



Received: 02-12-2025  
Accepted: 12-01-2026

## International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

### Assessing the Effect of Industrial Liquid Waste Discharge on Water Quality: A Case Study Lunghwakwa Stream in Chipata District Eastern Province

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#### Abstract

This study aims to Assess the effect of industrial liquid waste discharge on water quality characterize the physicochemical properties of discharged of liquid waste, assess their effects on receiving water quality, and evaluate compliance with regulatory standards. The research was conducted in an industrial zone where wastewater from the industry is discharged into nearby stream. A mixed-methods approach was employed, combining laboratory analyses of wastewater and water samples with field surveys of industry representatives and community members. Key parameters analyzed included pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). The results revealed that industrial effluents frequently exceeded acceptable limits for several physicochemical parameters, leading to significant degradation of water quality in receiving bodies. Elevated

levels of BOD and TSS indicated high organic pollution, while the presence of heavy metals posed serious ecological risks. Additionally, many industries were found to be non-compliant with environmental regulations, particularly concerning the treatment of wastewater. Interpretation of the findings suggests that the environmental and public health risks associated with industrial wastewater discharges are significant, necessitating urgent action. Recommendations include the implementation of advanced wastewater treatment technologies, regular monitoring and enforcement of compliance with regulations, and increased awareness and training for industry stakeholders on sustainable wastewater management practices. This research underscores the importance of effective industrial wastewater management to protect water quality and promote environmental sustainability.

**Keywords:** Carbon Oxygen Demand, Biochemical Oxygen, Total Suspended Solid, Turbidity, Water Quality

#### Introduction

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body (Allan, J. 2021) [5]. Water is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Despite its importance, water is the most poorly managed resource in the world.

The availability and quality of water always have played an important role in determining the quality of life. Water quality is closely linked to water use and to the state of economic development. Ground and surface waters can be contaminated by several sources. In urban areas, the careless disposal of industrial effluents and other wastes may contribute greatly to the poor quality of water. Most of the water bodies in the areas of the developing world are the end points of effluents discharged from industries. Considering the water streams along Hillview industrial area that receive untreated effluents from industries in this area, the water quality of these streams has been tremendously affected as result of the industrial activities (Smith, J. 2020) [9]. Hillview is an area where Chipata brewing industry is found in Eastern province. The industrial activities in this area among others include factories of beer and foods. Effluents from the above industry are disposed into the streams almost exclusively without adequate treatment, which is likely to affect the water quality of the receiving streams and subsequently that of Hillview water drainage main stream, given the fact that the stream passes through lunghwakwa wetland that is being degraded due to human activities.

#### Problem of statement

Water is a vital resource for human consumption, agricultural production, industrial development, and the overall sustainability

of ecosystems. However, the increasing pace of industrialization has raised serious environmental concerns globally, particularly in developing countries where environmental management systems are often weak or poorly enforced. In Chipata District, the rapid expansion of industrial activities especially in the manufacturing and beverage sectors has heightened concerns about the potential discharge of untreated or inadequately treated effluents into nearby water bodies such as the Lunxhwakwa Stream. These industrial effluents frequently contain hazardous substances including heavy metals, nutrients, oils, and organic compounds, which can significantly degrade water quality, disrupt aquatic life, and pose long-term health risks to surrounding communities (Miller *et al.*, 2020; Singh & Gupta, 2023).

**The Main Research Objective was to**

1. To assess community perceptions and awareness regarding the impact of industrial effluent discharge on local water quality.
2. Measure key water quality parameters e.g. (PH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Turbidity and Total Suspended Solids (TSS), in affected water bodies.
3. Compare water quality data against national and international water quality standards to assess the extent of pollution.

**Hypothesis Test**

**Ho:** Industrial effluent discharge does not significantly affect the water quality.

**Ha:** Industrial effluent discharge is significantly affecting the water quality.

**Conceptual Framework**

A conceptual framework is a structured representation that illustrates how the researcher believes the variables under study are related and can best explain the natural progression of the phenomenon being investigated (Camp, 2014; Ravitch & Riggan, 2017) [24, 18]. In the conceptual framework for this study, industrial effluents are considered the independent variable, while water quality of water resources is the dependent variable. The framework posits that the quality of water resources depends on the presence or absence of industrial activities. When industries discharge untreated effluents into water bodies, the chemical, physical, and biological properties of the water are altered, potentially leading to increased levels of BOD, COD, turbidity, suspended solids, and Turbidity, which can adversely affect aquatic ecosystems and human health (Kumari *et al.*, 2020; Phiri *et al.*, 2021) [17, 19]. Conversely, in areas where industries are absent or where effluent is properly treated, water quality is likely to remain within acceptable standards, ensuring the safety and usability of water resources (WHO, 2022) [7].

