

**ASSESSING THE USE OF IRON OXIDE AND SILICA IN INDUSTRIAL  
WASTEWATER TREATMENT**

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**S21B32/080**

**A FINAL YEAR PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING,  
DESIGN AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR  
THE AWARD OF A BACHELOR OF SCIENCE DEGREE IN CIVIL AND ENVIRONMENTAL  
ENGINEERING AT UGANDA CHRISTIAN UNIVERSITY**

**April, 2025**



## ABSTRACT

Lake Victoria, the world's largest tropical freshwater lake, supports critical ecological, economic and social functions across East Africa. However, increasing industrial pollution, particularly in Walukuba Masese (Jinja district), poses a serious threat. The uncontrolled discharge of untreated effluent especially from the sunbelt textile industry has led to elevated phosphorous levels, causing eutrophication, harmful algal blooms and aquatic degradation.

This study investigates the use of iron oxide and silica, as a sustainable method for phosphorous removal from industrial waste water. Laboratory experiments assessed adsorption efficiency based on parameters such as contact time, adsorbent dosage, Ph, and initial phosphorous concentration. The adsorption mechanism relies on Fe-O-P bond formation, where phosphates ions interact with hydroxyl groups on iron oxide surfaces. Silica enhances this process by increasing surface area structural stability.

Finding reveals that the iron oxide and silica combination offers a cost effective and environmentally sustainable alternative to conventional treatment methods. Significant reductions in phosphorous levels were observed, demonstrating the potential of this system to meet regulatory standards and protect Lake Victoria's aquatic ecosystem. This research highlights the importance of adopting innovative, efficient wastewater treatment technologies for long term water resource sustainability.

## **DECLARATION**

I hereby declare that this research proposal is entirely my own work and has not been submitted to any other institution for assessment other than this university

Signed.....

Date: .... / .... / ....

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S21B32/080.

## **APPROVAL**

This research project is submitted in partial fulfillment of the requirements for the award of a bachelor's degree in civil and environmental engineering at Uganda Christian University. The project has been reviewed, examined, and approved by my academic supervisor.

Supervisor: \_\_\_\_\_ Date: \_\_\_\_\_

## **ACKNOWLEDGEMENT**

I express my deepest gratitude to my supervisor, Mr. Job Gava, for their invaluable guidance, constructive feedback, and continuous support throughout this research. I also acknowledge the faculty members and laboratory technicians at Uganda Christian University and the central laboratory for their assistance in providing the necessary resources and technical expertise. Special thanks to my family and friends for their encouragement and unwavering support both financially unemotionally. I also appreciate the contributions of researchers whose work has greatly informed this study. Lastly, I extend my appreciation to the industry and organizations that provided access to their premises, relevant data and research materials.

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## **CHAPTER ONE: INTRODUCTION**

This chapter entails relevant information about the project, problem statement, objectives of the study, purpose of the study, justification and the scope of the study.

### **1.1. BACKGROUND**

Lakes provide essential ecological, social and economic benefits. Lake Victoria, the largest tropical fresh water lake plays a key role in supporting industries, fishing, agriculture and recreation of East Africa region, contributing to the Gross National Product (GNP) of a nation (Ndugga, 2021). The area surrounding Lake Victoria, specifically the Walukuba Masese landing site in Jinja District, is highly industrialized and densely populated, with a high proportion of the population living alongside the lake (Hussein, 2023). The industries in the lake's catchment area include fish processing, food and beverage, pharmaceuticals, plastics, mattresses, metal fabricating industries and textile industries. Careless disposal of industrial effluents and other waste materials has led to significant **water pollution**, particularly increasing the concentration of nutrients in the lake's waters, primarily from sunbelt textile industry.

Industrial pollution in Uganda is rising, posing a significant environmental risk. Pollution emitted by industries is one of the key contributors to the deterioration of water quality in the country. The availability and quality of water are directly linked to the quality of life, with water quality often reflecting the state of economic development. Groundwater and surface water bodies can be contaminated by several sources. In urban areas, careless disposal of industrial effluents and other wastes significantly contributes to poor water quality (Tariq & Mushtaq, 2023). Most

of the water bodies in developing regions are polluted by untreated effluents discharged from industries (Chowdhary, Bhargava, Mishra, & Khan, 2020).

Parts of Lake Victoria along the areas of walukuba masese in jinja district receive untreated effluents from surrounding industries, which have significantly degraded the water quality. These industries discharge waste into the lake almost without any adequate treatment, resulting in high concentrations of nutrients like phosphorous. This poses severe threats to both aquatic life and human health, leading to problems such as eutrophication, harmful algal blooms, loss of biodiversity, groundwater contamination, and acidification of the water (Taako & Andama, 2024). This research aims to assess the use of iron oxide nano bio-adsorbent to remove nutrients from waste water.

## **1.2. PROBLEM STATEMENT**

Pollution due to increased urban development has taken a toll on the fresh water ecosystems especially the proximal fresh water ecosystems, contributing to their deterioration, destruction and loss. Parts of Lake Victoria along the areas of walukuba masese in jinja district are affected by pollution from human activities like industrialization, sewage disposal among others (Marriott and Humphrey ,2023 ). **Lake victoria faces a significant challenge from the industrial effluents from the sunbelt industry, a leather tanning industry. These have high nutrient concentrations especially phosphorous in the water** (Walakira and Okot-Okumu, 2023). Recent studies have revealed that the phosphorous concentration in some parts of lake Victoria along the areas of walukuba masese landing sites exceed permissible levels with an average concentration of 35.67 mg/L which is way above

the concentration standards of NEMA which are set at 10mg/L (ministry of water and environment, 2023).

High phosphorous concentration in the effluent and subsequent catchment poses severe threats to both aquatic life and human health, in terms of eutrophication and harmful algal blooms. These impact the biodiversity, ground water contamination, acidification of the water, among others. The current situation calls for urgent attention to mitigate the adverse impacts of increased nutrient concentrations on the ecosystems and safeguard the health and wellbeing of the people in the mentioned catchment areas inclusive of those directly benefiting from the lake. This research aims at assessing the use of iron oxide and silica in industrial wastewater treatment.

### **1.3. OBJECTIVES**

#### **1.3.1. Main Objective**

To assess the use of iron oxide and silica in industrial wastewater treatment.

#### **1.3.2. Specific objectives**

1. To determine the Physicochemical parameters of the wastewater effluent
2. Assessing the performance of iron oxide and silica in phosphorous removal from wastewater.
3. To design a wastewater treatment system for the wastewater effluent using iron oxide and silica.

### **1.4. RESEARCH QUESTIONS**

1. What are the Physicochemical parameters of the wastewater effluent?
2. What is the performance of iron oxide and silica in phosphorous removal from wastewater.

### 3. How will the wastewater treatment system be designed?

#### 1.5. GEOGRAPHICAL SCOPE

Sunbelt textile industries located along walukuba and masese landing sites in Jinja district.

#### 1.6. JUSTIFICATION

The discharge of untreated industrial wastewater into aquatic ecosystems, such as lakes like Lake Victoria, poses significant health risks to communities that depend on these water sources. Elevated phosphorus levels in such effluents are a primary contributor to eutrophication, leading to detrimental effects like algal blooms, oxygen depletion, and degradation of water quality. Therefore, it is imperative to reduce phosphorus concentrations in wastewater to meet environmental discharge standards and protect aquatic ecosystems (Frankel,2022).

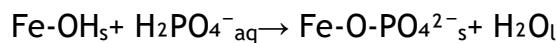
Iron oxide-based bio-adsorbents have emerged as a promising solution for phosphorus removal from wastewater. Their high surface area and abundance of active sites facilitate effective adsorption of phosphate ions. The mechanism involves the formation of hydroxyl groups on the iron oxide surface in aqueous environments, which interact with phosphate ions through ligand exchange reactions. This process results in the displacement of surface hydroxyl groups by phosphate, forming stable Fe-O-P bonds, thereby effectively removing phosphorus from the water.

To enhance the adsorption capacity of iron oxides, it is incorporated with bio-adsorbents like silica. Silica increases the overall surface area and reactivity of the composite material, providing additional active sites for pollutant binding. This

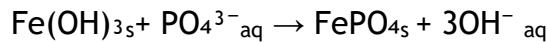
synergistic effect leads to higher adsorption capacities, making the composite material more efficient in removing contaminants from wastewater.

### 1.7. Adsorption Mechanism of Phosphorus

Iron oxides ( $\text{Fe}_2\text{O}_3$  or  $\text{Fe}_3\text{O}_4$ ) are known to have a high affinity for phosphate ions due to their surface charge and the ability to undergo ligand exchange reactions. In the presence of water, iron oxide surfaces become hydroxylated, forming -OH groups that can interact with phosphate ions ( $\text{PO}_4^{3-}$ ) in solution. The phosphate ions displace hydroxyl groups on the surface of the iron oxide particles, forming Fe-O-P bonds.



Phosphate ions bond with the iron oxide's hydroxyl groups, leading to the formation of inner-sphere complexes:



This mechanism allows for strong binding of phosphorus onto the iron oxide surface, effectively reducing its concentration in wastewater. The silica component of iron oxide further enhances this adsorption due to its increased surface area and reactivity, leading to higher adsorption capacities.

## CHAPTER TWO: LITERATURE REVIEW

### 2.0 INTRODUCTION

Water pollution due to excess nutrients such as phosphorus and nitrogen has become a major environmental concern worldwide. These nutrients, when present in excessive amounts, can lead to severe water quality degradation, eutrophication, harmful algal blooms, and oxygen depletion in aquatic ecosystems. Wastewater from industrial, agricultural, and urban activities is often loaded with these nutrients, requiring effective treatment methods. Among various strategies, adsorption using iron oxide nano bio-adsorbents has emerged as a promising solution for the removal of these nutrients, particularly phosphorus, from wastewater.

#### 2.1. Sources of Nutrient Contaminants in Textile Wastewater and Their Impact on Water Treatment

Textile wastewater contains various pollutants, including dyes, heavy metals, surfactants, and organic and inorganic nutrients. The presence of nutrients, particularly nitrogen and phosphorus compounds, is a significant concern as it can contribute to water pollution and eutrophication if not properly treated.

One major source of nutrients in textile wastewater is the use of synthetic dyes. Many dyes, including reactive, azo, and acid dyes which contain nitrogen-based functional groups. During the dyeing process, a considerable portion of these dyes remains unbounded to the fabric, and it is subsequently washed off, leading to increased nitrogen levels in the effluent. Furthermore, some dyes incorporate phosphorus compounds, further elevating the nutrient content in wastewater. Similarly, sizing agents and starch-based additives used in the pre-treatment phase introduce organic polymers such as starch, polyvinyl alcohol (PVA), and

carboxymethyl cellulose (CMC). When these substances degrade, they release ammonia, nitrates, and organic nitrogen into the wastewater, contributing to nutrient pollution.

Detergents and surfactants used in textile processing play a role in introducing nutrients into wastewater. Most of the commercial detergents contain phosphate-based compound that act as water softeners and cleaning enhancers. Since phosphates are highly soluble, they persist in wastewater and contribute to phosphorus pollution. If discharged without adequate treatment, these compounds promote excessive algal growth in water bodies, hence leading to eutrophication and oxygen depletion. Furthermore, biochemical reactions occurring within effluent holding tanks also elevate nutrient levels. As organic matter decomposes under microbial activity, nitrogenous compounds such as ammonia and nitrates are released, further increasing the nutrient concentration in wastewater, hence calling the need for treatment.

The source of water used in textile industries can also influence nutrient levels in the final effluent. If the water is sourced from rivers, lakes, or groundwater already containing high concentrations of nitrogen and phosphorus, these nutrients become part of the textile wastewater stream. Pre-treatment methods may not effectively remove all contaminants, resulting in an accumulation of nutrients in the discharged effluent. Furthermore, fabric softeners and finishing chemicals used in the final stages of textile production contain nitrogenous and phosphorus-based compounds, which dissolve into wastewater during washing and rinsing processes.

## **2.2. WASTEWATER**

Waste water is used water that has been affected by domestic, commercial and industrial use. Waste water is composed of 99.9% water and the remaining 0.1% contains organic matter, inorganic compounds and microorganisms (wang, 2021). Waste water effluents are released to a variety environment, like lakes, ponds, streams, rivers and estuaries.

### **2.2.1. COMPOSITION OF WASTE WATER**

Wastewater is a complex mixture of various substances originating from households, industries, and commercial activities. It is primarily composed of water, including both freshwater and contaminated natural water sources. A significant portion of wastewater consists of organic matter such as food waste, human and animal waste, oils, fats, proteins, and plant materials, which serve as energy sources for microorganisms in treatment processes. Nutrients like nitrogen and phosphorus, derived from detergents, human waste, and agricultural runoff, can lead to water pollution and eutrophication if untreated. Suspended solids, including sediments, soil, food particles, paper, and plastics, are also common in wastewater. Additionally, it may contain hazardous chemicals such as heavy metals, pesticides, solvents, pharmaceuticals, and industrial toxins, posing environmental and health risks. Pathogens, including bacteria, viruses, and parasites from human and animal waste, further highlight the need for proper wastewater treatment. The pH and temperature of wastewater vary depending on its source and can influence the efficiency of treatment processes, with higher temperatures generally enhancing microbial activity. Effective treatment is crucial to prevent pollution, protect ecosystems, and ensure safe water reuse (wang, 2021).

## **2.2.2. SOURCES AND TYPES OF WASTEWATER**

Wastewater which also known as raw sewage originates from households, industries, commercial or institutional facilities.

### **2.2.2.1. Domestic wastewater**

Domestic wastewater includes all water generated by home dwelling, public restrooms, public restrooms, schools and other health centers, apartments. They all produce high volumes of wastewater.

**Table 1: Types of domestic wastewater**

Type of Waste water	Source	Composition	Characteristics
Black water	Toilets, dishwashers, food preparation sinks	Human waste (feces & urine), toilet paper, cleaning agents, food residues	Highly contaminated, contains pathogens, organic matter, and dissolved chemicals
Grey water	Bathroom sinks, laundry machines, bathtubs, spas	Soap, detergents, skin cells, hair, grease, and dirt	Does not contain human waste, lower contamination, suitable for reuse after treatment

<b>Yellow Water</b>	Urine collected separately from toilets	Pure urine without fecal contamination	Can be used for fertilizer production due to nutrient content (nitrogen & phosphorus)
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#### 2.2.2.2. Industrial wastewater

Industrial wastewater refers to liquid waste generated from industrial processes such as manufacturing, food processing, and other production activities. The composition and level of contamination in industrial wastewater vary depending on the type of industry and the chemicals involved in its operations. Industrial wastewater is generally classified based on its **physical, chemical, and biological properties** (Łukasz Wujcicki, 2023).

