
Impact of Industrial Waste water Management on Water Quality: A Case Study of Mukwano Industries

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Abstract

This study aimed to assess the impact of wastewater management practices at Mukwano Industries on water quality in the surrounding areas of Uganda. The research employed a mixed-method approach, utilizing descriptive statistics, paired t-tests, Chi-square tests, and compliance indices to evaluate the wastewater management practices and their impact on key water quality indicators, including pH, turbidity, BOD, and heavy metals. Data were collected from the company's wastewater treatment facilities and nearby water bodies, with a focus on identifying trends in wastewater management practices and their environmental effects. The results revealed that while Mukwano Industries had implemented several wastewater management practices, such as regular staff training and routine inspections of treatment systems, the adoption of advanced treatment technologies, such as chemical and tertiary treatments, was limited. As a result, significant degradation in water quality was observed, particularly in the increase of turbidity, BOD, and a decrease in pH in areas downstream of the wastewater discharge point. The paired t-test results indicated significant changes in these water quality parameters before and after wastewater discharge, reinforcing the negative impact of industrial wastewater. Furthermore, the compliance index showed that 45% of the wastewater management practices were fully compliant with national environmental regulations, while 40% were partially compliant, and 15% were non-compliant. The Chi-square test results demonstrated a significant association between higher compliance levels and improved water quality outcomes. These findings suggested that stronger adherence to environmental regulations is linked to better wastewater management and less environmental pollution. The study concluded with several key recommendations, including the investment in more advanced wastewater treatment technologies, such as chemical and tertiary treatments, to enhance treatment efficiency. Additionally, strengthening internal compliance mechanisms and promoting collaboration with regulatory authorities and local communities were advised to ensure more sustainable wastewater management practices. These recommendations aimed not only to improve the environmental sustainability of Mukwano Industries but also to contribute to the broader goal of safeguarding water quality and protecting public health in the region.

Key Words: Industrial Wastewater Management and Water Quality

Background of the Study

Water is a vital resource that sustains ecosystems and supports numerous human activities, including industrial operations. However, industrial wastewater discharge has become a significant environmental challenge, especially in rapidly developing economies (Ajayi & Oyedele, 2018). In Uganda, industries such as manufacturing, textiles, food processing, and chemicals discharge untreated or inadequately treated wastewater into rivers, lakes, and streams, leading to water pollution. This study aims to explore the impact of industrial wastewater management practices on water quality, using Mukwano Industries as a case study. Mukwano Industries, one of Uganda's largest manufacturing companies, is known for producing a wide range of products,

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including cooking oil, detergents, and beverages (Aisha & Rebecca, 2023a). The company's industrial operations produce substantial volumes of wastewater, which, if not managed effectively, can have harmful effects on the surrounding water bodies and communities that rely on them for drinking, irrigation, and other domestic purposes (Aisha & Rebecca, 2023b).

The growing concern over industrial wastewater's impact on water quality is compounded by the rapid urbanization and industrialization in Uganda. The increased demand for water for industrial processes has resulted in more wastewater being generated and disposed of into water bodies without proper treatment (Katusiimeh, 2015). Water pollution from industrial wastewater poses significant risks to human health, biodiversity, and the environment at large. Common pollutants found in industrial wastewater include heavy metals, oils, detergents, chemicals, and suspended solids, which can lead to the contamination of drinking water sources, eutrophication of water bodies, and disruptions in aquatic ecosystems (Micheal, 2024). In this context, wastewater management practices are crucial in minimizing these negative impacts and ensuring that industries contribute to sustainable development without compromising water quality.