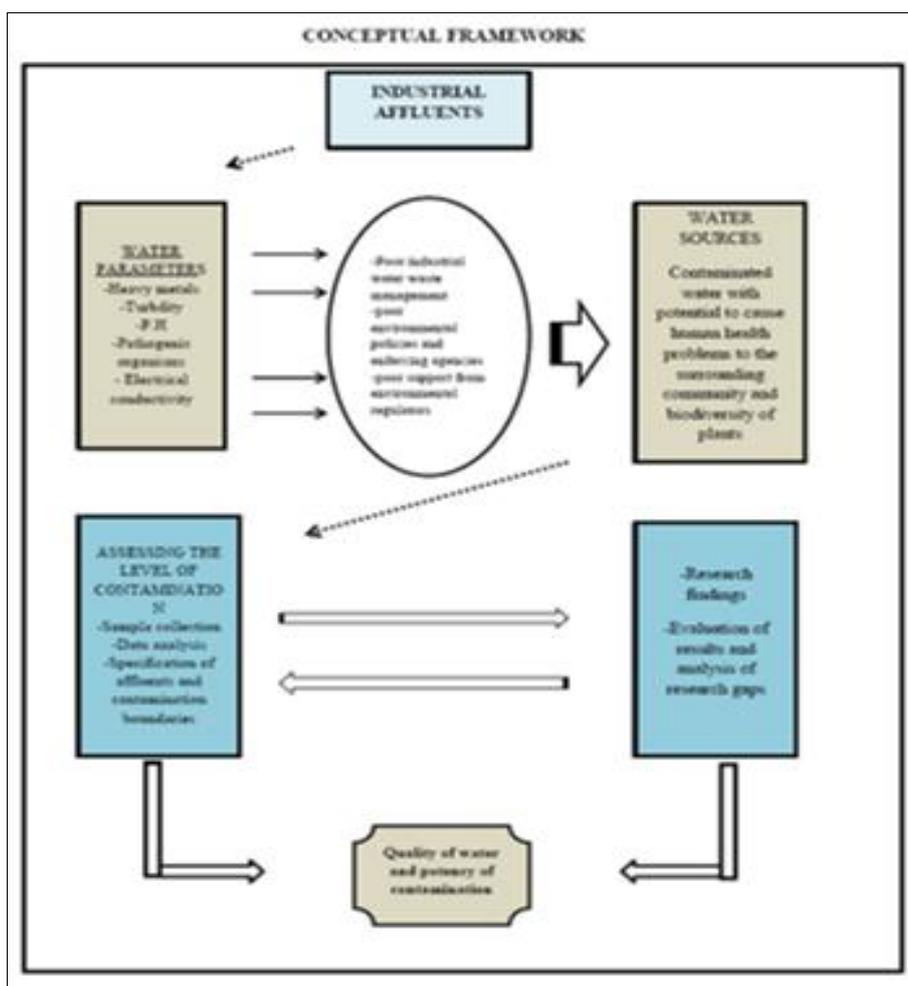


Fig 1: Conceptual framework

## Literature Review

This chapter provides a comprehensive review of existing literature on water pollution caused by industrial effluents. It discusses various pollutants, including heavy metals, organic compounds, and nutrients, highlighting their sources, mechanisms of entry into water bodies, and ecological impacts (Johnson & Lee, 2019; Tchounwou *et al.*, 2012 [22]). The review also examines previous studies that have investigated the effects of industrial discharge on aquatic ecosystems, emphasizing the detrimental effects of untreated effluents on water quality and aquatic biodiversity. Key findings from these studies indicate that industrial effluents can significantly alter water chemistry by increasing biochemical oxygen demand (BOD), chemical oxygen demand (COD), turbidity, and suspended solids, while elevating concentrations of heavy metals such as lead, cadmium, and zinc, which can bioaccumulate in aquatic organisms and pose serious environmental and human health risks (Brown *et al.*, 2018; Kumari *et al.*, 2020) [15, 17].