There are two main categories of industrial wastewater:

- 1. Inorganic Industrial Wastewater** - This type originates from industries such as steel production, electroplating plants, and coal processing facilities. It primarily contains **inorganic pollutants**, including heavy metals, acids, and other non-biodegradable substances.
- 2. Organic Industrial Wastewater** - This is generated from industries that heavily rely on organic compounds for their processes, such as **textile manufacturing, tannery operations, and chemical**

**production.** The wastewater from these industries contains **organic pollutants**, including dyes, solvents, and biodegradable chemicals

#### **2.2.2.3. Characteristics of constituents of wastewater.**

Constituents of Waste Water are characterized in terms of their physical, chemical, and **biological composition.**

##### **2.2.2.3.1. Physical characteristics**

###### **Turbidity**

Turbidity is a measure of water clarity, typically caused by suspended particles such as organic matter and fine particles like clay. High turbidity in wastewater effluent can severely affect aquatic ecosystems by reducing light penetration, hindering aquatic plants from performing photosynthesis, and disrupting the natural balance of the water body (Walakira & OkotOkumu, 2023). Turbidity is quantified using a nephelometric method, which involves passing light through the water sample and measuring the light that is scattered by particles. The unit of measurement for turbidity is the Nephelometric Turbidity Unit (NTU). According to the National Environment Management Authority (NEMA), the acceptable discharge standard for wastewater effluent is 300 NTU.

###### **Total Suspended Solids (TSS)**

Total suspended solids (TSS) refer to particles that are not soluble in water and remain suspended due to their density being less than water. These particles can include organic and inorganic matter. A common source of TSS is untreated or improperly treated wastewater effluent. TSS is a critical parameter in wastewater quality

analysis as it impacts aquatic life by reducing oxygen levels and light penetration, creating poor water conditions.

#### **2.2.2.3.2. Chemical characteristics**

##### **PH**

pH is the measure of the concentration hydrogen ions, indicating whether water is acidic ( $\text{pH} < 7$ ), neutral ( $\text{pH} = 7$ ), or alkaline ( $\text{pH} > 7$ ). The pH is an important parameter as it affects other water treatment processes. Wastewater effluent having a pH value that is not within the NEMA discharge standards will have a negative impact on the receiving water bodies when discharged. Effluent with low pH levels can cause acidity in the receiving water bodies affecting fish in terms of growth and reproductive activities (Aghalari et al,2023). pH in wastewater affects the biological reactions and low levels inhibits growth of nitrifying bacteria which are essential for removing ammonia and nitrates from wastewater.

##### **Biochemical Oxygen Demand (BOD)**

Biochemical Oxygen Demand (BOD) is a measure of the amount of dissolved oxygen required by aerobic microorganisms to decompose organic matter present in wastewater. High BOD levels indicate a high concentration of organic pollutants, which can originate from agricultural runoff, industrial effluents, and sewage (Zayed, 2023). When wastewater with high BOD is discharged into surface water, it depletes the dissolved oxygen levels, threatening aquatic organisms, particularly fish, which rely on oxygen for respiration. BOD is measured over five days (BOD5), and results are expressed in milligrams per liter (mg/L). BOD testing is essential for evaluating the performance of wastewater treatment systems and determining effluent quality.

### **Chemical Oxygen Demand (COD)**

Chemical Oxygen Demand (COD) refers to the amount of oxygen required to chemically oxidize organic and inorganic compounds in water. It is a crucial parameter for assessing the organic load in wastewater and its impact on receiving water bodies (Mensah, 2022). High COD levels in wastewater indicate the presence of pollutants, and discharging such effluent can drastically reduce dissolved oxygen levels, further stressing aquatic life.

COD analysis provides a rapid estimate of organic pollution in water samples.

### **Total Phosphorus**

Total phosphorus refers to the sum of all phosphorus forms in wastewater, including soluble and insoluble forms. Ortho-phosphates are the most easily removed form of phosphorus during wastewater treatment. Phosphorus typically enters wastewater from domestic sources such as detergents, human waste, and food residues. High phosphorus levels in wastewater discharged into water bodies contribute to eutrophication, promoting excessive algal growth (Wang, 2021). This algal overgrowth leads to oxygen depletion in the water as algae die and decompose, resulting in the death of aquatic organisms due to insufficient oxygen levels.

### **pH**

pH is a measure of the hydrogen ion concentration, indicating whether water is acidic ( $\text{pH} < 7$ ), neutral ( $\text{pH} = 7$ ), or alkaline ( $\text{pH} > 7$ ). The pH of wastewater affects many chemical and biological processes, including treatment efficiency. Wastewater effluent that falls outside the NEMA discharge standard range for pH can disrupt the receiving water bodies. For example, low pH (acidic) wastewater can affect the reproductive and growth processes of fish and other aquatic life. pH is commonly

measured using a pH meter, making it an essential parameter for water quality assessment.

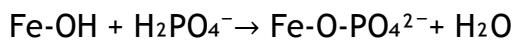
### **2.3. Iron oxide bio-adsorbent**

#### **2.3.1. Iron Oxide Bio-Adsorbents for Phosphorus Removal**

Iron oxide-based materials are particularly effective in removing phosphorus from wastewater due to their high affinity for phosphate ions. The silica material significantly increases their surface area, allowing for greater adsorption capacity. The interaction between iron oxide and phosphate ions typically occurs via chemisorption, where phosphate binds to the surface of iron oxide particles, forming strong Fe-O-P bonds.

#### **Adsorption Mechanism and Equations**

The removal of phosphorus using iron oxide nano bio-adsorbents follows a surface adsorption process that can be described by the chemical reaction below



This reaction represents the binding of phosphate ions to the surface of iron oxide ( $\text{Fe}_2\text{O}_3$ ). The adsorptive capacity of iron oxide is influenced by factors such as pH, initial phosphorus concentration, and the presence of competing ions in the water. Phosphates typically form inner-sphere complexes with iron hydroxides.

The high affinity of iron oxides for phosphate ions can be attributed to their ability to form stable complexes through surface hydroxyl groups. Various studies have demonstrated the efficacy of iron oxide in adsorbing phosphate ions from

wastewater, with significant removal efficiencies across a range of operating conditions . $\text{Fe(OH)}_3 + \text{PO}_4^{3-} \rightarrow \text{FePO}_4 + 3\text{OH}^-$

Iron oxide bio-adsorbents are especially useful in tackling phosphorus pollution due to their rapid kinetics, high adsorption capacities, and the ability to regenerate and reuse the adsorbent. Nanoparticles are also more effective in reaching and interacting with target pollutants in complex water matrices, such as those found in industrial wastewater.

### **2.3.2. Factors Affecting Phosphorus Adsorption pH Levels**

The adsorption of phosphorus is highly pH-dependent, with maximum removal typically observed in slightly acidic conditions (pH 4-6). At lower pH, the surface charge of iron oxides becomes more positive, enhancing the electrostatic attraction between the adsorbent and phosphate anions **Presence of Competing Ions**

The presence of other anions, such as sulfates or nitrates, can compete with phosphate for adsorption sites, potentially reducing the efficiency of phosphorus removal.

#### **Temperature**

Higher temperatures can increase the adsorption rate but may also reduce the equilibrium capacity by affecting the adsorbent's structure and the interaction strength between the phosphate ions and iron oxides.

#### **Adsorbent Dosage**

The amount of nano bio-adsorbent used also plays a crucial role in determining the efficiency of phosphorus removal. Higher dosages provide more active sites for

phosphate binding but can lead to aggregation of nanoparticles, reducing surface area and effectiveness

#### **2.3.2.1. Recent Advances in Phosphorus Removal Technologies**

In recent years, there has been considerable progress in developing hybrid and composite materials for phosphorus adsorption. Iron oxide nanoparticles, when combined with natural polymers such as chitosan or cellulose, offer enhanced removal efficiency due to the synergistic effects of the metal oxide and the polymer matrix. These materials not only provide high adsorption capacities but also exhibit better stability in wastewater conditions.

Additionally, advances in the synthesis of magnetic iron oxide nanoparticles allow for easy separation of the adsorbent from the treated water, making the process more efficient. This magnetic property enables the adsorbent to be recovered and reused, reducing operational costs in wastewater treatment plants (Łukasz Wujcicki, 2023).

### **2.3. Wastewater Treatment**

#### **Introduction**

Wastewater treatment is a process designed to remove contaminants from wastewater before it is released into the environment. Municipal wastewater treatment plants play a critical role in protecting ecosystems by ensuring that treated effluent meets regulatory discharge standards before being returned to water bodies (Aghalari, 2020). Treatment processes vary but typically involve physical, chemical, and biological methods to eliminate organic, chemical, and physical pollutants.

## **Adsorption**

Adsorption is a wastewater treatment method in which molecules (adsorbates) adhere to the surface of a solid material (adsorbent). This process is widely used to remove pollutants from wastewater, particularly at low concentrations. Adsorption is favored due to its simplicity and effectiveness, especially in comparison to methods such as coagulation and flocculation, which tend to produce large amounts of sludge (Tran, 2023). Adsorbents with high affinity for target pollutants, such as iron oxide nano bio-adsorbents, can significantly improve the efficiency of wastewater treatment, especially in removing nutrients like phosphorus.

### **2.3.1. Types of Bio-Adsorbents**

Various types of bio-adsorbents are being developed to enhance wastewater treatment, focusing on sustainable and biodegradable materials such as chitosan, cellulose, and iron oxide nanoparticles. These materials are advantageous due to their large surface area, mechanical strength, and environmental compatibility, making them effective in adsorbing contaminants.

### **2.3.2. Factors Affecting Adsorption**

#### **Adsorbent Dose**

The amount of adsorbent used directly affects the adsorption process. An increase in adsorbent dosage increases the availability of active sites for pollutant capture, leading to higher removal efficiency.

#### **Contact Time**

The duration of contact between the adsorbent and the wastewater influences the extent of adsorption. Longer contact times generally lead to greater adsorption as

more time allows for equilibrium to be reached between the adsorbent and the pollutant.

## pH

The pH of the wastewater plays a critical role in adsorption efficiency, as it affects both the adsorbent surface charge and the ionization state of the pollutants. Optimal pH levels enhance adsorption by maximizing the interaction between the adsorbent and the pollutant.

## Temperature

Temperature influences the chemical reactions involved in adsorption. Typically, an increase in temperature speeds up reaction rates but may also decrease adsorption capacity as the adsorbate may desorb from the adsorbent surface.

### **2.4. LEGISLATION ON WASTEWATER MANAGEMENT**

Policy and regulatory frameworks are crucial in governing, guiding and maintaining wastewater treatment practices. They provide a regulatory framework for environmental protection, sustainability, and public health. Standards, protocols and guidelines have been set by international organizations such as World Health Organization. These standards set bench marks for wastewater treatment and discharge, they cover various characteristics including nutrient availability and effluent limits. These standards are important as they confirm compliance of wastewater treatment plants with environmental and public health standards.

#### **2.4.1. The United Nations (UN)**

UN works with various member states to develop international guidelines and standards for wastewater management.

- **International Organization for Standardization (ISO)**

The International Organization for Standardization sets standards for wastewater management aiming at ensuring sustainable wastewater treatment and disposal. ISO provides a framework for wastewater management, including determination of the wastewater quality. Some of the standards set by ISO that are in line with wastewater management include;

- ❖ ISO 14001:2015 - Environmental Management Systems - Requirements with Guidance for use. It provides the framework for management of environmental impacts, treatment and disposal of wastewater.
- ❖ ISO 24511:2017 - water quality- this standard provides for determination of Biochemical Oxygen Demand (BOD) in wastewater effluent and river water using the open reflux method.
- ❖ ISO 25649-1:2017-Water quality- this standard provides for the determination of the Chemical Oxygen Demand (COD) in wastewater effluent and river water using closed reflux method.

#### **2.4.2. African Union (AU)**

The African Union is a regional intergovernmental organization which aims at promoting development and cooperation among the various countries in Africa. The African Union promotes and supports waste-water management through several means which include;

1. **Promotion of regional cooperation**

The African Union plays a crucial role in promoting regional cooperation on wastewater management. It does so by bringing together countries to share ideas, experiences and best practices on wastewater management.

## **2. Provision of technical and financial support**

The African Union plays a role in providing both technical and financial support to the African countries, enhancing their wastewater management practices and infrastructure. Some of which include funding for wastewater treatment plants, new technological development for wastewater management among others.

## **3. Rising awareness**

The African union promotes awareness about wastewater management practices, importance of managing wastewater among others. It does this by organizing workshops and conferences which promote best wastewater management practices.

### **2.4.3. East African Standard**

The aim of the East African Standard is to indicate the quality of the effluent to be discharged on land or water bodies, among the several countries that make up the East African Community. This is done in order to promote a consistent approach towards the prevention of water pollution as per the regulation. Therefore, the wastewater to be discharged into the environment (land or water bodies) should be free from;

- a) Floating debris and other materials in amounts sufficient to be noticeable and that can lead to deterioration of the environment

- b) Substances that will settle in receiving water bodies and which substances can adversely affect aquatic life.
- c) Nutrients such as Nitrogen and Phosphorous in concentrations that promote eutrophication of the receiving water bodies with its undesirable effects.

The wastewater from all municipal and industrial establishments includes but are not limited to the ones listed below;

1. The oil and gas industry from production and refining, including natural and petroleum gas
2. The pulp and paper industry
3. Pharmaceutical, agrochemical, mining, textile among others
4. Wastewater that is derived from households, business buildings, institutions among others which may contain storm water, ground water or surface runoff

### **Requirements For Wastewater Discharged on Land and Into Water Bodies**

The East African standard specifies requirements of wastewater discharged on land and into water bodies from municipal and industrial activities. However, it does not include requirements for hazardous effluents which are classified as restricted substances.

#### **Specific requirements**

##### **Physical and chemical requirements for municipal and industrial wastewater**

Wastewater effluent shall comply with the requirements in the table below when tested in accordance with the prescribed methods.