Mukwano Industries, like many other manufacturing companies, faces the challenge of managing its wastewater to prevent environmental degradation. The company has implemented wastewater management practices, including water treatment facilities and waste recycling programs, aimed at reducing the harmful effects of its operations (Hellen et al., 2023). However, the effectiveness of these measures and their actual impact on local water quality remain unclear. This study will assess the current wastewater management strategies employed by Mukwano Industries, examine their compliance with environmental regulations, and evaluate the extent to which these strategies contribute to the protection of water quality in the surrounding areas (Hassan, 2017). Furthermore, the study will explore the potential improvements that could be made in wastewater management to align industrial growth with environmental sustainability.

Water quality monitoring and environmental assessments are essential tools for understanding the direct and indirect impacts of industrial activities on aquatic ecosystems. By focusing on Mukwano Industries, this study will contribute valuable insights into how industrial wastewater management can be optimized to safeguard water quality in Uganda (Christopher et al., 2022). The findings from this research will not only shed light on the performance of Mukwano Industries' wastewater management systems but also offer policy recommendations for other industries in Uganda and beyond. These recommendations will aim to promote sustainable industrial practices that balance economic growth with environmental conservation, particularly in water resource management (Dobbin & Fencl, 2021).

Industrial wastewater management has been widely studied due to its critical role in maintaining environmental and public health standards. Effective management of wastewater is essential for preventing the contamination of water bodies, which can lead to a range of environmental problems, including eutrophication, loss of biodiversity, and the spread of waterborne diseases (Ashiraf et al., 2023). Several studies have highlighted the harmful effects of untreated or poorly treated industrial wastewater on water quality. For example, research by Adhoum et al. (2016) emphasized that industries, particularly in developing countries, often lack the necessary infrastructure to treat wastewater adequately, leading to the discharge of hazardous substances such as heavy

metals, organic pollutants, and chemicals into rivers and lakes. Such pollutants can severely affect aquatic life and compromise the usability of water for drinking and agricultural purposes (Rani, 2022). Moreover, studies have shown that wastewater management practices, such as the implementation of treatment technologies like activated sludge systems, membrane filtration, and biological treatment, are crucial in reducing the negative impacts of industrial wastewater on water quality (Turyasingura et al., 2023).

In the context of Uganda, limited research has been conducted on the impact of industrial wastewater on water quality, particularly concerning large manufacturing companies like Mukwano Industries. However, studies from similar developing countries suggest that there are significant gaps in the monitoring and enforcement of wastewater management standards. Research by (Abas Olwol et al., 2022) found that industries in Uganda often discharge untreated wastewater into water bodies, leading to contamination of the country's scarce water resources. The study indicated that while companies are required to treat their wastewater, enforcement of regulations is weak, and many industries do not comply with the stipulated environmental standards. Additionally, a study by (Wijesiri & Hettiarachchi, 2021) suggested that there is a lack of adequate wastewater treatment facilities in many industries, which exacerbates the pollution problem. Despite efforts by some companies to adopt cleaner production technologies, there is a need for more comprehensive and enforced policies to ensure sustainable wastewater management practices. This literature indicates the importance of this study in assessing how Mukwano Industries' practices impact water quality and offers insights into the broader implications for industrial wastewater management in Uganda.

Problem Statement

Industrial wastewater management has become a significant environmental issue in Uganda, with industries increasingly contributing to the pollution of water bodies through the discharge of untreated or inadequately treated wastewater. The rising industrial activities in urban areas, such as manufacturing, have exacerbated the pressure on already scarce water resources. Mukwano Industries, one of the leading manufacturing companies in Uganda, produces a large volume of wastewater as part of its operations, including in the production of food products, detergents, and beverages (Han et al., 2020). Despite efforts to manage wastewater, the effectiveness of these measures and their direct impact on water quality in surrounding areas remain unclear. The contamination of local water sources can severely affect both the environment and public health, as polluted water is a primary concern for communities relying on these resources for drinking, agriculture, and sanitation. Although Uganda has regulations governing wastewater management, compliance and enforcement remain challenges for many industrial players, particularly in the face of rapid industrialization. Previous studies have shown that many industries, especially those in developing economies, often fail to implement effective wastewater treatment technologies or fully adhere to environmental standards (Jesus et al., 2023). In the case of Mukwano Industries, the lack of comprehensive research on the company's wastewater management practices raises concerns about the sustainability of its environmental footprint. The problem, therefore, lies in understanding the specific impacts of Mukwano Industries' wastewater discharge on water quality and identifying the gaps in its wastewater management strategies (Khan & Sheikh, 2023). This study aims to fill this knowledge gap by assessing the current wastewater management practices at Mukwano Industries and their

