infrastructure, improved accessibility to necessary spare parts, and enhanced community awareness of wastewater management practices. A collaborative effort between government, industry, and community stakeholders is essential to address the outlined challenges. These initiatives should aim not only to ensure operational reliability and efficiency but also to mitigate the associated risks of environmental pollution and public health impacts. Continued investment in both technology and community engagement will be vital for the sustainable operation of WWTPs in the region

The analysis of the current operational status and viability of the eleven wastewater treatment plants (WWTPs) surveyed reveals a complex landscape affected by both technological and socio-environmental factors. While certain plants, such as the Akaki Kality WWTP, demonstrate effective management and operational consistency, others, particularly the Bole Arabsa 2B WWTP, face significant functional challenges. These include equipment malfunctions, aging infrastructure, and corrosion, all of which impede the treatment processes.

The survey indicated that all WWTPs implement pretreatment and primary treatment processes, with secondary treatment processes being commonly used but fraught with issues. The aging assets and a lack of renewal are prominent challenges that hinder overall operational efficiency, which underscores the need for improved maintenance practices. This is particularly critical given the increased pressures from population growth, local agricultural activities, and industrial contributions to wastewater loads, all of which further complicate the treatment landscape.

Technological analysis shows that the Membrane Bioreactor (MBR) technology is favored among the facilities due to its high efficiency in contaminant removal, while the Up Flow Anaerobic Sludge Blanket Reactor (UASBR) technology offers benefits such as energy savings and reduced sludge production. However, the land requirements for UASBR may limit its application in densely populated areas.

Ethics Approval

The study received ethical approval from the Kotebe University of Education Research Ethics Review committee, in accordance with the Ethiopia National Research Ethics Review Guideline (Fifth Edition).

Declaration of consent

Written informed consent was obtained from all participants who took part in the study, after explaining the purpose and significance of the research. Data collection proceeded only after obtaining fully informed verbal consent from the participants, and confidentiality measures were implemented to protect their privacy by excluding their names and personal identification information.

Funding Declaration

The authors declare that no external funding was received for the conduct of this study.

Data availability statement

The Data Availability statement of this manuscript, indicating that data can be requested from the corresponding author (Dessalew Berihun Adam, Email: berihun.dessalew@kue.edu.et).

Author contributions

Dessalew Berihun Adam: Conceptualization, Writing-review and editing data, curation. **Yidnekachew Abraham:** Methodology, Investigation, Writing original draft

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