**Table 2: physical and chemical requirements**

S/N	Parameter	Requirements	Test method
1.	BOD <sub>5</sub> at 20°C, mg/l max.	50	ISO 5815-2
2.	COD, mg/l, max	100	ISO 15705
3.	Color, TCU, max	300	ISO 7887
4.	pH	5-9	ISO 10523
5.	Total Suspended Solids (TSS), mg/l, max	80	ISO 11923
6.	Turbidity, NTU	30	ISO 7027-1
7.	Total Dissolved Solids, mg/l, max	1500	ASTM D 5907-13

#### **2.4.4. Uganda at National Level**

Management of waste water in Uganda is a very crucial to protect the environment from the adverse impacts that arise from poor management of waste-water. Wastewater management in Uganda is regulated by several laws and regulations.

#### **2.4.5. National Environment Act Cap 153.**

The National Environment Act provides a legal framework for sustainable environmental management, establishing an authority as a coordinating, monitoring and supervisory body for that purpose. This act establishes NEMA as the principal

agency for the management of the environment, providing a range of measures to promote effective wastewater management in the Country.

- **Environmental Impact Assessment (EIA).** This act ensures that all the projects, wastewater treatment projects for example, that may have significant impacts on the environment undergo an EIA before their approval.
- **Permits and licenses.** According to this act, all the entities that discharge their effluent into the environment obtain a permit from National Environment Management Authority (NEMA). The permit sets various standards for effluent discharge and ensures that all the entities meet those standards before discharging their effluents into the environment.
- **Environmental Audits.** According to this act, individuals and the entities must assess the impacts of their activities on the environment including wastewater management. Therefore, the entities and individuals should always conduct environmental audits.
- **Public participation.** The act ensures public participation as it requires the public to take part in the decision-making processes related to wastewater management and other issues of the environment.
- **Fines and penalties.** The act imposes fines and penalties to the violators of the act, including the individuals or entities who do not improperly dispose of their wastewater.
- **Closure of facilities.** The government is given power and authority by the act to close down facilities that do not adhere to the effluent discharge standards. All the facilities, including wastewater management facilities that pose a threat to the environment and public health will be closed.

## **2.5. Standards for wastewater discharge according to the water Act, Cap 152**

These standards for treated effluent being discharged into the environment is established by the Authority in consultation with the lead agency under the National Environment Act, Cap 153 section 26

**Table 3: maximum permissible limits**

<b>SN</b>	<b>MAXIMUM PERMISSIBLE LIMITS</b>	
1	BOD5	50mg/l
2	COD	100mg/l
3	pH	6.0-8.0mg/l
4	Phosphate(total)	10 mg/l
5	Turbidity	300 NTU
6	Total suspended solids	100 mg/l
7	Total dissolved solids	1200mg/l

The national Environment Act, Cap 153 of Uganda provides a framework for managing and protecting the environment inclusive of wastewater management.

## CHAPTER THREE: METHODOLOGY SAMPLE COLLECTION

### 3.1. SAMPLING (APHA 1060)

We implemented the **grab sampling method**, where samples were collected at a single point in different time intervals from specific locations. This technique ensures that a snapshot of the water quality is obtained at that specific moment, reflecting the effluent's condition at a given time. Samples were collected three times daily over three different days to ensure a representative and comprehensive dataset. And this was done in triplicates. It was done when the textile industry was still in operation. The first sample was picked at 8:30am, second sample was picked at 12:30pm and the third sample was picked at 4:30pm. Care was taken to label sampling containers properly and to avoid contamination by rinsing the containers with distilled water prior to collection. Preservation of the samples was done by storing them in a cooler box to maintain their chemical integrity and prevent alterations in concentration during transportation.

### 3.2. Laboratory Tests

**Table 4: Laboratory tests**

S/N	SPECIFIC OBJECTIVE	PARAMETER	METHODOLOGY
1	To determine the Physicschemical parameters of the wastewater effluent	COD Total phosphorous pH	APHA 5220 APHA 4500 APHA 4500 H APHA 2450

		Total suspended solids Turbidity	APHA 213
2	To assess the performance of iron oxide bio-adsorbent.	Contact time Optimum dose rate	Batch adsorption test Column tests
3	To design a wastewater treatment system using iron-oxide nano bio-adsorbent		Water research and design manual

### **3.3. DETERMINATION OF THE PHYSICOCHEMICAL PARAMETERS OF THE WASTEWATER EFFLUENT**

#### **3.3.1. Laboratory Analysis**

The laboratory analysis was conducted using the American Public Health Association Standard methods (APHA, 1995) and the corresponding equipment used for analyzing each parameter is as explained below

Reagents were prepared such as potassium dichromate solution which is an oxidizing agent and silver sulphate solution which is a catalyst.

The collected wastewater sample was placed in a digestion and the prepared reagents which are potassium dichromate solution and silver sulphate solution were

added. The vessel is sealed to prevent escape of volatile compounds during the reaction. The mixture was then heated at a temperature of about 150-170 degrees Celsius for two hours so as to oxidize the organic matter.

The mixture was cooled to room temperature and excess potassium dichromate solution is titrated with ferrous ammonium sulfate which is a standard solution using an indicator. The COD of the wastewater sample was then be determined.

#### **Total phosphorous (APHA standard 4500)**

Reagents for phosphorous analysis were prepared, this included acid solution preparation for digestion. to convert all species of phosphorous into ortho-phosphate.

A measured volume of the sample was placed in clean test tubes and ammonium molybdate added to it. The mixture was mixed thoroughly and then allowed to react to form molybdenum blue complex.

A reducing agent solution was added to form a blue coloration and absorbance of the solution at a specific wavelength was measured using a spectrophotometer. A calibration curve was then prepared using known concentrations of standard phosphate solutions to establish a relationship between absorbance and phosphorous concentration.

The sample absorbance was compared with calibration curve to determine total phosphorous concentration. To ensure accuracy, blank samples were used. pH (APHA Standard 4500-H)

A Portable Hach Multimeter was used to measure the pH after calibrating the instrument using a buffer solution. The pH probe was rinsed with distilled water and

inserted into the wastewater sample to take readings. Accurate pH measurement is crucial for understanding the acidity or alkalinity of the wastewater, which influences treatment processes and effluent discharge quality.

### **Turbidity (APHA standard 2130)**

Turbidity was measured using a **turbidimeter**. The sample was thoroughly mixed and transferred to a clean container before being placed in the device. The turbidimeter measured the amount of light scattered by the suspended particles in the sample, providing the turbidity in **Nephelometric Turbidity Units (NTU)**. Calibration of the turbidimeter with standards ensured accuracy and consistency of readings.

### **Total Suspended Solids (APHA standard 2540)**

The water sample was mixed thoroughly and then filtered through a weighed standard glass-fiber filter. The residue that is retained on the filter was then oven dried at a temperature of 103 -105 degrees Celsius to a constant weight.

The increase in the weight of the filter paper is the total suspended solid and it was obtained by getting the difference between the weight of filter paper and the weight of filter paper plus the residue in mg/l.

**Table 5:** Standard methods for testing

S/N	PARAMETERS	STANDARD METHOD
1	COD	Closed reflux method
2	pH	8156 pH Electrode Test using a pH multimeter
3	Total phosphorous	APHA 4500
4	Turbidity	turbidimeter
5	Total suspended solids	Spectrophotometric method

### **3.3.2. ASSESSING THE PERFORMANCE OF IRON OXIDE AND SILICA IN PHOSPHOROUS REMOVAL FROM WASTEWATER.**

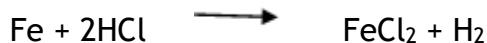
#### **3.3.2.1. Material Acquisition and Preparation**

Iron-oxide bio adsorbent is a combination of iron-oxide and silica. The rice husk from which the silica will be extracted is obtained from a rice milling factory in Kayunga town, Mukono.

#### **3.3.2.2. Iron-Oxide Particles**

Steel waste was obtained from steel scrap, its crushed and grinded into fine particles using a grinder. The steel waste is washed with water or acid solutions to remove impurities such as oils, dirt. The steel waste is then treated with hydrochloric acid

to dissolve the iron into a solution which contains iron ions. The resulting product is iron chloride solution and the undissolved residues are filtered out.



Ferrous chloride solution was oxidized by adding hydrogen peroxide to give ferric chloride solution.



Distinguishing between ferric chloride and ferrous chloride was done using aqueous ammonia, a pale green precipitate of ferrous hydroxide was formed and a reddish-brown precipitate of ferric hydroxide was also formed.

### 3.2.2.3. Preparation of Rice Husk

The rice husk contains silica which is to be extracted and used. The rice husk was washed to remove impurities and then dried at a temperature of about 100°C until the moisture was completely removed.

The dried rice husk was subjected to controlled burning in a furnace at a temperature of 500-700°C to obtain rice husk ash which is rich in silica. The rice husk ash was grinded when collected from the furnace and sieved through the 0.075mm sieve to ensure uniformity in particle size. It was then collected and kept in a polythene bag which was free from damage.

The rice husk ash was treated with 1 mole of sodium hydroxide under stirring of 80°C to produce sodium silicate. The solution was neutralized using HCl to precipitate silica which was then filtered, washed and dried. The X-ray Fluorescence technique was used to identify and quantify the different elements in the rice husk ash under an X-ray Fluorescence Spectrometer.

To obtain iron-oxide nano bio adsorbent, the extracted silica was combined with iron-oxide nano particles by placing both in water and stirring. The resulting mixture was heated in a muffle furnace at a temperature of 500°C to form iron-oxide nano bio adsorbent.

#### **3.2.2.4. Optimum Dose Rate**

Effluent samples were tested using various doses of the iron-oxide bio-adsorbent. In a jar test, increasing amounts of the adsorbent were added to separate samples, while one jar acted as a control. Samples underwent rapid and slow stirring, followed by a 30-minute settling period. The treated samples were analyzed for parameters such as turbidity, TSS, COD, and total phosphorus. The optimal dose rate was determined by assessing the percentage removal of nutrients.

The values that were obtained after the use of iron-oxide bio-adsorbent were denoted,  $D_2$  and the initial values of the wastewater effluent were denoted  $D_1$ . Therefore, the percentage removal of the iron-oxide nano bio adsorbent was obtained using the formula,

$$\text{Percentage removal} = (D_1 - D_2) / D_1 \times 100\%$$

#### **Batch adsorption**

A batch adsorption test is a laboratory experiment which is used when evaluating the adsorption capacity of the material to be used for contaminant or pollutant removal.

#### **Procedure**

1. A known amount of the iron oxide bio-adsorbent was added to a known volume of the wastewater effluent and it was thoroughly mixed.

2. The mixture was then allowed to settle for a contact time of; 30, 60 and 120 mins
3. At the end of each predetermined time, the concentration of the pollutant that remained in the solution after settling were determined using the APHA Standards.
4. The removal efficiency of the iron oxide nano bio-adsorbent was done by subtracting the pollutant concentration in the remaining solution after settling from the initial pollutant concentration in the solution and then dividing by the initial pollutant concentration.
5. The procedure was repeated for different amounts of iron oxide nano bio adsorbent to determine the optimum dosage.

### **COLUMN EXPERIMENT**

Column experiment was performed by using a packed bed using a 300mm length of the plastic column having an internal diameter of 80mm and the iron oxide-silica composite was packed inside the column

The column was layered with a support material, glass wool upon loading the adsorbent to prevent loss of the adsorbent during operation. The bed height was varied to 60mm, 80,100 and 150mm

### **PROTOTYPE DESIGN**

The prototype design is a multi-stage wastewater treatment system utilizing iron oxide for adsorption and silica for filtration. The process begins with raw water collection in the first bucket, where wastewater is held temporarily before treatment. A controlled valve regulates the flow of wastewater into the next stage, ensuring a steady and manageable treatment process. The second stage, the adsorption unit, consists of a second bucket containing iron oxide, which is

responsible for removing phosphates and organic pollutants, including chemical oxygen demand (COD). To enhance the adsorption efficiency, a motor stirs the mixture continuously for 60 minutes, allowing maximum interaction between the iron oxide and the contaminants. Once the adsorption process is complete, a valve releases the partially treated water into the next phase.

The filtration unit is designed using a cut jerrican filled with silica to a depth of 50 cm. This stage is crucial for removing suspended solids (Total Suspended Solids - TSS) and reducing turbidity, thereby improving the clarity and overall quality of the treated water. Silica acts as a physical filter, trapping fine particles and ensuring that the effluent is free from visible impurities. The final stage involves the collection of treated water in a separate container for testing and evaluation. This ensures that the treatment process has effectively reduced pollutants and improved water quality before potential reuse or safe discharge. Your prototype demonstrates a simple yet effective approach to wastewater treatment, integrating adsorption and filtration techniques for efficient pollutant removal.

NB: BOTH THE CONTACT TIME AND OPTIMUM DOSE ARE OBTAINED FROM THE BATCH EXPERIMENTS.



**Figure 1 : Prototype design**

## **CHAPTER FOUR: RESULTS AND DISCUSSIONS**

### **4.1. Preamble**

This chapter includes the results obtained from the tests following the standard procedures, interpretation and discussion of the results in relation to our study. The findings of the study are well in agreement with the scientific hypothesis and the research objectives as listed above.

### **4.2. Introduction**

This chapter presents the results from our research study, it provides solutions to the three objectives following the procedures from the methodology. For the analysis of the physio-chemical quality the tests were carried out triplets to get the average contamination level of the water sources. These results provide a comprehensive understanding of how the water is contaminated.

### **4.3 Analysis of Physico-chemical parameters of the wastewater effluent.**

The wastewaters extracted from sunbelt textile industry outlet and this was collected three times of the day morning, afternoon and evening for three different times. We found the waste water to be contaminated as shown in the table below.

**Table 6: physical chemical parameters and their concentrations.**

Parameters	Duration	1st	2nd	3rd	mean	standard deviation
Chemical oxygen demand	morning	240	264	206	236.6667	29.14332399
	afternoon	286	304	230	273.3333	38.5918817
	evening	187	187	194	189.3333	4.041451884
Total suspended solids						
	morning	406	394	230	343.3333	98.33276836
	afternoon	609	273	438	440	168.0089283
Total phosphates	evening	400	380	406	395.3333	13.61371857
	morning	30.4	31.4	28.4	30.06667	1.527525232
	afternoon	36.2	38.9	31.9	35.66667	3.530344648
	evening	26.4	28.4	25.9	26.9	1.322875656

PH	morning	8.17	8.05	8.23	8.15	0.091651514
	afternoon	7.54	7.76	8.18	7.826667	0.325166624
	evening	8.06	8.11	7.79	7.986667	0.172143351
Turbidity	morning	47.1	52.1	34.5	44.56667	9.069362344
	afternoon	50.4	48.3	36.6	45.1	7.435724578
	evening	32.43	29.6	31.8	31.27667	1.485810665

Results analysis and interpretation of sunbelt textile industry since we found out that it does not meet the concentration standards of NEMA.

