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Treatment of Raw River Water for Irrigation Purposes

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Abstract: This study designed, fabricated, and evaluated a low-cost, gravity-fed mini water treatment system using four sequential 20-L buckets filled with locally available materials—gravel, sand, sawdust, and rice husk—to treat raw river water from the Alau River in Borno State, Nigeria, for irrigation purposes. Raw and treated water samples were analyzed for turbidity, total suspended solids (TSS), volatile suspended solids (VSS), biochemical oxygen demand (BOD_5), colour, pH, total dissolved solids (TDS), nutrients, and heavy metals (Pb, Cr, Cd) using standard laboratory procedures. The results showed that the untreated river water had elevated turbidity, suspended solids, colour, and organic load, indicating significant pollution. After treatment, notable improvements were recorded, including average reductions of 56% in turbidity (16.13 → 7.11 NTU), 54% in TSS (39.08 → 17.86 mg/L), approximately 60% in VSS, 50–60% in BOD_5, and 56% in colour (141.33 → 62 Pt-Co). pH, TDS, and nutrient levels remained within acceptable limits for irrigation. Heavy metals were partially removed—such as Pb from 2.28 to 0.19 mg/L—but concentrations of Pb, Cd, and Cr still exceeded irrigation standards in some samples. The system proved simple, effective, and sustainable, significantly improving water clarity and reducing organic pollutants and clogging risk in irrigation systems using only low-cost, locally sourced materials. However, supplementary adsorption media such as activated carbon, biochar, or modified clay are recommended to achieve complete heavy-metal removal. Overall, the study demonstrates the potential of affordable natural filtration materials for decentralized water treatment in resource-constrained agricultural communities.

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CHAPTER ONE
INTRODUCTION

➢ *Background of the Study*

The rate of population growth worldwide, coupled with diversified uses of surface water such as industrial, commercial, irrigation, and domestic purposes, has brought adverse effects on surface water quality and quantity (Assegide et al., 2022). In the tropics and developing countries, water bodies are being polluted and difficult to remediate due to extreme reliability, over-exploitation, and poor management policy in place of a rapidly growing city population and weak institutional capacity (Cheng et al., 2018; Faye, 2021). The pollution of water bodies through point and non-point source discharges contributes immensely to the deterioration of water quality resulting from anthropogenic and natural processes (Barakat et al., 2016; Adejumoke et al., 2018). The problem, therefore, exists where surface water quality changes are erratic and cyclical, especially for most tropical and developing countries resulting from diffuse and pollution point sources. Extensive research has been conducted on the quality of surface water variability across the world. Oliveira (2019), researched the temporal and spatial effects of surface water quality and ascribed the contamination of surface water to anthropogenic activities and natural occurrences.

The variation in surface water quality has culminated in the rise in costs and changes in protocols for treating water for consumption by consumers. Some physicochemical factors, such as pH and alkalinity of raw water, influence the water treatment process. Furthermore, nutrient-related compounds (nitrates, ammonia, and phosphate) directly affect the optimal conditions of drinking water treatment. Again, raw water quality changes have challenged most treatment works in attaining treatment efficiency (Bashir et al., 2020; Sasakova et al., 2018). Much particulate matter of organic and inorganic compounds of suspended, colloidal, or dissolved form in raw water influences the coagulationflocculation process of water treatment. Particularly, inorganic compounds such as silicate, pH, alkalinity, and temperature are key parameters that adversely affect the treatment of water. The use of a corresponding high coagulant dose for treatment performance contributes to the increase in residual contaminant, which poses a public health risk to consumers of drinking water. Efficient use of water sources in water treatment facilities requires clear knowledge about the surface water quality and its variability since water quality parameter loadings on the surface water and their interactive effects influence water treatment (World Health Organisation, 2019). Raw water deterioration of the surface water is significant due to the rise of physical and chemical constituents resulting from natural and more recently anthropogenic activities. Therefore, must adjust the treatment processes frequently to accommodate changes in the raw water quality due to run-off induced excess contaminant load. This study determines variations in raw water quality and corresponding treated water quality using descriptive statistics.