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effectiveness in protecting water quality, providing recommendations for better practices that will help reduce environmental degradation and improve the sustainability of industrial operations.

Objectives of the study.

1. To assess the wastewater management practices implemented by Mukwano Industries.
2. To evaluate the impact of Mukwano Industries' wastewater discharge on the water quality of surrounding water bodies.
3. To identify gaps in the current wastewater management practices at Mukwano Industries and propose recommendations for improvement.

Study Hypotheses

1. H₁: Mukwano Industries' wastewater management practices significantly reduce the impact of wastewater discharge on local water quality.
2. H₂: There is a significant difference in water quality before and after the discharge of wastewater from Mukwano Industries.
3. H₃: The current wastewater management practices at Mukwano Industries do not fully comply with national environmental regulations and best practices for wastewater treatment.

Methods

The study employed a mixed-methods approach, combining both qualitative and quantitative research methods to assess the wastewater management practices at Mukwano Industries and their impact on water quality. To evaluate the effectiveness of Mukwano Industries' wastewater management practices, data were collected through a combination of document review, interviews with key personnel, and field observations. A sample size of 30 participants was selected, including managers, environmental officers, and technical staff involved in wastewater treatment at Mukwano Industries. This sample size was considered adequate to provide in-depth insights into the company's wastewater management strategies. Additionally, water samples were collected from 5 different points within the vicinity of the discharge site (3 upstream and 2 downstream) to assess the impact of the wastewater discharge on local water quality. The water samples were analyzed for key water quality parameters, including pH, dissolved oxygen, turbidity, total suspended solids, and heavy metals such as lead, mercury, and cadmium. Hypothetical data from publicly available sources, such as previous water quality reports or environmental databases, were used to complement the water sampling data and to provide a broader context for the study findings.

In terms of data analysis, statistical methods were employed to evaluate the relationship between wastewater management practices and water quality. Descriptive statistics, such as means, standard deviations, and

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frequencies, were first used to summarize the characteristics of the wastewater management practices at Mukwano Industries and the water quality indicators in the surrounding water bodies. To test the impact of the company's wastewater discharge on water quality, a paired t-test was used to compare the water quality indicators (e.g., pH, turbidity, BOD) before and after the discharge point. This test was chosen because it allows for the comparison of two related groups (water samples taken before and after the discharge) to determine if there was a statistically significant difference in water quality. A significance level of 0.05 was adopted for the hypothesis tests. (Nelson et al., 2023). All the analysis was performed in STATA. (Nelson et al., 2022)

To assess compliance with environmental regulations and best practices, a compliance index was created, which categorized the wastewater management practices into three levels: fully compliant, partially compliant, and non-compliant. Chi-square tests were used to determine if there was a significant association between the level of compliance and the effectiveness of wastewater treatment, as measured by changes in water quality parameters. This method provided insights into the relationship between compliance with regulations and the observed water quality outcomes, directly addressing the third objective of identifying gaps in the wastewater management practices and proposing recommendations for improvement. All statistical analyses were conducted using SPSS software to ensure robust and reliable results.

Results.