#### 4.3.1. Chemical oxygen demand

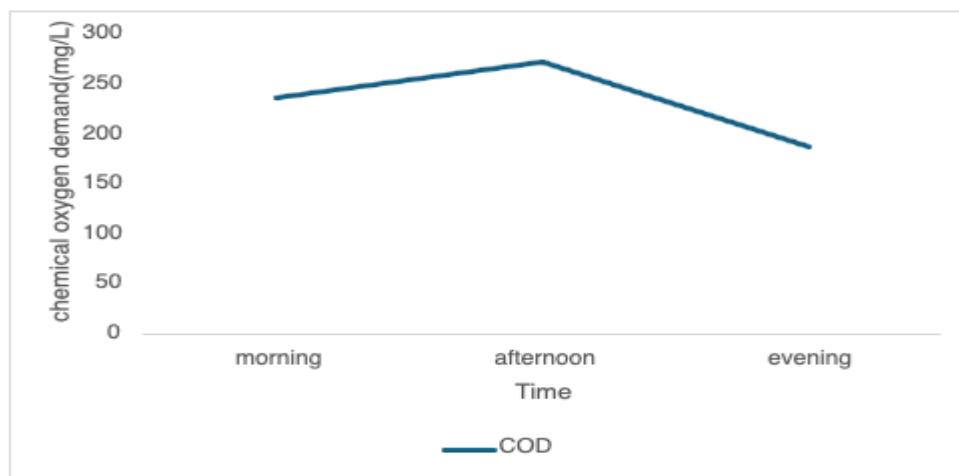
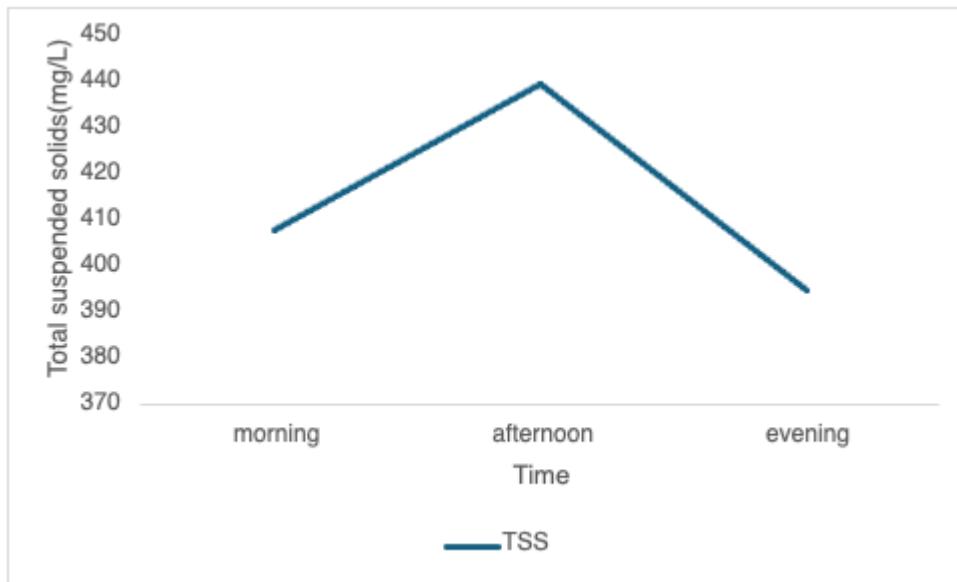


Figure 2: chemical oxygen demand with time

The values above got from the laboratory tests done on the wastewater effluent of sunbelt textile industry show that the water is highly contaminated. This shows the presence of COD because the average mean value is also large which is 233.11 mg/L with a standard deviation of  $\pm$  29.1.

The chemical oxygen demand (COD) in the wastewater from the textile company exhibited a notable diurnal variation. COD, a measure of the amount of organic pollutants in water, averaged  $236.7 \pm 29.1$  in the morning, increased to  $273.3 \pm 38.6$  in the afternoon, and then decreased to  $189.3 \pm 4.04$  in the evening. This fluctuation likely reflects changes in the factory's operations and wastewater treatment processes throughout the day. Increased production activity during the afternoon could lead to a higher concentration of pollutants in the wastewater, thus elevating the COD levels. Conversely, reduced activity in the evening may result in lower COD. Additionally, the efficiency of the wastewater treatment plant might vary throughout the day, potentially struggling to handle peak loads in the afternoon or experiencing fluctuations in factors like temperature or chemical balance that impact treatment effectiveness. Variations in the composition of the influent wastewater, including the types and amounts of pollutants discharged, could also contribute to the observed COD changes. While less probable, minor inconsistencies in sampling or the influence of diurnal biological activity within the treatment system might also play a role.

#### 4.3.2. Total suspended solids

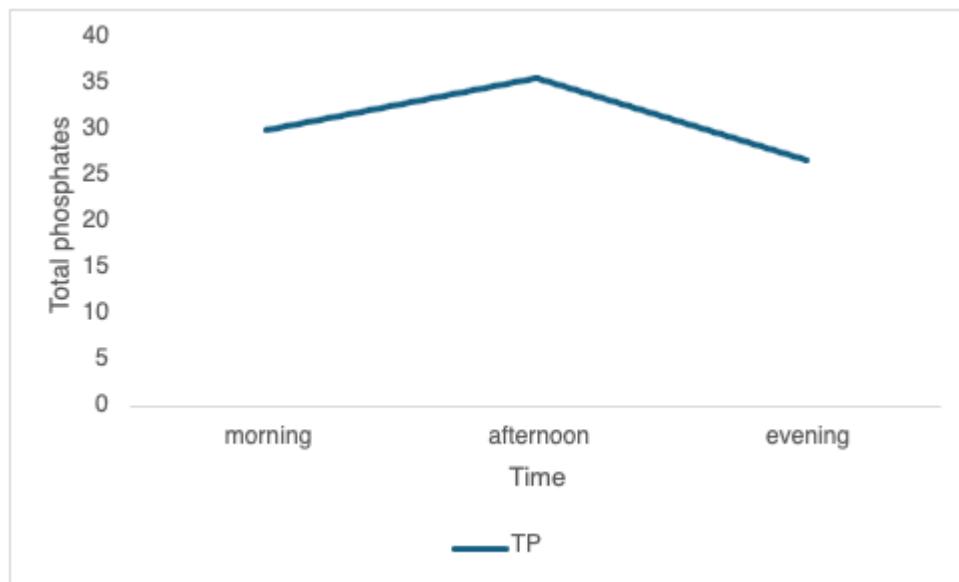


**Figure 3: total suspended solids variation with time**

The values above got from the laboratory tests done on the wastewater effluent of sunbelt textile industry show that the water is highly contaminated. This above results show the presence of total suspended solids because the average mean value is large which is 329.88 mg/L with a standard deviation of  $\pm 98.33$ .

The mean is  $343.3 \pm 98.3$  in the morning and it increased to  $440 \pm 168.0$  in the afternoon and reduced to  $395.3 \pm 13.6$  in the evening.

#### 4.3.2. Total phosphates

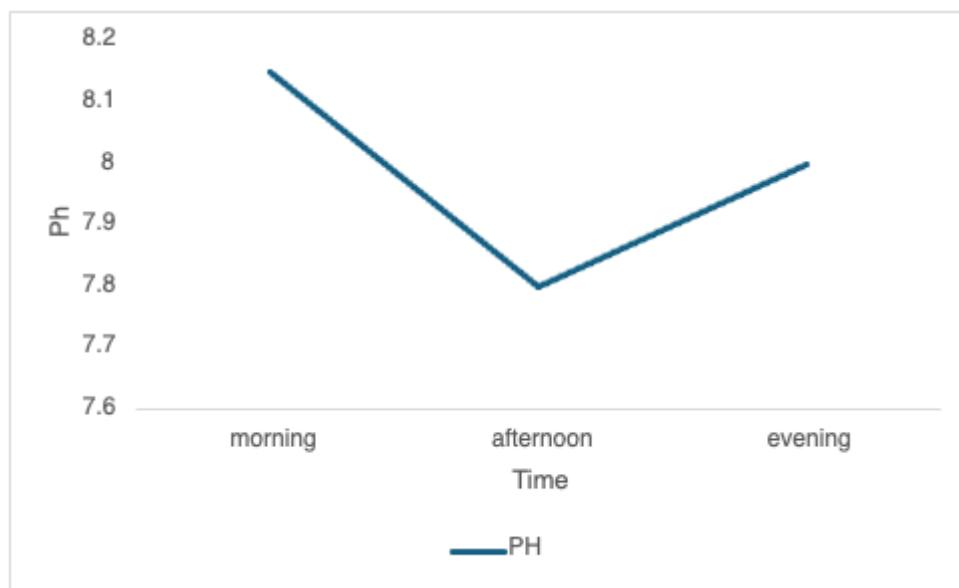


**Figure 4 : total phosphates variation with time**

The values above got from the laboratory tests done on the wastewater effluent of sunbelt textile industry show that the water is highly contaminated. This shows the presence of total Phosphorous because the average mean value is also large which is 30.88mg/L with a standard deviation of  $\pm 1.5$ .

The mean is  $30.06 \pm 1.52$  in the morning and it increased to  $35.67 \pm 3.5$  in the afternoon and reduced to  $26.9 \pm 1.3$  in the evening.

#### 4.3.3. pH

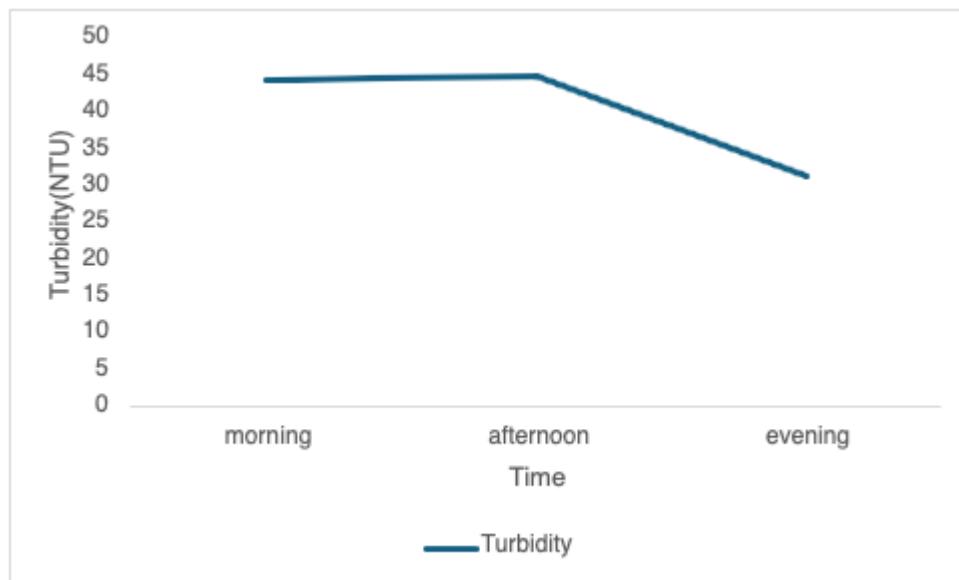


**Figure 5:** Ph variation with time

The values above got from the laboratory tests done on the wastewater effluent of sunbelt textile industry show that the water is highly contaminated. These above results show the presence of pH because the average mean value is large which is 7.99mg/L with a standard deviation of  $\pm 0.09$ .

The mean is  $8.15 \pm 0.09$  in the morning and it decreased to  $7.83 \pm 0.32$  in the afternoon and increased to  $7.99 \pm 0.17$  in the evening.

#### 4.3.4. Turbidity



**Figure 6: turbidity variation with time**

The values above got from the laboratory tests done on the wastewater effluent of sunbelt textile industry show that the water is highly contaminated. These above results show the presence of turbidity because the average mean value is large which is 40.31mg/L with a standard deviation of  $\pm 9.1$ .

The mean is  $44.6 \pm 9.06$  in the morning and it decreased to  $45.1 \pm 7.4$  in the afternoon and increased to  $31.27 \pm 1.4$  in the evening.

#### 4.4 Assessing the performance of iron oxide bio-adsorbent during the removal of nutrients from waste.

Effluent samples were tested using various doses of the iron-oxide. In a Batch adsorption test, increasing amounts of the adsorbent were added to separate samples, while one jar acted as a control. Samples underwent rapid stirring of about 140 rpm to 170 rpm, followed by a 30-minute settling period. The concentration of

the parameters is tested after 30 minutes and after 60 minutes in order to determine the contact time of the iron oxide. And the treated samples were analyzed for parameters such as turbidity, TSS, COD, and total phosphorus. The optimal dose rate was determined by assessing the percentage removal of nutrients as shown below.

#### **4.4.1. Results and interpretation (Batch Adsorption test)**

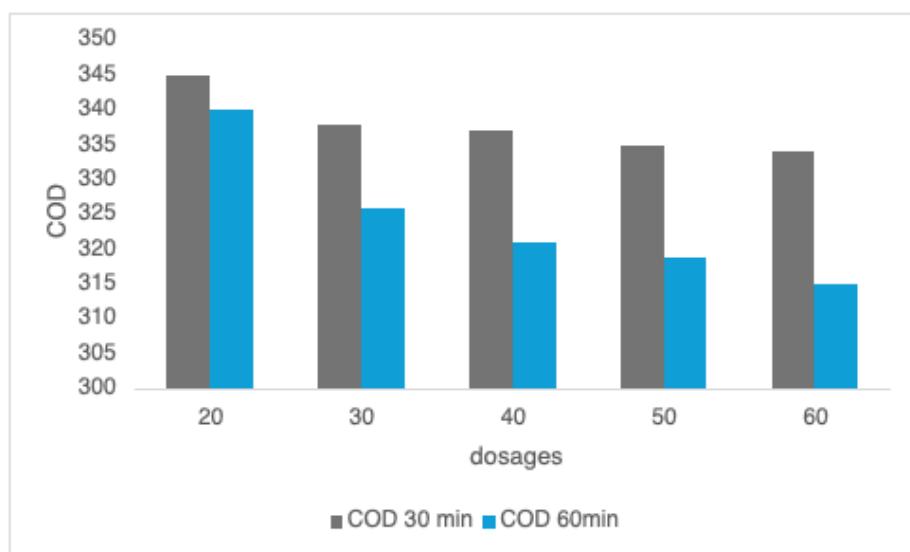
##### **4.4.1.1. Optimum Dosage**

At a dosage of 50 mg/L, a TP removal efficiency of 54.8% is achieved with a contact time of 60 minutes.