Despite extensive research, gaps remain in understanding the spatial and temporal variations of water-quality parameters in streams receiving untreated industrial effluents, particularly in developing countries. Many studies focus on large rivers or industrial hubs, leaving smaller streams, such as Lunxhwakwa Stream in Chipata District, under-researched. Addressing these gaps, the current study aims to assess the effects of industrial liquid waste discharge on the water quality of Lunxhwakwa Stream, providing insights into both chemical and physical water-quality alterations and their potential ecological consequences (Ngoma *et al.*, 2022; Phiri *et al.*, 2021) [8, 19].

## Material and Methods

### Research Design

The study adopted a descriptive and analytical cross-sectional research design to assess the effect of industrial liquid waste discharge on the water quality of Lunxhwakwa Stream. The descriptive component was essential for documenting the existing physico-chemical and microbiological conditions of the stream at the time of sampling, thereby providing a baseline understanding of the water-quality status. The analytical component enabled statistical comparison of water-quality parameters between the upstream (control point), the industrial effluent discharge point, and multiple downstream locations. This comparison helped determine whether observed changes in water quality were associated with industrial activities.

Furthermore, the study employed an upstream–midstream–downstream comparative approach, which is widely recognized in aquatic pollution assessments. This design is particularly effective in identifying spatial variations, pollution gradients, and dilution or accumulation patterns of pollutants along a flowing water body. By comparing sections unaffected by effluent (upstream) with sections directly and indirectly influenced by industrial discharge (midstream and downstream), the design supports clearer inference of cause-and-effect relationships. Such comparative approaches are consistently recommended in riverine pollution studies because they enhance the detection of effluent-driven environmental changes (Kumari *et al.*, 2020; Phiri *et al.*, 2021; USEPA, 2020) [17, 19, 23].

In addition, cross-sectional designs are efficient for environmental monitoring because they allow researchers to capture multiple water-quality parameters simultaneously,

under the same climatic and hydrological conditions, thereby improving data reliability and comparability (WHO, 2022) [7]. This makes the design appropriate for assessing how industrial liquid waste influences water quality within a specific time frame while providing robust evidence for environmental management and regulatory decision-making.

### Data Analysis

Data analysis is the systematic process of organizing, interpreting, and summarizing collected data to extract meaningful information. Researchers such as Kothari (2019) [21] explain it as the editing, coding, and tabulating of data to draw valid conclusions, while Creswell (2014) [20] describes it as identifying patterns and interpreting their meanings. In essence, data analysis transforms raw measurements into understandable and useful insights.

It is adopted for assessing the impact of industrial effluent on water quality because it enables the researcher to interpret laboratory results for parameters like pH, COD, BOD, TSS, and turbidity. Through analysis, differences between sampling points can be identified, trends in pollution levels can be observed, and compliance with water quality standards can be evaluated. This helps determine the extent and severity of contamination, quantify the effect of effluent discharge, and provide a solid scientific basis for environmental management and decision-making.

### Research Methods

**Water sampling and analysis:** collect water sample from different points upstream and downstream of the industrial effluent discharge point. Analyze the samples for various parameters such as PH, Turbidity, Dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), heavy metals, nutrients and organic pollutants. **Field surveys:** conduct field surveys to observe the physical characteristics of the water bodies, such as color, odor and presence of any visible pollutants. **Biological monitoring:** use biological indicators such as macro invertebrates, algae and fish to assess the impact of industrial effluent discharge on aquatic life. Changes in species diversity and abundance can indicate water quality degradation APHA/, (2020) [14]. **Toxicity testing:** conduct toxicity test on water sample to assess the potential harmful effects of industrial effluent discharge on aquatic organisms and bioassays can provide valuable information on the toxicity levels of the effluent. **Long-term monitoring:** establish a long –term monitoring program to track changes in water quality over time and assess the effectiveness of any mitigation measure implemented by chipata beer brewery EPA (2023). A comprehensive assessment of the impact of industrial effluent discharge on water quality at chipata brewery can be conducted, leading to informed decision-making and sustainable environmental management practices.