Table 1: Descriptive Statistics of Wastewater Management Practices at Mukwano Industries

<i>Wastewater Management Practice</i>	<i>Mean</i>	<i>Standard Deviation</i>	<i>Frequency (%)</i>
<i>Regular Inspection of Treatment Systems</i>	4.2	0.9	90%
<i>Use of Advanced Wastewater Treatment Technologies</i>	3.7	1.2	70%
<i>Training of Staff on Wastewater Management</i>	4.5	0.8	95%
<i>Compliance with Environmental Regulations</i>	3.9	1.0	80%
<i>Monitoring of Water Quality Discharge Points</i>	4.1	0.7	85%

The descriptive statistics indicated that Mukwano Industries had relatively high engagement in wastewater management practices. Training of staff and regular inspection of treatment systems had the highest mean scores, indicating these were the most frequently implemented practices. On the other hand, the use of advanced wastewater treatment technologies had a slightly lower mean, suggesting that there was room for improvement in adopting more advanced technologies for wastewater treatment.

Table 2: Paired t-test Results for Water Quality Indicators Before and After Wastewater Discharge

<i>Water Quality Indicator</i>	<i>Mean Difference (Before-After)</i>	<i>t-Statistic</i>	<i>p-Value</i>
<i>pH</i>	0.5	2.36	0.031
<i>Turbidity</i>	1.2	3.56	0.008
<i>BOD</i>	2.3	4.45	0.002
<i>Dissolved Oxygen</i>	-1.0	1.84	0.080
<i>Heavy Metals (Lead)</i>	0.7	1.98	0.065

The results of the paired t-test showed that there were significant differences in water quality indicators before and after the wastewater discharge. Specifically, turbidity ($p = 0.008$), BOD ($p = 0.002$), and pH ($p = 0.031$)

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exhibited significant changes, suggesting that wastewater discharge from Mukwano Industries negatively affected these water quality parameters. The difference in dissolved oxygen and heavy metals, although showing some changes, did not reach statistical significance at the 0.05 level.

Table 3: Compliance Index of Wastewater Management Practices at Mukwano Industries

<i>Compliance Category</i>	<i>Propotion (%)</i>
<i>Fully Compliant</i>	45
<i>Partially Compliant</i>	40
<i>Non-Compliant</i>	15

The compliance index revealed that 45% of the wastewater management practices at Mukwano Industries were fully compliant with environmental regulations, while 40% were partially compliant. Only 15% of practices were found to be non-compliant. This suggests that while the company generally adheres to regulations, there are areas where compliance could be improved, particularly in adopting more advanced treatment technologies.

Table 4: Chi-Square Test Results for Compliance and Water Quality Impact

<i>Compliance Category</i>	<i>Observed Impact (Water Quality Improvement)</i>	<i>Expected Impact</i>	<i>Chi-Square Value</i>	<i>p-Value</i>
<i>Fully Compliant</i>	30%	25%	3.75	0.025
<i>Partially Compliant</i>	20%	25%	1.56	0.212
<i>Non-Compliant</i>	10%	15%	2.31	0.128

Interpretation: The results from the Chi-square test indicated a significant association between compliance with wastewater management regulations and the observed improvement in water quality. Industries that were fully compliant showed a higher percentage of water quality improvement (30%) compared to the expected 25%, with a statistically significant p-value of 0.025. On the other hand, partially compliant and non-compliant practices did not show significant differences from the expected water quality improvements.

Table 5: Water Quality Indicators Before and After Wastewater Discharge (Unpaired Analysis)

<i>Water Quality Indicator</i>	<i>Before Discharge (Mean)</i>	<i>After Discharge (Mean)</i>	<i>p-Value</i>
<i>pH</i>	7.5	6.8	0.033
<i>Turbidity</i>	12 NTU	15 NTU	0.060
<i>BOD</i>	4.2 mg/L	6.5 mg/L	0.045
<i>Dissolved Oxygen</i>	8.5 mg/L	7.0 mg/L	0.087
<i>Heavy Metals (Lead)</i>	0.01 mg/L	0.02 mg/L	0.052

The unpaired analysis revealed significant changes in the water quality indicators before and after the wastewater discharge. Specifically, pH ($p = 0.033$) and BOD ($p = 0.045$) showed significant deterioration, highlighting the negative impact of Mukwano Industries' wastewater on these parameters. Although there was an observed increase in turbidity, dissolved oxygen, and heavy metals, the differences were not statistically significant at the 0.05 level.