Increasing the dosage to 60 mg/L results in a higher removal efficiency (63.6%) but does not reduce the contact time, indicating that 50 mg/L may be the optimum dosage considering efficiency and contact time.

#### **4.5. Results and analysis and interpretation of the results after the use of the iron oxide during the adsorption test**

##### **4.5.1. Chemical oxygen demand**



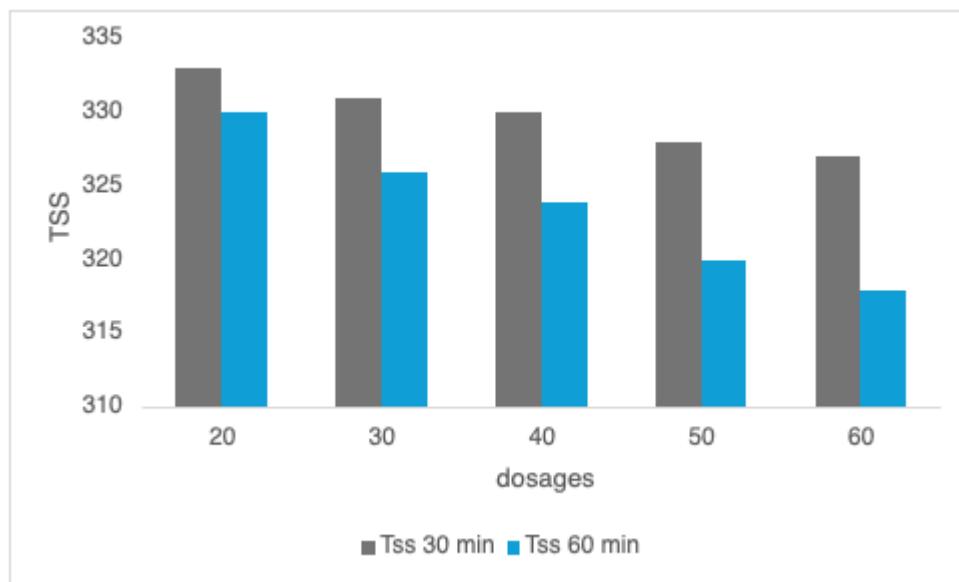
**Figure 7: chemical oxygen demand variation with dosages**

At 60 minutes: COD reduces from 340 mg/L (20 mg/L dose) to 318 mg/L (60 mg/L dose).

At 30 minutes: COD reduction is less significant compared to 60 minutes since less adsorption occurs within the shorter time.

Trend: The graph shows a gradual downward slope, with COD decreasing as dosage increases, but with a more pronounced drop at 60 minutes.

#### 4.5.2. Total suspended solids



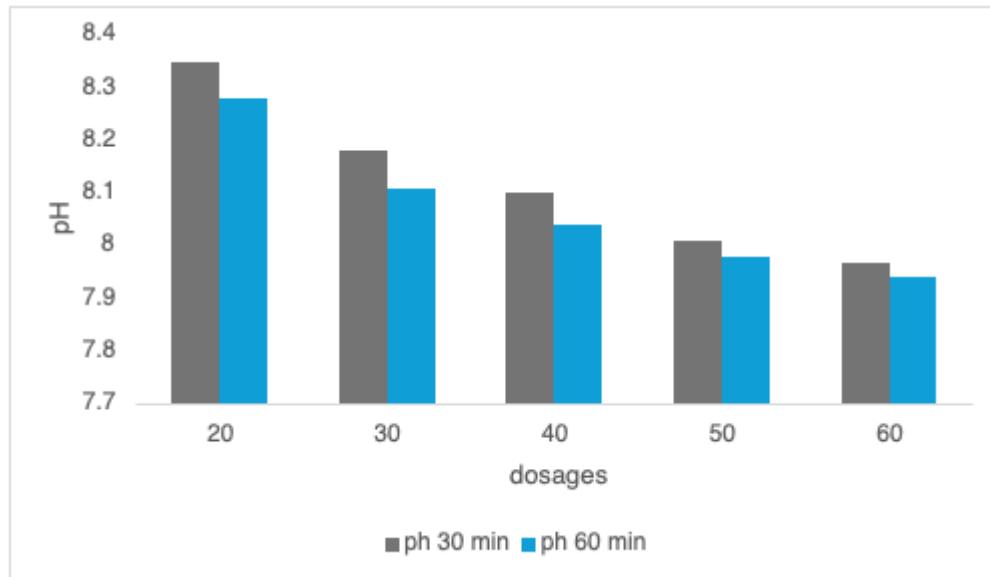
**Figure 8: total suspended solids variation with dosages**

At 60 minutes, Total suspended solids decrease significantly with increasing dosage, showing higher adsorption efficiency at higher dosages. The values decrease from 330 mg/L (20 mg/L dose) to 318 mg/L (60 mg/L dose).

At 30 minutes, Total Phosphate reduction is less effective compared to 60 minutes since adsorption is incomplete, meaning TSS concentrations are higher than those at 60 minutes.

Trend: The graph shows a downward curve, with more effective removal at higher dosages and longer contact times.

#### 4.5.3. pH



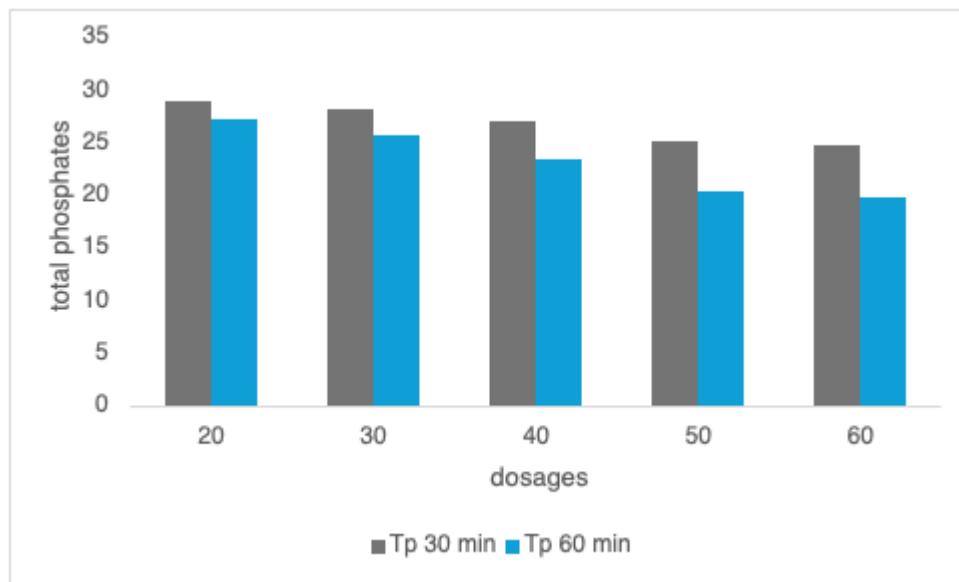
**Figure 9: Ph variation with dosages**

At 60 minutes, pH decreases significantly with increasing dosage, showing higher adsorption efficiency at higher dosages. The values decrease from 8.28 mg/L (20 mg/L dose) to 7.94 mg/L (60 mg/L dose).

At 30 minutes, pH reduction is less effective compared to 60 minutes since adsorption is incomplete, meaning pH concentrations are higher than those at 60 minutes.

Trend: The graph shows a downward curve, with more effective removal at higher dosages and longer contact times.

#### 4.5.4. Total phosphates



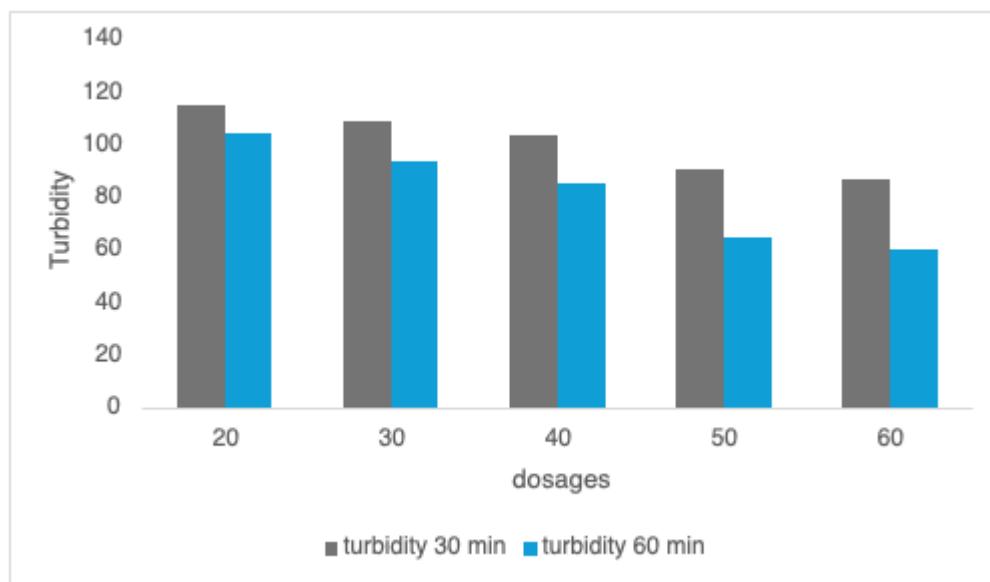
**Figure 10: total phosphates variation with dosages**

At 60 minutes, Total Phosphates decrease significantly with increasing dosage, showing higher adsorption efficiency at higher dosages. The values decrease from 27.3 mg/L (20 mg/L dose) to 19.8 mg/L (60 mg/L dose).

At 30 minutes, Total Phosphate reduction is less effective compared to 60 minutes since adsorption is incomplete, meaning TP concentrations are higher than those at 60 minutes.

Trend: The graph shows a downward curve, with more effective removal at higher dosages and longer contact times.

#### 4.5.5. Turbidity



**Figure 11:** turbidity variation with dosages

At 60 minutes, Turbidity decreases significantly with increasing dosage, showing higher adsorption efficiency at higher dosages. The values decrease from 104.6 mg/L (20 mg/L dose) to 60.8 mg/L (60 mg/L dose).

At 30 minutes, Turbidity reduction is less effective compared to 60 minutes since adsorption is incomplete, meaning Turbidity concentrations are higher than those at 60 minutes.

Trend: The graph shows a downward curve, with more effective removal at higher dosages and longer contact times.

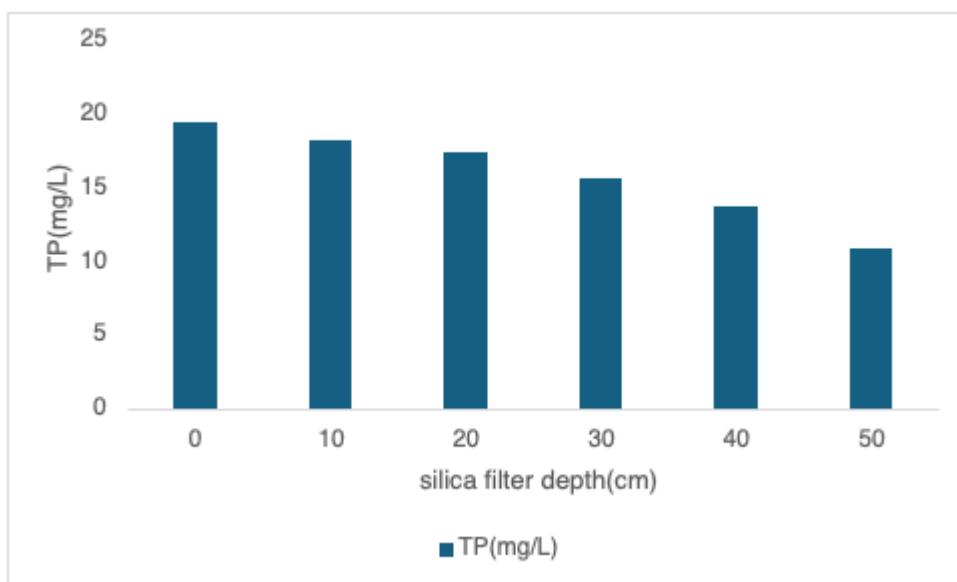
#### 4.6. Wastewater Filtration Using Silica Media

Following the TP reduction, the wastewater was further treated using silica filtration to improve the quality of the other parameters, and this was done by varying the different depths of the silica in order to determine the optimum depth which was

50cm since we attained a maximum reduction of the concentration of the parameters at that depth as shown below.

#### **4.7. Results and analysis and interpretation of the results after further use silica.**

##### **4.7.1. Total phosphates**



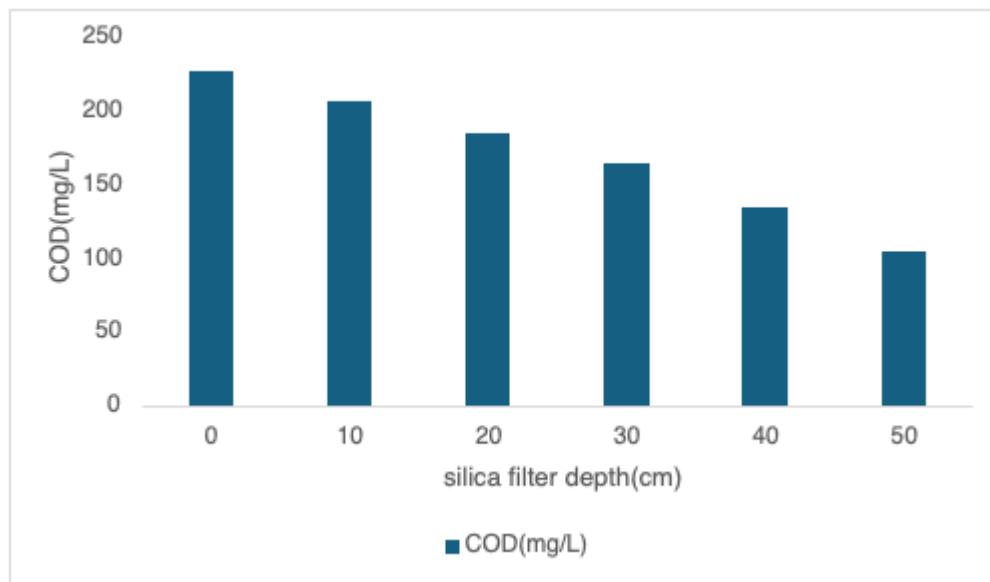
**Figure 12: total phosphates variation with silica depth**

As silica filter depth increases, Total phosphorous concentration decreases from 18.32 mg/L (10 cm) to 10.89 mg/L (50 cm).