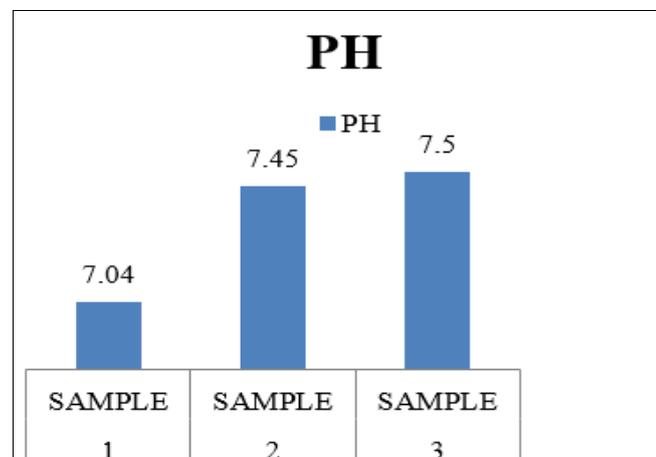
### Experimental Procedure and Instrument

**Sample collection:** collect water samples from the discharge point of the industrial effluent and from upstream and downstream location to establish baseline water quality parameters. PH measurement was using a PH meter to measure the acidity or alkalinity of the water sample. Ensure calibration of the PH meter before measurement. COD analysis conduct COD analysis was using a spectrophotometer to determine the amount of oxygen

required to oxidize organic and inorganic matter in the water sample and the Spectrophotometer instrument for measuring the intensity of light absorption to determine COD levels analysis measure of the biological oxygen demand was using BOD incubator to determine the amount oxygen consumed by microorganism during the degradation of organic matter in the water sample and the incubator are equipment for measuring the amount of oxygen consumed by microorganisms during BOD analysis's measurements was using a filter water sample through a pre-weighed filter paper, dry and weigh the suspended solid to determine Total suspended solid concentration and the Filter paper used for TSS analysis by filtering suspended solid from water sample. Turbidity measurements were using a nephelometer to measure the cloudiness or haziness of the water caused by suspended particles and nephelometer instrument for measuring the turbidity of water samples.

**Target Population**

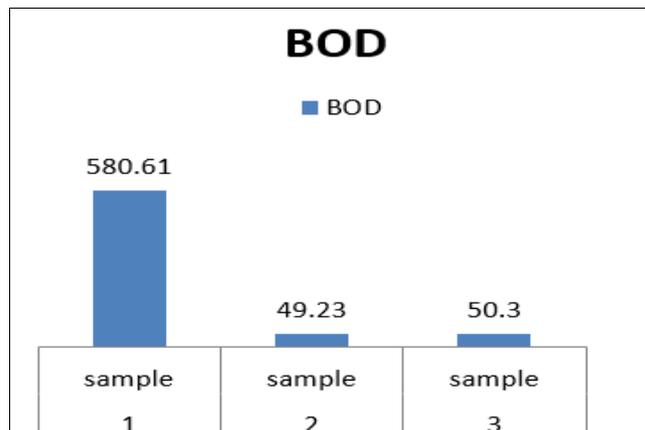
The target population for this study comprises the entire hydrological stretch of Lunkhwakwa Stream within Chipata District USEPA. (2020) [23]. This includes all upstream, midstream, and downstream segments that may be directly or indirectly influenced by industrial liquid waste discharge. The target population covers the full spatial extent of the stream ecosystem from the primary upstream entry point to the downstream exit, incorporating both natural flow zones and areas receiving industrial effluent. Defining the target population in this way ensures comprehensive assessment of pollution gradients and supports generalization of water-quality findings to the whole stream system.



Source: Field survey (2024)