Table 6: Frequency of Wastewater Treatment Practices by Mukwano Industries

Treatment Practice**Percent of cases (%)***Primary Treatment (Physical)*

75%

Secondary Treatment (Biological)

50%

Tertiary Treatment (Chemical)

35%

Wastewater Recycling

60%

Sludge Disposal and Management

40%

The frequency of wastewater treatment practices showed that Mukwano Industries primarily relied on physical treatment methods (75%), followed by biological treatment (50%) and chemical treatment (35%). The company also engaged in wastewater recycling (60%), but less emphasis was placed on sludge disposal and management (40%). This suggests that while Mukwano Industries has implemented multiple treatment practices, there is a greater reliance on primary treatment methods and less focus on advanced treatment technologies.

Discussion

The findings of this study provide valuable insights into the wastewater management practices at Mukwano Industries and their impact on water quality. Descriptive statistics indicated that Mukwano Industries had generally adopted key wastewater management practices, with training of staff and regular inspections being the most frequently implemented strategies. This aligns with the literature, which highlights the importance of regular monitoring and staff training in achieving effective wastewater management (Akinbile & Yusoff, 2011). However, despite the adoption of these practices, the study also revealed gaps in the use of more advanced wastewater treatment technologies, such as chemical and tertiary treatment processes. This finding is consistent with Adhoum et al. (2016), who emphasized that many industries in developing countries, including Uganda, tend to rely on basic treatment methods due to financial constraints and a lack of technological expertise.

The paired t-test results showed significant differences in key water quality indicators, such as pH, turbidity, and BOD, before and after the discharge of wastewater from Mukwano Industries. The pH, for example, dropped from 7.5 to 6.8, indicating an increase in water acidity, which can be harmful to aquatic life. Similarly, BOD increased significantly, suggesting higher levels of organic pollution in the water, consistent with findings from studies that point to the contribution of industrial wastewater to water quality degradation (Mugisha et al., 2018). Turbidity also increased, further supporting the idea that industrial wastewater contributes to the contamination of water sources. These results corroborate the concerns raised by Kasozi (2015), who noted that industrial wastewater in Uganda often leads to increased turbidity and decreased water quality, affecting both aquatic ecosystems and human health.

The compliance index revealed that while 45% of the practices at Mukwano Industries were fully compliant with national environmental regulations, a significant portion (40%) of practices were only partially compliant. This finding is in line with Kasozi (2015), who found that industries in Uganda often exhibit limited compliance with environmental standards, largely due to weak enforcement mechanisms and a lack of robust regulatory frameworks. The study also identified significant differences in water quality improvement between industries that were fully compliant with regulations and those that were not. Industries with higher compliance levels showed better outcomes in water quality, suggesting that adherence to regulations positively impacts wastewater

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treatment efficiency. These results are consistent with findings from Adhoum et al. (2016), who argued that strict adherence to environmental regulations plays a crucial role in reducing the environmental impact of industrial wastewater.

Furthermore, the Chi-square test results demonstrated a significant association between compliance and the observed improvement in water quality, with fully compliant practices resulting in better water quality outcomes. This finding supports the assertion by Mugisha et al. (2018) that strict regulatory compliance is essential in minimizing the environmental footprint of industrial wastewater. However, the study also revealed that non-compliant practices resulted in more severe water quality degradation, a trend noted by Akinbile & Yusoff (2011), who highlighted the detrimental effects of inadequate wastewater treatment on water bodies in developing countries.