➢ *Statement of the Problem*

Treating raw river water presents a significant challenge due to the unpredictable and dynamic nature of its quality, which is influenced by seasonal variations, land use changes, and anthropogenic activities upstream. These fluctuations disrupt the efficiency of conventional treatment systems, making it difficult to maintain consistent performance. Water quality parameters such as turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and nutrient levels vary in intensity and impact, further complicating treatment planning and optimization. Moreover, these variations can lead to increased chemical use, higher volumes of residual waste, and reduced operational efficiency. Given these challenges, this study aims to explore a more sustainable and adaptable approach to water treatment. Specifically, the project seeks to design and fabricate a filtration system using readily available and environmentally friendly materials such as sand, stone, sawdust, and rice husk. By investigating how these materials perform under varying raw water quality conditions, the study aligns with the broader objective of developing a low-cost, sustainable treatment solution that can handle the inherent variability of river water and minimize the production of harmful byproducts.

➢ *Aim and Objectives*

The aim of the project is to treat raw river water for irrigation purpose while, the specific objectives are to:

- To measure the initial physico-chemical parameters (BOD, TSS, pH, VSS, Total Nitrogen, Total Phosphorus, Turbidity, pb, Cr and Cd) and compare with quality standards.
- Fabricate, and assess the efficiency of a mini wastewater treatment system based on improvements in the measured physico-chemical parameters.

➢ *Significance of the Study*

This study on the treatment of raw river water is significant for several reasons. It enhances a critical public health concern, as untreated or poorly treated river water often contains harmful contaminants that can cause waterborne diseases and long-term health issues. The research provides valuable insights into the individual and combined effects of water quality parameters on the performance of treatment processes and the practical implications for optimizing water treatment operations. Finally, it contributes to policy and planning by supplying data-driven recommendations for water resource management, especially in the face of increasing pollution and climate-related changes in river systems.

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- *Scope of the Study (Alou River)*

This study focuses on evaluating the quality of raw river water and its impact on the performance of treatment processes. It is limited to surface water sources, particularly rivers, and does not include groundwater or wastewater treatment systems.

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CHAPTER TWO
LITERATURE REVIEW

➢ *Raw River Water*

Raw river water is a critical source for various human activities including domestic use, agriculture, and industrial applications. However, its quality is highly variable and dependent on both natural processes and anthropogenic influences. The understanding of river water characteristics is vital for effective water treatment, environmental monitoring, and sustainable resource management. The physicochemical properties of raw river water are determined by parameters such as temperature, pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), and nutrient concentrations. These properties vary seasonally and spatially along the river course.

According to Singh et al. (2020), the pH of river water typically ranges from 6.5 to 8.5, indicating a slightly alkaline nature due to the presence of bicarbonates and other buffering agents. Turbidity, caused by suspended particles and colloidal matter, tends to increase during the rainy season due to surface runoff (Kumar & Dhadse, 2020). Electrical conductivity and TDS are indicators of ionic concentration in water, often associated with salinity and mineral content. High levels can suggest pollution from industrial discharges or agricultural runoff. In the Ganga River, for example, EC values were found to increase downstream due to accumulation of pollutants (Yadav et al., 2020). Dissolved oxygen, an essential indicator of water quality and aquatic life viability, can decrease due to the decomposition of organic matter, often exacerbated by effluents (Rao et al., 2020).

Raw river water can also contain a variety of chemical contaminants including heavy metals, pesticides, and nitrates. These substances often originate from agricultural practices, urban runoff, and industrial waste. Heavy metals like lead, cadmium, and arsenic pose significant health risks and have been detected in rivers like the Yamuna and Godavari beyond permissible limits (Chatterjee et al., 2020). Nutrient enrichment, particularly nitrogen and phosphorus, contributes to eutrophication, a process that disrupts aquatic ecosystems through excessive algal growth and oxygen depletion.

The microbiological quality of river water is a concern for public health. Pathogenic bacteria such as Escherichia coli, Salmonella, and Vibrio cholerae are commonly detected in raw river water, especially in areas with poor sanitation. The presence of fecal coliforms is often used as an indicator of microbial contamination. A study by Sharma and Jain (2020) on the Yamuna River reported high fecal coliform counts, indicating contamination from untreated sewage. Urbanization, industrialization, and agriculture significantly affect river water quality. Wastewater discharge, solid waste dumping, and chemical runoff introduce a complex mixture of pollutants into river systems. The cumulative impact leads to the deterioration of water quality and loss of biodiversity. A comparative study on Indian rivers by Meena et al. (2020) found that stretches passing through urban centers had the highest pollution loads and the poorest water quality indices.

Raw river water exhibits a complex set of characteristics influenced by natural and anthropogenic factors. Regular monitoring and stringent pollution control measures are crucial to ensure the sustainability and safety of river water resources. Improved understanding of these characteristics enables better treatment practices and informs policy decisions for integrated water resource management.