This occurs because deeper filtration provides more surface area and retention time for phosphorus adsorption and removal.

Graph Shape: A downward curve showing a gradual but consistent reduction in total phosphates.

#### 4.7.2. Chemical oxygen demand



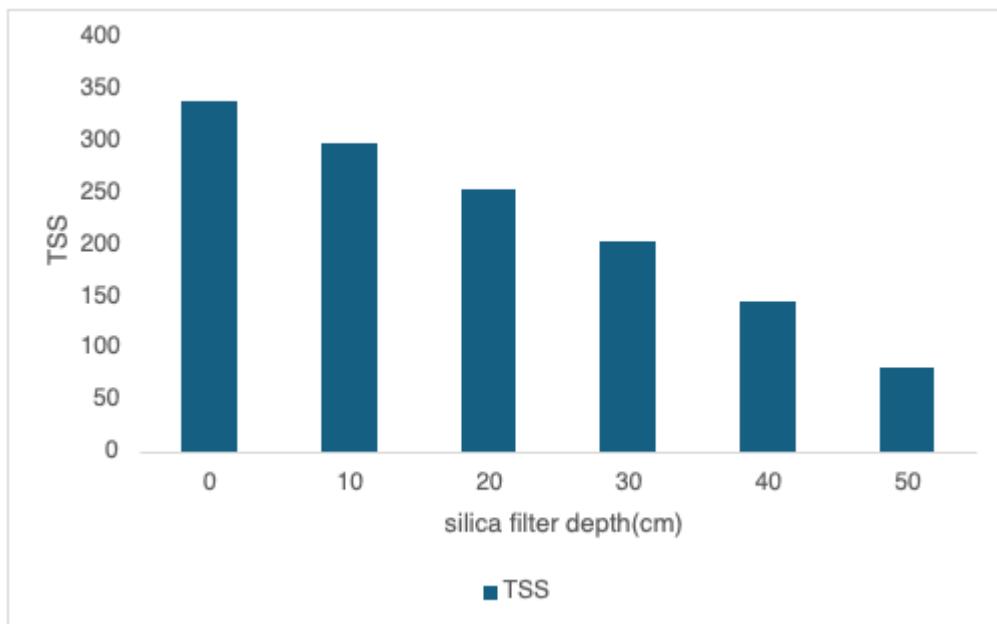
**Figure 13: chemical oxygen demand variation with silica depth**

Chemical Oxygen Demand decreases from 207 mg/L (10 cm) to 105 mg/L (50 cm).

This is because the deeper the filter media, the more organic matter gets adsorbed or broken down, leading to lower COD values.

Graph Shape: A gradually decreasing trend where COD levels drop steadily as the filter depth increases.

#### 4.7.3. Total suspended solids



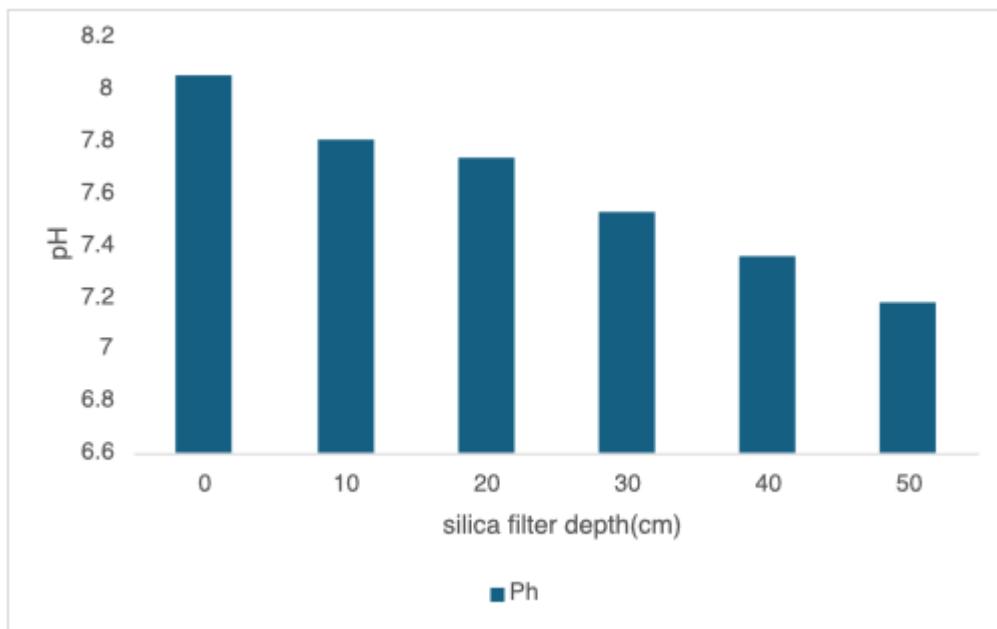
**Figure 14: total suspended solids variation with silica depth**

As silica filter depth increases, Total suspended solid concentration decreases from 299 mg/L (10 cm) to 83 mg/L (50 cm).

This occurs because deeper filtration provides more surface area and retention time for adequate adsorption and removal.

Graph Shape: A downward curve showing a gradual but consistent reduction TSS.

#### 4.7.4. PH



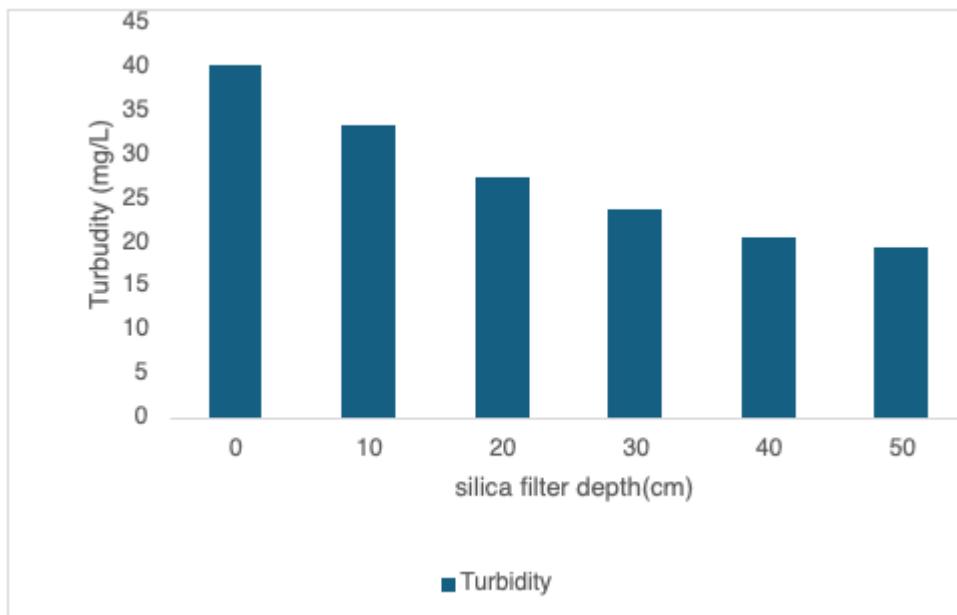
**Figure 15: Ph variation with silica depth**

PH decreases from 7.81 mg/L (10 cm) to 7.18 mg/L (50 cm).

This is because the deeper the filter media, the more organic matter gets adsorbed or broken down, leading to lower PH values.

Graph Shape: A gradually decreasing trend where PH levels drop steadily as the filter depth increases.

#### 4.7.5. Turbidity



**Figure 16: turbidity variation with silica depth**

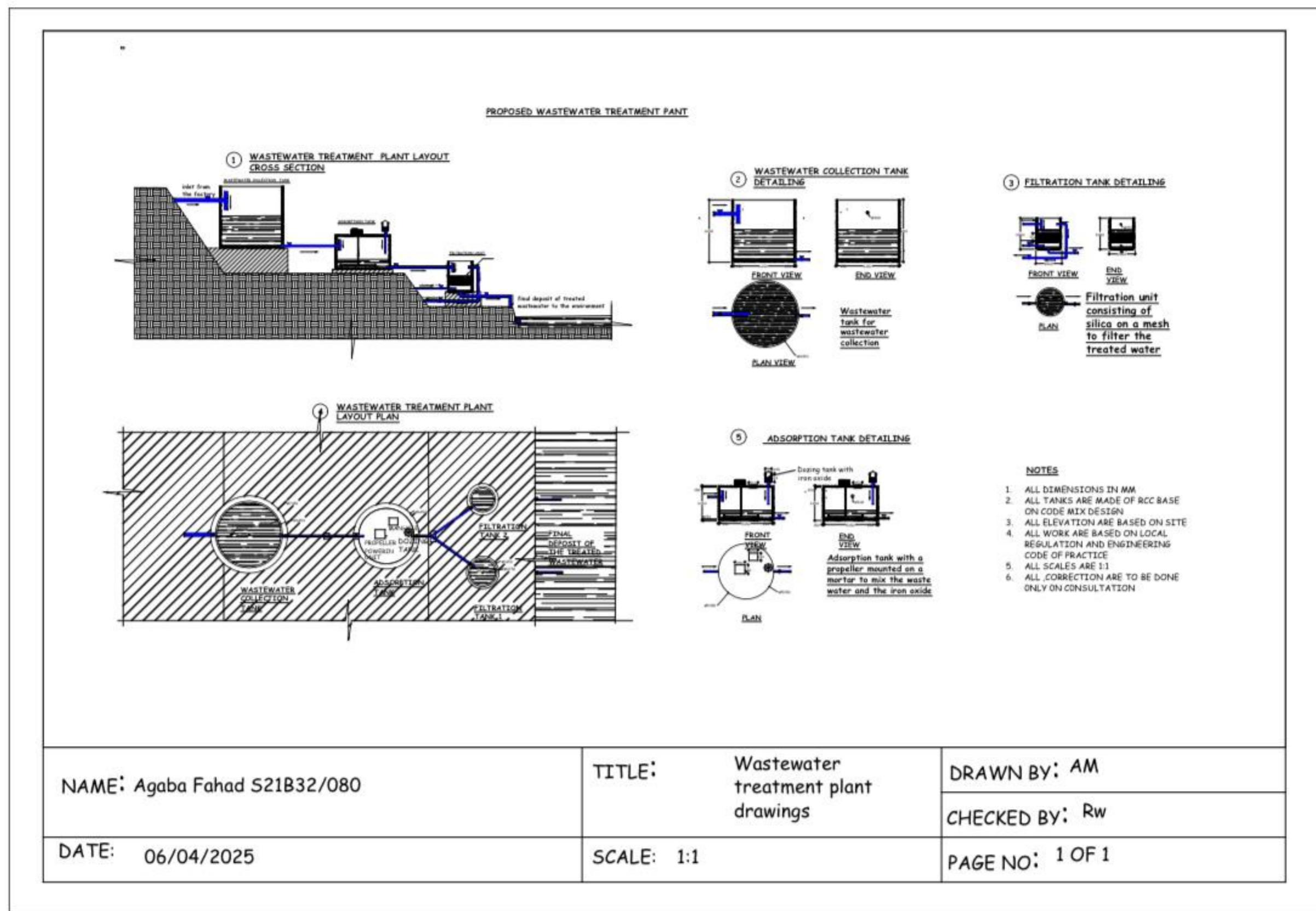
Turbidity decreases from 37.3 mg/L (10 cm) to 19.9 mg/L (50 cm).

This is because the deeper the filter media, the more organic matter gets adsorbed or broken down, leading to lower turbidity values.

Graph Shape: A gradually decreasing trend where turbidity levels drop steadily as the filter depth increases.

#### 4.8. DESIGN OF A WASTEWATER TREATMENT SYSTEM

The design of the effluent treatment system mainly entailed design of the mixing unit



#### **4.8.1. Collection chamber**

Textile wastewater discharge =  $700\text{m}^3/\text{day} \times 3 \text{ days}$

Textile wastewater tank should have a capacity of  $2100\text{m}^3$

Textile wastewater discharge =  $700\text{m}^3/\text{day}$

Peak factor is 1.7

Design flow capacity =  $700\text{m}^3/\text{day} \times 1.7$

Design flow capacity =  $1190\text{m}^3/\text{day}$

#### **4.8.2. Adsorption tank design**

Contact time = 1hr

Design flow capacity =  $1190\text{m}^3/\text{day}$

Required volume of the adsorption tank capacity =  $(1190/24) \text{ m}^3/\text{hr.} \times 1\text{hr}$

Required volume of the adsorption tank capacity =  $50 \text{ m}^3$

Assume a depth of 2.2m

Cross sectional area of the adsorption tank =  $(50)/2.2$

Cross sectional area of the adsorption tank =  $22\text{m}^2$

So, the radius is 2.6m

**Dimensions of the impeller for the motor (Considering a radial impeller)**

**Diameter of the impeller**

Q is the flow rate in  $\text{m}^3/\text{s} = 0.01378 \text{ m}^3/\text{s}$

N is the rotational speed = 300 rpm

H is the head developed by the impeller 3m (to maintain uniform mixing of the wastewater and iron oxide)

### Calculate the specific speed of the impeller

$$N_s = (n/Q)/H^{(3/4)}$$

$$N_s = (300/0.01378)/3^{(3/4)}$$

$N_s = 15$  (since the specific speed of the impeller is 15, it means that the required impeller type is the Radial impeller)

### Calculation for the shaft power (shaft power is the power needed to drive the impeller)

$$\text{Shaft power } P = (\rho Q g H) / \eta$$

Where,

N is the impeller speed

$\eta$  is efficiency of the impeller, taking the efficiency of a radial impeller as 90%

$\rho$  is the fluid density

$$\text{Shaft power } P = (1000 \times 0.01378 \times 9.81 \times 3) / 0.9$$

Shaft power  $P = 451\text{W} = 0.451\text{Kw}$  is the power needed to drive the impeller

### Impeller diameter

The impeller diameter is calculated from;

$$D = (N^2 \times Q) / 4\pi N \eta$$

Where;