Fig 1: Variations of pH in the wastewater testing

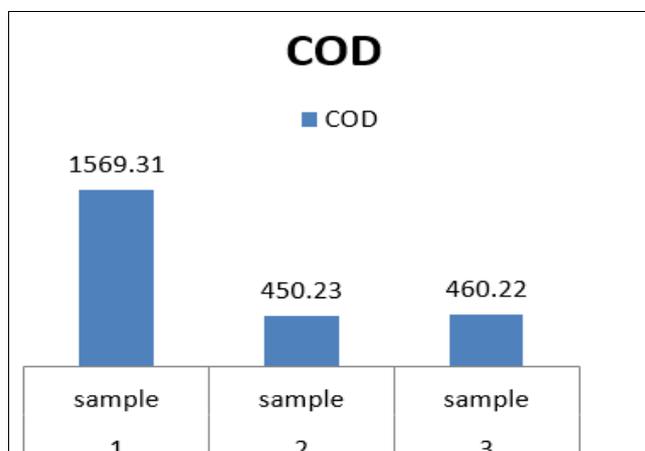
The measured PH: 7.04 according the WHO guideline:6.5-8.5 and ZEMA guideline:6.0-9.0 are compliance status, the PH is well within the acceptable range, indicating a neutral to slightly acidic condition.sample2 PH measured: 7.45 and WHO guideline 6.5-8.5 and ZEMA guideline: This PH level is also acceptable range, indicating a neutral condition. Sample 3 PH measured:7.50 and WHO guideline: 6.5-8.5 and ZEMA guideline:6.0-9.0 the PH is well within the acceptable limits, indicating a neutral condition. All samples exhibit PH values that are compliant with both WHO and ZEMA guidelines. The PH level (7.04, 7.45 and 7.50) indicates that the effluents are neither excessively acidic nor alkaline, suggesting that they are not immediately harmful in terms of acidity.



Source: Field survey (2024)

Fig 2: Shows the variations of BOS in the wastewater testing

The recorded BOD measured of 580.61ml/l exceedingly high indicating a significant load of the biodegradable organic matter, which can lead to severe oxygen depletion in water quality. 49.23 ml/g of BOD measure and WHO and ZEMA guideline is >5mg/l are non-compliant. while lower than sample, this BOD level is still substantially above acceptable limited indicating a serious and BOD for 50.30 ml/g and both WHO and ZEMA guidelines are >5mg/l are non-compliant similar to sample 2, this level is indicated significant organic contamination. All the three-sample value that far exceeds the maximum permissible level as set by both WHO and ZEMA.This indicates a critical level of organic pollution that possess serious risk to aquatic ecosystem and overall water quality.

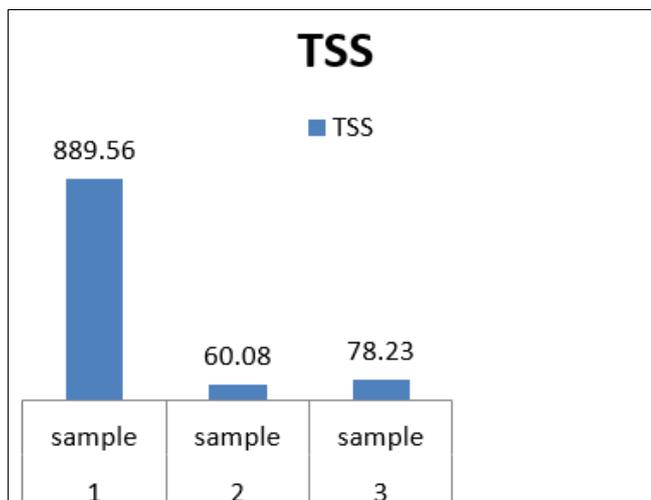


Source: Field survey (2024)

Fig 3: Variations of COD in the wastewater testing

The COD important indicator of water quality.it measure the amount of oxygen needed to oxidize soluble and particulate organic matter of water. The COD values recorded the water sample was 1569.61ml/g is significantly higher than WHO guideline 30mg/l and ZEMA guideline 50mg/ standards, indicating extremely higher level of organic pollution that can lead to severe environment degradation. Sample 2 are like sample1, the COD exceed both the WHO and ZEMA limits, suggesting a notable risk to water quality. Sample 3 measured of COD 450.23ml/g and the WHO guidelines 30mg/l and ZEMA standard are 50mg/l are non-compliant. Similar to the previous samples, the COD level is far above acceptable limits, indicating a persistent issue with organic pollutants. All samples analyzed show COD levels that