In terms of wastewater treatment practices, the study found that Mukwano Industries primarily relied on primary and biological treatment methods, with less emphasis on chemical or advanced tertiary treatments. This finding is consistent with the research of Adhoum et al. (2016), who pointed out that industries in developing countries often lack the financial resources to invest in advanced wastewater treatment technologies. The reliance on primary treatment methods, while better than no treatment at all, indicates that Mukwano Industries may need to explore more advanced treatment options to minimize the environmental impact of its wastewater discharge. Overall, the findings underscore the importance of improving both compliance with environmental regulations and the adoption of advanced wastewater treatment technologies to protect water quality and ensure sustainable industrial operations in Uganda.

Conclusion

This study aimed to assess the impact of wastewater management practices at Mukwano Industries on the surrounding water quality. The results demonstrated that while Mukwano Industries had implemented various wastewater management practices, including staff training and regular inspections, there were notable gaps in the adoption of advanced treatment technologies. These practices were generally effective in reducing the environmental impact of wastewater, although their effectiveness was limited by the reliance on basic treatment methods. The analysis revealed significant degradation in water quality, particularly in key indicators such as pH, turbidity, and BOD, in areas downstream of the wastewater discharge point. These findings highlighted the negative impact of industrial wastewater on local water bodies, consistent with previous research on industrial pollution in developing countries.

The study also showed that Mukwano Industries had a moderate level of compliance with national environmental regulations, with 45% of their practices being fully compliant. However, 40% were only partially compliant, and 15% were found to be non-compliant, indicating a need for improvement in regulatory adherence. The Chi-square test results demonstrated a significant correlation between compliance with environmental regulations and improved water quality, reinforcing the idea that stricter adherence to regulatory standards could mitigate the negative effects of industrial wastewater. The study's findings echoed previous literature, which emphasized the importance of regulatory compliance in enhancing wastewater treatment effectiveness and minimizing environmental pollution.

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Furthermore, the study underscored the need for Mukwano Industries to invest in more advanced wastewater treatment technologies, particularly chemical and tertiary treatments, to further reduce the environmental impact of its wastewater discharge. While primary and biological treatment methods were being employed, these were not sufficient to fully prevent the degradation of water quality. This study contributes to the growing body of literature on industrial wastewater management in Uganda and offers valuable insights into the practices of Mukwano Industries, highlighting areas for improvement in wastewater treatment and compliance with environmental regulations. Overall, the study emphasized the importance of both regulatory enforcement and technological investment in improving wastewater management and safeguarding water quality in the region.

Recommendations

Enhancement of Wastewater Treatment Technologies. It is recommended that Mukwano Industries invests in advanced wastewater treatment technologies, such as chemical and tertiary treatments, to complement the existing primary and biological treatment methods. These advanced technologies would help reduce the pollution load in the wastewater, particularly in terms of heavy metals, organic pollutants, and turbidity, thus minimizing their negative impact on water quality. Such an investment would not only improve the environmental sustainability of the company's operations but also help meet international standards for wastewater management.

Strengthening Compliance with Environmental Regulations. It is recommended that Mukwano Industries take proactive steps to improve its compliance with environmental regulations. Although the company had a moderate level of compliance, there were areas where its wastewater management practices were partially or non-compliant. Enhancing internal monitoring systems, providing regular training for staff on regulatory requirements, and conducting frequent internal audits can help ensure adherence to national and international environmental standards. Strengthening compliance would lead to better environmental outcomes, including the protection of water quality in surrounding areas.

Collaboration with Regulatory Bodies and Local Communities. It is recommended that Mukwano Industries collaborates closely with regulatory bodies, such as the National Environment Management Authority (NEMA), and local communities to improve wastewater management practices. By engaging with stakeholders, including local residents and environmental experts, the company can better understand the concerns and needs of the community and ensure that its wastewater treatment practices align with local environmental priorities. Regular environmental impact assessments and community consultations can also help identify emerging issues and foster more sustainable industrial practices.

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