Q is the flow rate in  $\text{m}^3/\text{s}$

$Nq$  is the pumping number

$D$  is the impeller diameter

$N$  impeller speed in r.p.m.

$$D = (N^2 \times Q) / 4\pi Nq$$

$$D = (120^2 \times 0.0138) / 4\pi \times 1$$

$$D = 2.5m$$

### **Area of the impeller**

$$\text{Area} = (\pi \times D \times W) / 2$$

Where,  $D$  is the impeller diameter

$W$  is the impeller width, its obtained from,

$W = (D-d)/2$   $D$ - diameter of the impeller and  $d$ - is the hub diameter which is 30% of impeller diameter

$$W = (2.5 - 0.75) / 2 = 0.875m$$

So, Area of the impeller;

$$\text{Area} = (\pi \times 2.5 \times 0.875) / 2$$

$$\text{Area} = 3m^2$$

### **Impeller Thrust ( $T$ )**

$$T = (\rho \cdot N^2 \cdot D^4) / 4\pi$$

Where;

$T$  is the thrust force in KN

$\rho$  is the fluid density

$N$  is the impeller speed

D is the impeller diameter

$$T = (f \cdot N^2 \cdot D^4) / 4\pi$$

$$T = (1.01 \times 120^2 \times 2.5^4) / 4\pi$$

$$T = 45.2 \text{ KN}$$

#### 4.8.3. Filter design

Design flow capacity =  $1190 \text{ m}^3/\text{day}$

Rate of filtration =  $120 \text{ liters/m.min}$

Rate of filtration =  $(0.120 \times 60) \text{ m}^3/\text{m}^2 \text{ hr.}$

Rate of filtration =  $7.2 \text{ m}^3/\text{m}^2 \text{ hr.}$

#### Number of units of the filtration systems

$$N = 1.22 \sqrt{Q}$$

Where, Q is million liters per day

So, converting  $1190 \text{ m}^3/\text{day}$  to million liters per day gives 1.19 million liters per day

$$N = 1.22 \sqrt{1.19}$$

N = 1.3, so approximate to 2 filters

Considering 2 silica filters with period of filters of 20hrs/day

Assuming 20hrs/day allows for 4 hours of downtime for backwashing, maintenance and other operational requirements. Design guidelines and standards from the American Water Works Association.

Design flow capacity =  $(1190 \text{ m}^3/\text{day})$

Design flow rate =  $49.6 \text{ m}^3/\text{day}$

Design flow capacity =  $(1190 \text{ m}^3/\text{day})/2$

Design flow capacity of each filter =  $595 \text{ m}^3/\text{day}$

Flow rate =  $(595 \text{ m}^3/\text{day})/20\text{hrs}$

Flow rate =  $29.6 \text{ m}^3/\text{hr.}$

### Cross sectional Area

Cross sectional area of each of the filter = Flow rate/ Rate of filtration

Cross sectional area of the filter =  $(29.6 \text{ m}^3/\text{hr.})/ 7.2 \text{ m}^3/\text{m}^2 \text{ hr.}$

Cross sectional area of the filter =  $4 \text{ m}^2$

Hydraulic loading rate = flow rate/surface area

Hydraulic loading rate =  $1190/165$

Hydraulic loading rate =  $7.2 \text{ m}^3/\text{m}^2 / \text{day}$

Hydraulic loading rate =  $0.3 \text{ m}^3/\text{m}^2 / \text{hr.}$

### Diameter of the filter

Area =  $\pi d^2 / 4$

So, diameter  $d = 2.3 \text{ m}$

### Bed volume (volume of the silica)

Bed volume =  $\pi (Bed \text{ diameter}/2)^2 \times bed \text{ depth} \times porosity$

But; bed depth = flow rate/ ( $60 \times$  Surface loading rate)

bed depth (for the silica) =  $29.6 / (60 \times 0.35)$

bed depth =  $1.4 \text{ m}$

Surface loading rate =  $0.35 \text{ m}^3/\text{m}^2/\text{h}$

Bed volume =  $\pi (2.2/2)^2 \times 1.4 \times 0.7$

Bed volume = 4m<sup>3</sup>

### Dimensions of the filter

Filter depth = filter media depth + freeboard + under-drain depth

Assume an under-drain depth of 0.6m

Filter depth = 1.4+ 0.05 + 0.6

Filter depth = 2.05m

Filter volume = filter area x filter depth

Filter volume = 4 x 2.05

Filter volume = 8m<sup>3</sup>

Filter weight = filter media volume x filter media density (2400kg/m<sup>3</sup>)

Filter media weight = 8 x 2400

Filter media weight = 19200kg

Hydraulic retention time per filter = Volume of the filter/ flow rate

Hydraulic retention time = 8/29.6

Hydraulic retention time = 0.27 hrs. = 16 minutes

#### 3.2.3.1. Head loss Calculations

Using Hazen's equation for Rapid Sand filters

$$H = (0.132 \times (Q/A)^2) \times (L/1000) / (f \times g)$$

$$H = (0.132 \times (29.6/4)^2) \times (2.05/1000) / (1010 \times 9.81)$$

$$H = 1.495 \times 10^6 \text{ m}$$

$$H = (0.132 \times (Q/A)^2) \times (L/1000) / (f \times g)$$

Where,

H is head loss(m)

Q is the flow rate

A is the filter area

L is the filter depth

$\rho$  is density of water

G is acceleration due to gravity

#### **4.9. TABLE SHOWING INITIAL CONCENTRATION (BEFORE TREATMENT) AND AFTER TREATMENT FOR 3 CONSECUTIVE DAYS.**

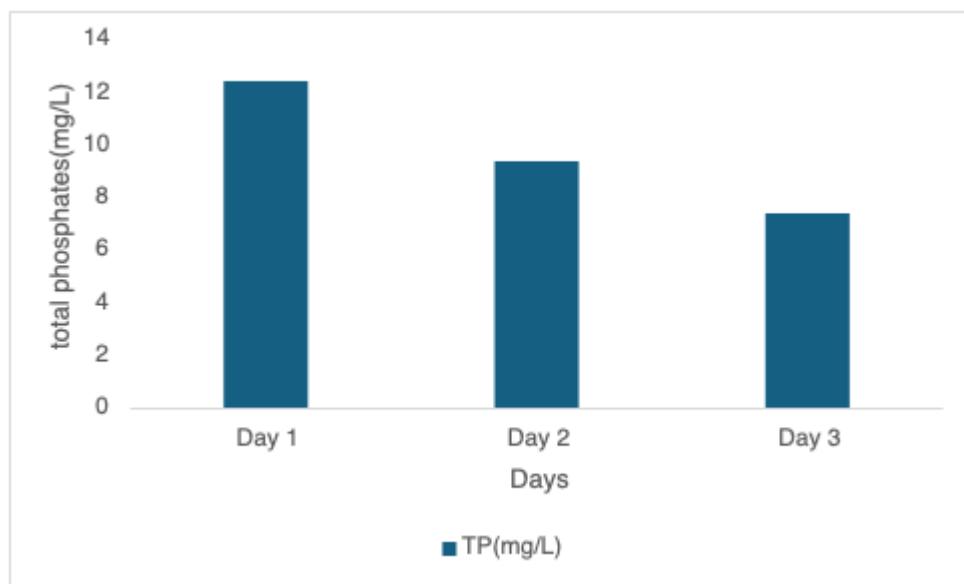
We ran the prototype to imitate our design, and we obtained the results below, which help assess the effectiveness of our wastewater treatment system. The prototype was designed to remove key pollutants, including phosphates, organic matter, suspended solids, and turbidity, using a combination of adsorption and filtration techniques.

**Table 7: Showing initial concentration before and after treatment**

Parameter	Before Treatment	Day 1	Day 2	Day 3	Average
Total Phosphates (mg/L)	35.5	12.43	9.43	7.43	9.763333
Chemical Oxygen Demand (mg/L)	371	182.5	142.7	113.5	146.2333

<b>Total Suspended Solids (mg/L)</b>	389	95.7	55.6	39.3	63.53333
<b>pH</b>	8.4	8.15	7.45	7.1	7.566667
<b>Turbidity (NTU)</b>	120	28.7	20.7	16.9	22.1

#### 4.9.1. Total Phosphates (mg/L)



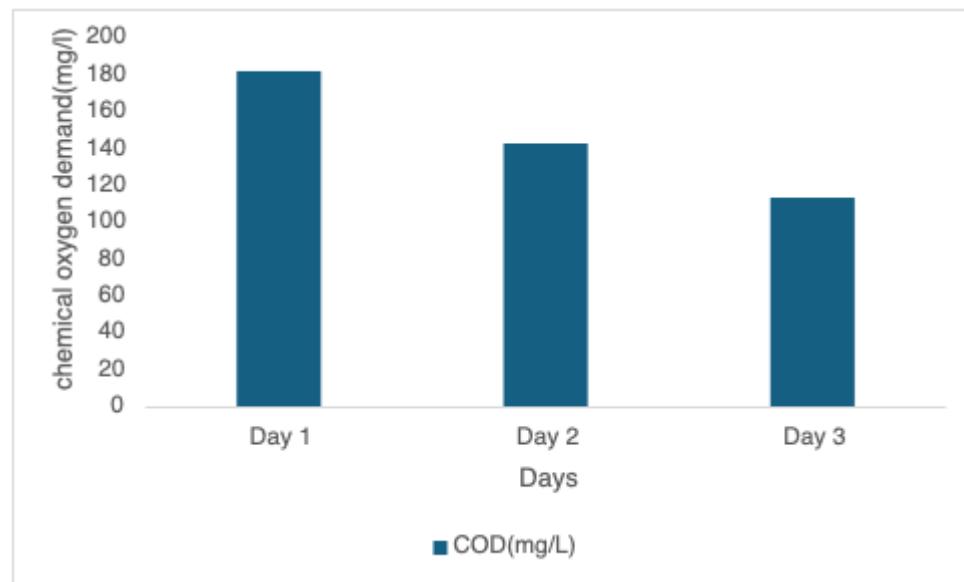
**Figure 18:** total phosphates variation with days

- **Before Treatment:** 35.5 mg/L
- **After Treatment (Day 1 to Day 3):** Decreased from 12.43 mg/L to 7.43 mg/L
- **Average:** 9.76 mg/L

**Explanation:** Total phosphates refer to the concentration of phosphorus compounds in the water, which contribute to nutrient pollution and eutrophication in water bodies. The significant reduction from 35.5 mg/L to an average of 9.76 mg/L indicates that the

iron oxide adsorption unit effectively removed phosphates. The decrease over time suggests that the adsorption process continues to improve as the system operates.

#### 4.9.2. Chemical Oxygen Demand (COD) (mg/L)

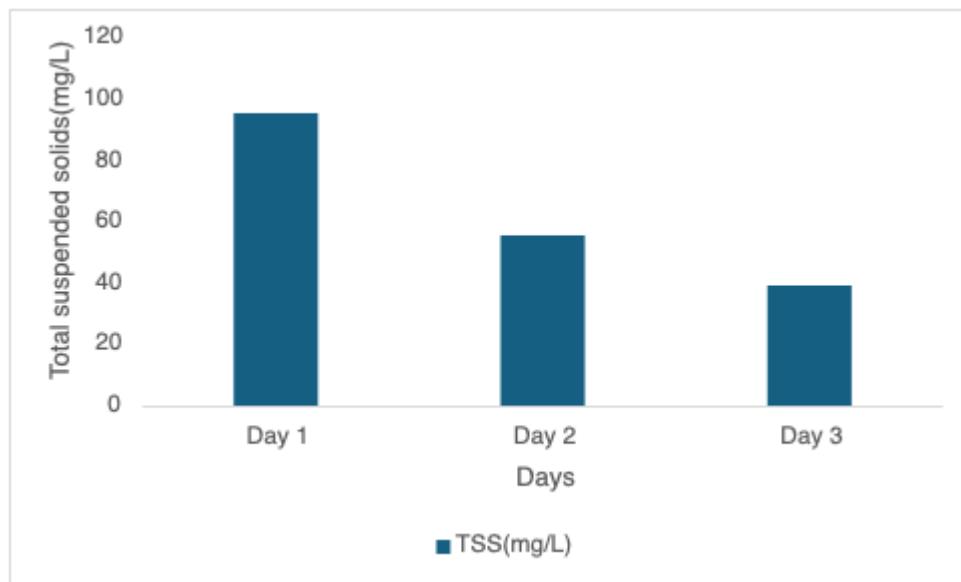


**Figure 19:** chemical oxygen demand variation with days

- **Before Treatment:** 371 mg/L
- **After Treatment (Day 1 to Day 3):** Reduced from 182.5 mg/L to 113.5 mg/L
- **Average:** 146.23 mg/L

**Explanation:** COD measures the amount of oxygen required to oxidize organic matter in wastewater. High COD values indicate heavy organic pollution. The drop in COD levels suggests that organic pollutants were significantly adsorbed by iron oxide. A 60.6% reduction on average means the prototype is effectively removing organic and inorganic pollutants.

#### 4.9.3. Total Suspended Solids (TSS) (mg/L)

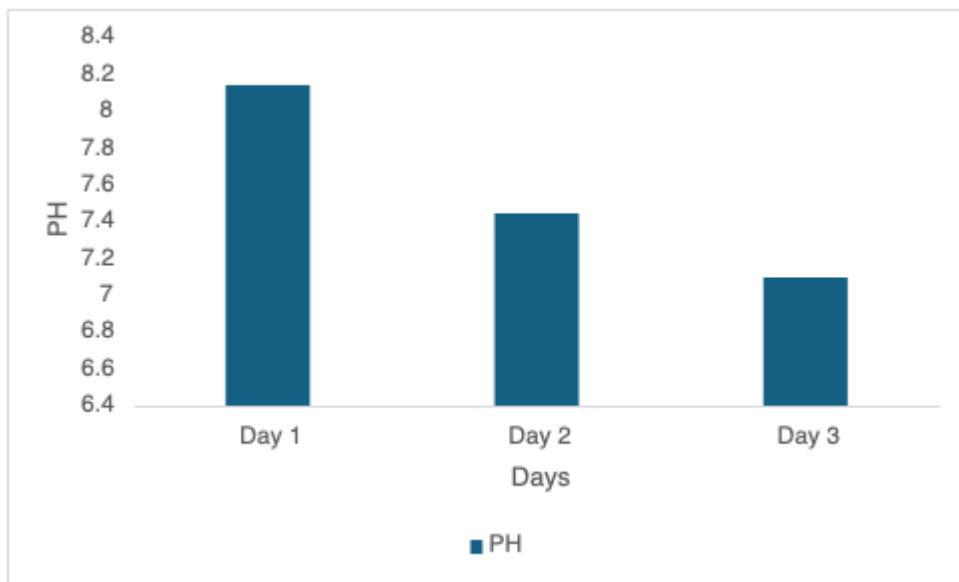


**Figure 20: total suspended solids variation with days**

- **Before Treatment:** 389 mg/L
- **After Treatment (Day 1 to Day 3):** Reduced from 95.7 mg/L to 39.3 mg/L
- **Average:** 63.53 mg/L

**Explanation:** TSS represents solid particles suspended in the wastewater, which contribute to turbidity and poor water quality. The filtration unit with silica successfully reduced TSS by around 83.7% on average, demonstrating its effectiveness in removing fine suspended particles from the treated water.