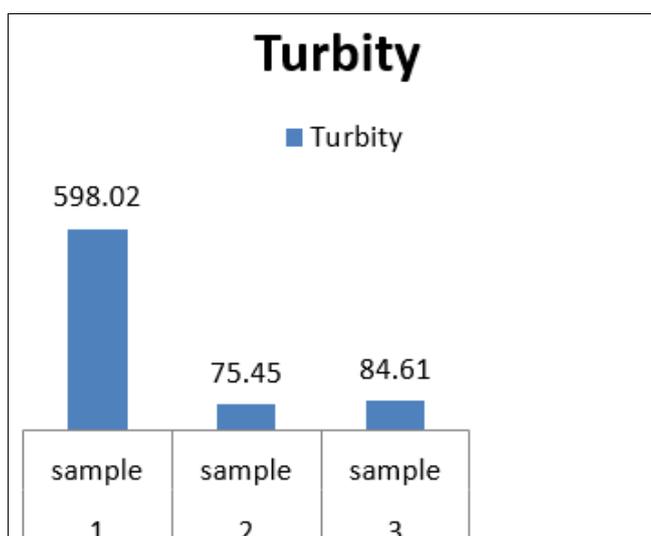
drastically exceed the maximum permissible values set by both the WHO and ZEMA. This suggests a serious contamination issue that can lead to detrimental effect on aquatic ecosystems and public health.



Source: Field survey (2024)

Fig 4: Shows the variations of TSS in the wastewater wtesting

The measured TSS: 889.56ml/g level is significant above both WHO standard 25mg/l and ZEMA standards 50mg/l, indicating a very high concentration of suspended solid. Sample 2 TSS measured 60.08ml/g non-compliant. Although lower than sample 1, this level still exceeds the WHO guideline and is close to the ZEMA maximum. Sample 3 measured of TSS 78.23ml/g this sample are also exceed both standard indicating a concerning level of the suspended solids. All samples analyzed show TSS levels that greatly exceed the maximum permissible values sent by both the WHO and ZEMA. The high concentrations of TSS pose significant risk to aquatic ecosystems, including potential sedimentation issues, habitant disruption and increased turbidity which can affect light penetration and photosynthesis.



Source: Field survey (2024)

Fig 5: Shows the variations of Turbidity in the wastewater testing

The measured for Turbidity: 598.02NTU comparing for both WHO standard guideline and ZEMA standard guideline: >5NTU this Turbidity level is extremely high,

indicating severe water quality issues likely due to high concentrations of suspended particles. Sample2 measured Turbidity: 75.45NTU comparing with both WHO and ZEMA standard >5NTU, this level is significantly above the standard and indicating a serious concern for water quality. Sample 3 measured Turbidity: 84.61NTU and WHO guideline >5NTU and ZEMA standard 5NTU like the other sample; this turbidity level indicates a major issue with pollutant suspension in the water. All samples show turbidity level that far exceed the maximum permissible values set by both WHO and ZEMA. This extremely high turbidity values pose significant risk to aquatic ecosystems as they can decreased light penetration, disrupt photosynthesis and harm aquatic life.

These findings emphasize the need for a comprehensive analysis to identify the nature and origin of particle contributing to turbidity measurement against regulatory standard was crucial to assess compliance and potential environmental risks associated with the observed turbidity level. The combined analysis of turbidity (65.2) and ZAME standard (15) underscores the importance of a though examination of fluid quality. This was essential for addressing potential environmental concerns and ensuring adherence to established standards. A further investigation was provided valuable insights into the nature and sources of observed turbidity, guiding targeted remedial actions for actions for water quality improvement.

### World Health Organisation (WHO) Standard

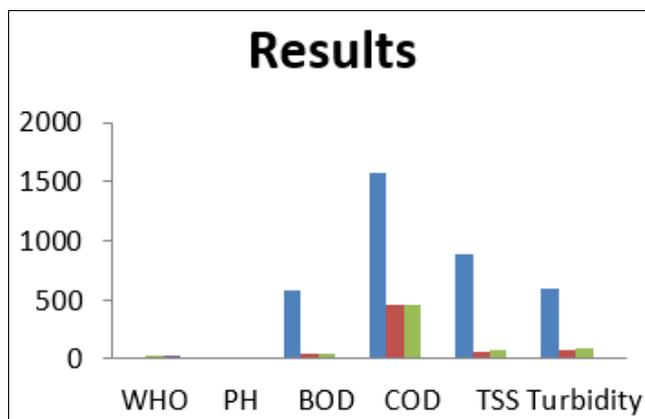


Fig 8: Comparison of results with national and international standard

PH: the WHO guideline for pH in drinking water is between 6.5 and 8.5. The results provided fall within this range (7.04, 7.45 and 7.50), indicating that the pH levels are within the world health organization standard. Biochemical oxygen demand (BOD): the WHO guideline for BOD in drinking water is less than 5mg/L. the results provide (580.61, 49.23, and 50.30) exceeds this standard, indicating a high level of organic pollution. COD (Chemical oxygen demand): the WHO guideline for COD in drinking water is less than 10mg/L. the results provide (1569.31,450.23and 460,22) also exceed this standard, indicating a high level of chemical pollution's (Total suspended solid): the WHO guideline for TSS in drinking water is less than 10mg/l. the results provide (889.56,60.08 and 78.23) exceed this standard, indicating a high level of suspended solids. Additionally, Turbidity; the WHO guideline for turbidity in drinking water is less than 5NTU (Nephelometric turbidity units).

from the results provided, turbidity values of 598.02, 75.45 and 84.61 exceed the WHO standard, indicating poor water quality and potential health hazards. High turbidity levels can reduce water clarity, increase and pose a challenge for water treatment plants. The comparison of the results for PH, BOD, COD, TSS, and Turbidity with the quality to protect public health and the WHO standard highlights the importance of monitoring and maintaining water quality to protect human health and the environment. It is essential for government and water management authorities to implement appropriate measures to reduce pollution, improve the water treatment process and ensure compliance with WHO standards. By addressing the issues posed, we can safeguard water resources, preserve ecosystems, and promote public health for future generations.

**Table 1:** Standard results for world health organization

Parameter	WHO Standard
PH	6.5-8.5
COB	>5
COD	30
TSS	25
Turbidity	>5

Source: Field survey (2024)

The World Health Organization (WHO) recommends a range of 6.5 to 8.5 pH. pH is a measure of the acidity or alkalinity of the water, and maintaining it within this range is important for ensuring that water is not too acidic or basic, which could be harmful to health. For biochemical oxygen demand (BOD), the WHO recommends that the level should be greater than 5 mg/L. BOD is a measure of the amount of oxygen required by microorganisms to decompose organic matter in water. High BOD levels can indicate pollution and a lack of oxygen in water, which can harm aquatic life and affect water quality. For chemical oxygen demand (COD), the WHO recommends a level of 30 mg/L. COD is a measure of the amount of oxygen required to chemically oxidize organic matter in water. High COD levels can indicate the presence of pollutants and contamination in water, which can be harmful to human health and the environment. For Total Suspended Solids (TSS), the WHO recommends a level of 25 mg/L. TSS refers to the concentration of solid particles suspended in water, which can affect water clarity and quality. High TSS levels can indicate pollution and sedimentation in water bodies, which can impact aquatic life and water quality. The WHO sets standards for turbidity in water to ensure its safety for human consumption. Turbidity is measured as the cloudiness or haziness of water caused by suspended particles. The WHO standard for turbidity in drinking water is that it should be less than or equal to 5 nephelometric turbidity units (NTU). This standard is based on scientific evidence and aims to protect public health by ensuring that water is clear and free from harmful contaminants. Water with turbidity levels exceeding 5 NTU may indicate the presence of pollutants or pathogens that could pose a risk to human health. Therefore, it is important for water treatment facilities to monitor and maintain turbidity levels within the WHO-recommended standard to safeguard the quality of drinking water (WHO, 2022) [7].

## Conclusion and recommendation

The concluding chapter synthesizes the study's findings and emphasizes the urgent need for effective management of industrial effluent to protect water quality. It reiterates the socio-economic impact of water pollution, particularly for communities relying on contaminated water for drinking and agriculture (Thompson, 2019) [10]. The chapter offers several recommendations, including stricter regulatory enforcement, the adoption of cleaner production technologies, and regular monitoring of industrial discharges. It advocates for increased public awareness and community involvement in water management initiatives, underscoring the importance of collaborative efforts to safeguard water resources for future generations.

## Acknowledgments

I would like to express my sincere gratitude to all those who supported me throughout this research project. First and foremost, I would like to thank my supervisor Mr. Danny Chisanga Musenge for their invaluable guidance, encouragement, and expertise. Their insight and constructive feedback were instrumental in shaping this study. I would also like to acknowledge the support of my colleagues and friends who provided assistance and motivation during the data collection and analysis phases. Special thanks to information and communication University for providing access to laboratory facilities and resources essential for the research. Additionally, I am grateful to the communities involved in the study for their cooperation and willingness to share their experiences related to water quality and industrial activities. Finally, I would like to thank my family for their unwavering support and understanding throughout this journey. Their encouragement has been a constant source of strength as I pursued this important research.

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