#### 4.9.4. pH

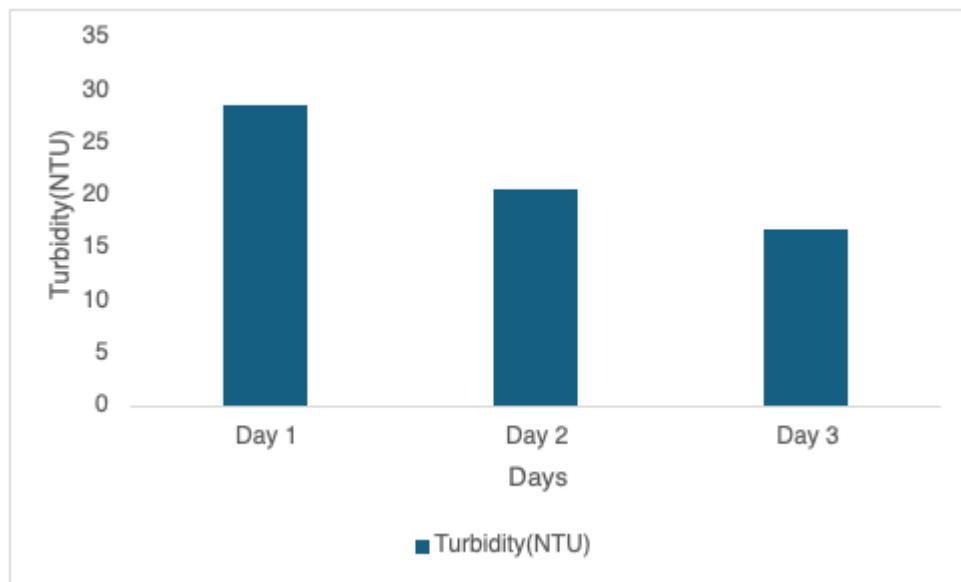


**Figure 21:** Ph variation with days

- **Before Treatment:** 8.4
- **After Treatment (Day 1 to Day 3):** Stabilized from 8.15 to 7.1
- **Average:** 7.57

**Explanation:** The pH value indicates the acidity or alkalinity of water. Before treatment, the wastewater was slightly alkaline (pH 8.4). The adsorption and filtration processes helped stabilize the pH, bringing it closer to neutral (7.57 on average). This is beneficial because neutral pH is ideal for most water treatment applications.

#### 4.9.5. Turbidity (NTU)



**Figure 22:** turbidity variation with days

- **Before Treatment:** 120 NTU
- **After Treatment (Day 1 to Day 3):** Reduced from 28.7 NTU to 16.9 NTU
- **Average:** 22.1 NTU

**Explanation:** Turbidity a measure of water clarity, caused by suspended solids and organic matter, was significantly reduced using silica filtration unit. The unit effectively removed fine particulate matter, resulting in an average turbidity reduction to 22.1 NTU which indicated a significant improvement in water clarity. However, due to complex composition of wastewater, the filtration unit alone was not sufficient for complete treatment. As a result, the system was considered as part of a blended treatment approach, integrating the silica filtration unit with other processes such as sedimentation. This multistage setup enhanced the overall treatment efficiency and ensured broader contaminant removal in line with environmental discharge standards.

## **CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

### **5.1 Conclusion**

The study identified key physicochemical parameters of wastewater effluent from Sunbelt Textile Industries, including high levels of phosphorus, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), and turbidity. These parameters exceeded environmental discharge limits, indicating the need for effective treatment before discharge into aquatic ecosystems such as Lake Victoria.

Iron oxide bio-adsorbents demonstrated high efficiency in removing phosphorus and reducing COD levels in wastewater. The adsorption process was significantly influenced by pH, contact time, and adsorbent dosage. The addition of silica improved adsorption capacity by increasing surface area and providing additional active sites for pollutant binding.

The designed wastewater treatment system effectively combined iron oxide and silica-based filtration to reduce phosphorus, COD, and TSS levels. The system demonstrated improved pollutant removal efficiency, making it a promising solution for textile industry wastewater treatment.

## **5.2 Recommendations**

- Continuous monitoring of wastewater quality should be conducted to ensure compliance with regulatory standards. Additional analyses should include nitrogen compounds, heavy metals, and microbial contaminants to assess the full extent of pollution. Implementation of pre-treatment methods, such as sedimentation or filtration, can enhance subsequent treatment processes.
- Further optimization studies should be conducted to determine the best conditions for adsorption, including pH levels, adsorbent dosage, and retention time. Research should also explore the potential for adsorbent regeneration and reusability to enhance sustainability and cost-effectiveness. Additionally, pilot-scale studies should be conducted before large-scale implementation.
- The treatment system should be further optimized by integrating multiple adsorption stages or hybrid treatment methods (e.g., biological treatment or coagulation) for enhanced performance. Scaling up the system for industrial application should be explored, including cost-benefit analysis and long-term performance assessments. Regular maintenance and monitoring should be conducted to ensure sustained efficiency over time.

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*Volume 1: Air, Water and Energy Resources*, pp.235-256.

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## APPENDICES

### APPENDIX 1: PICTORIAL



Figure 23: waste water sample



Figure 24 : silica extraction



Figure 25: sieve size used for sieving silica



Figure 26: silica



Figure 27: burning of silica



Figure 28 extraction of silica from rice husk ash

## APPENDIX 2: LABORATORY RESULTS

 <b>NATIONAL WATER AND SEWERAGE CORPORATION</b> CENTRAL LABORATORY - BUGOLORI P.O BOX 7053 KAMPALA Email: waterquality@nasc.co.ug				
Student: ACHOLA Margret Pascal (S21B32/041) & AGABA Fahad (S21B32/080) Address: Uganda Christian University Mukono (Uganda) Date Sample Tested: 31/01/2025				
Waste water sample analysis results for Masese, Jinja central / Jinja city .				
Parameters	Results			National Standards for Discharge of effluent into the environment
	Morning 8:30am	Afternoon 2:30pm	Evening 5:30pm	
Chemical Oxygen demand (mg/L)	206	230	194	70
Total Suspended solids (mg/L)	423	438	406	50
Total phosphates (mg/L)	28.4	31.9	25.9	5
pH	8.23	8.18	7.79	5.0 - 8.5
Turbidity (NTU)	34.5	36.3	31.8	25

Remarks: The results for the water samples tested were as above.  
 Analysed by: Wanyera Julius -(QCO) &  
 ACHOLA Margret Pascal  
 AGABA Fahad (S21B32/080)



31 JAN 2025

NATIONAL WATER AND SEWERAGE CORPORATION  
 CENTRAL LABORATORY - BUGOLobi  
 P.O BOX 7053 KAMPALA Email: waterquality@mweg.co.

Student: ACHOLA Magret Pascal S21B32/041 &  
 AGA BA Fahad S21B32/080  
 Address: Uganda Christian University  
 Mukono (Uganda)

Date sample tested: 17th March 2025.



Breakthrough Analysis Results.

Initial total Phosphate concentration: 35.67 mg/l.

TIME (mins)	Final total phosphate Concentration (mg/l.)
0	0
15	1.50
30	4.70
45	7.78
60	14.10
75	28.97
90	33.10
105	34.68
120	35.19

Table showing initial concentrations (before treatment) and after treatment for 3 consecutive days.

Parameter	Before Treatment	After Treatment		
		Day 1 17th/03/2025	Day 2 18th/03/2025	Day 3 19th/03/2025
Total Phosphates (mg/l.)	35.5	12.43	9.43	7.36
Chemical Oxygen Demand (mg/l.)	371	182.5	142.7	113.5
Total Suspended Solids (mg/l.)	389	96	56	39
pH	8.4	8.15	7.45	7.16
Turbidity (NTU)	120.0	28.7	20.7	16.9

Remarks: The results for the water samples tested were as above.

Analysed by: Wanyera Julius (OCO) &

ACHOLA Magret Pascal

AGA BA Fahad

Am | 03 | 2025



NATIONAL WATER AND SEWERAGE CORPORATION  
CENTRAL LABORATORY - BUGOLobi  
P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: ACHOLA Margret Pascal (S21B32/041) &

AGABA Fahad (S21B32/080)

Address: Uganda Christian University  
Mukono (Uganda)

Date Sample Tested: 17/01/2025

Waste water sample analysis results for Masese, Jinja central / Jinja city .

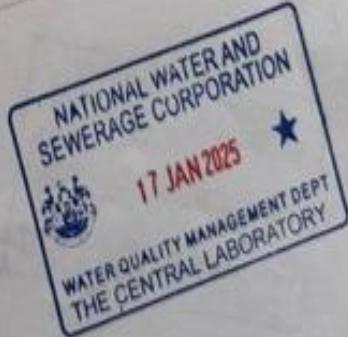
Parameters	Results			National Standards for Discharge of effluent into the environment
	Morning 8:30am	Afternoon 2:30pm	Evening 5:30pm	
Chemical Oxygen demand (mg/L)	264	304	187	70
Total Suspended solids (mg/L)	394	273	380	50
Total phosphates (mg/L)	31.4	38.9	28.4	5
pH	8.05	7.76	8.11	5.0 - 8.5
Turbidity (NTU)	52.1	48.3	29.6	25

Remarks: The results for the water samples tested were as above.

Analysed by: Wanyera Julius -(QCO) &

ACHOLA Margret Pascal

AGABA Fahad (S21B32/080)





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Student: ACHOLA Margret Pascal (S21B32/041) &

AGABA Fahad (S21B32/080)

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 10/01/2025

Waste water sample analysis results for Masese, Jinja central / Jinja city .

Parameters	Results			National Standards for Discharge of effluent into the environment
	Morning 8:30am	Afternoon 2:30pm	Evening 5:00pm	
Chemical Oxygen demand (mg/L)	240	286	187	70
Total Suspended solids (mg/L)	406	609	400	50
Total phosphates (mg/L)	30.4	36.2	26.4	5
pH	8.17	7.54	8.06	5.0 - 8.5
Turbidity (NTU)	47.1	50.4	32.43	25

Remarks: The results for the water samples tested were as above.

Analysed by: Wanyera Julius -(QCO) &

ACHOLA Margret Pascal

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NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY - BUGOLobi

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Student: ACHOLA Magret Pascal S21B32/041 &

AGABA Fahad S21B32/080

Address: Uganda Christian University  
Mukono (Uganda)

Date sample tested: 7th February 2025.

NATIONAL WATER AND  
SEWERAGE CORPORATION

07 FEB 2025

WATER QUALITY MANAGEMENT DEPT  
THE CENTRAL LABORATORY

Analysis results after treatment with 10% iron oxide in one litre of wastewater from Masese JinjaCentral.

Table showing the concentrations at a contact time of 30 minutes for different dosages

Parameter	Iron oxide dosages(mg/L)				
	20	30	40	50	60
Chemical oxygen demand (mg/L)	345	338	337	335	334
Total suspended solids(mg/L)	333	331	330	328	327
pH	8.35	8.18	8.10	8.01	7.97
Total phosphates(mg/L)	29.1	28.3	27.1	25.2	24.8
Turbidity (NTU)	115.1	109.1	103.9	90.7	87.5

Table showing the concentrations at a contact time of 60 minutes for different dosages

Parameter	Units	Iron oxide dosages(mg/L)				
		20	30	40	50	60
Chemical Oxygen Demand	mg/l	340	326	321	319	315
Total Suspended Solids	mg/L	330	326	324	320	318
pH		8.28	8.11	8.04	7.98	7.94
Total Phosphates	mg/l	27.3	25.8	23.6	20.4	19.8
Turbidity	NTU	104.6	94.2	85.5	65.2	60.8

#### Waste filtration using silica Media

Following The TP reduction, the wastewater is further treated using silica filtration to improve other water quality parameter.

Sample	Silica Filter Depth (cm)	TP (mg/L)	COD (mg/L)	TSS (mg/L)	pH	Turbidity (NTU)
1	10	18.32	207	299	7.81	37.3
2	20	17.49	185	254	7.74	35.8
3	30	15.66	165	204	7.53	30.2
4	40	13.82	135	146	7.36	26.7
5	50	10.89	105	83	7.18	19.9

Remarks: The results for the water samples tested were as above.

Analysed by: Wanyera Julius (QCO) &

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In any Correspondence on  
this subject please  
quote No.

DFD 020/2025

31<sup>st</sup> January 2025

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THE REPUBLIC OF UGANDA

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#### REPORT OF ANALYSIS

##### Description of the Samples

One sample in a black polythene bag containing Silica from Rice Husk Ash was submitted by Ms. Achola Margaret Pascal, on 27<sup>th</sup> January 2025, and analysed on 29<sup>th</sup> January 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Grey sand sample packed in a black polythene bag,	01	Sample "A" DFD 020/2025

##### Analysis Requested

Elemental analysis

##### Method of Analysis

Elemental analysis was done using the XRF Method.

##### Results of Analysis

The above sample has been analyzed with the following results as below.

Parameter	Units	Results	
		silica sample	DFD 020/2025
Silicon dioxide	% m/m	98.78	
Potassium Oxide	% m/m	0.70	
Manganese (II) Oxide	% m/m	0.25	
Calcium Oxide	% m/m	0.17	
Iron (III) Oxide	% m/m	0.09	
Chloride	ppm	44.7	
Phosphorous pent oxide	ppm	23.0	
Titanium di oxide	ppm	4.0	
chromium (III) oxide	ppm	0.3	

##### Remarks

1. Results relate to sample analyzed and are reported as on received basis.

*S. Semalago* 20/01/2025

Semalago Fredrick  
Government Analyst

"Go Scientific for a Safe and Just Society"

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