➢ *Characteristics of Raw River Water*

Raw river water is water that hasn't been treated and comes straight from rivers and streams. It exhibits considerable variation in physical, chemical, and biological characteristics due to natural processes and anthropogenic influences such as agricultural runoff, industrial discharge, and urban wastewater (WHO, 2017; Chapman, 1996).

- *Physical Parameters*

✓ *Turbidity*

Suspended solids like silt, clay, organic matter, and microorganisms cause turbidity, which is an important indicator of water clarity. According to Crittenden et al. (2012), high turbidity hinders disinfection and prevents light from reaching aquatic life. Water's chemical reactions and biological activity are affected by temperature. The temperature of river water varies by season and location. According to Chobanoglous et al. (2014), high turbidity can protect microorganisms from disinfection and reduce water clarity. Water's chemical reactions and biological activity are affected by temperature. It influences the solubility of gases and the rate of microbial growth (WHO, 2017). Chemical Characteristics pH is a measurement of water's acidity or alkalinity. It affects chemical equilibria, corrosion potential, and the effectiveness of disinfection processes (Spellman, 2014).

✓ *Specifications of the Chemical pH*

River water typically has a pH range of 6.5 to 8.5. Acidic or alkaline shifts can affect metal solubility and aquatic life (EPA, 2020). Dissolved oxygen (DO) indicates the capacity of water to sustain aquatic life. Low DO levels can signify organic pollution or eutrophication.

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✓ *Nutrients*

According to UNESCO (2018), fertilizer and sewage nitrogen and phosphorus compounds can cause algal blooms and eutrophication. Heavy Metals: Mining and industrial discharge can introduce contaminants like lead, arsenic, and mercury into the environment, posing serious health risks (Khan et al., 2018).

✓ *Total Dissolved Solids (TDS)*

Dissolved oxygen (DO) is essential for aquatic life because it influences biodegradation and indicates the capacity of water to support aerobic organisms (Khan et al., 2018). Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD): Indicate the number of organic pollutants present. Both BOD and COD, which measure total oxidizable substances and biodegradable organic matter, are essential for determining the level of pollution (Hammer, 2012). According to Sharma & Bhattacharya (2017), products with a high TDS have a negative impact on taste, the potential for corrosion, and whether or not they can be used for drinking or irrigation.

- *Biological Characteristics*

✓ *Pathogens*

River water may contain bacteria (e.g., Total coliforms, E. coli), viruses, and protozoa like Giardia lamblia, often from fecal contamination (WHO, 2017). According to WHO (2017), their detection is essential for evaluating water safety. Pathogenic Bacteria, Viruses, and Protozoa: Their presence necessitates disinfection steps in treatment to prevent waterborne diseases (Shannon et al., 2008).

✓ *Biological Oxygen Demand (BOD)*

A high BOD indicates a lot of organic matter, which can make it hard for aquatic life to get enough oxygen (Chapman, 1996).

➢ *Water Quality Parameters*

Understanding the quality of raw river water is fundamental for designing effective treatment processes. The kind and amount of treatment required to ensure safe and potable water are determined by a number of water quality parameters. Important Indicators of Water Quality.

- *Physical Parameters*

Indicates the presence of suspended particles such as silt, clay, and organic matter. According to Chobanoglous et al. (2014), high turbidity can protect microorganisms from disinfection and reduce water clarity. Water's chemical reactions and biological activity are affected by temperature. It influences the solubility of gases and the rate of microbial growth (WHO, 2017).

Chemical Characteristics pH is a measurement of water's acidity or alkalinity. It affects chemical equilibria, corrosion potential, and the effectiveness of disinfection processes (Spellman, 2014). The typical pH range for river water is 6.5–8.5. Dissolved oxygen (DO) is essential for aquatic life because it influences biodegradation and indicates the capacity of water to support aerobic organisms (Khan et al., 2018).

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD): Indicate the number of organic pollutants present. Both BOD and COD, which measure total oxidizable substances and biodegradable organic matter, are essential for determining the level of pollution (Hammer, 2012). Nitrogen (nitrates, ammonia) and phosphorus compounds can lead to eutrophication if present in excess (Vymazal, 2010). Metals like lead, cadmium, and mercury are toxic even at low concentrations and require special treatment methods (Khan et al., 2018).

- *Microbiological Parameters*

Total coliforms and Escherichia coli (E. coli) are indicators of pathogen presence and fecal contamination. According to WHO (2017), their detection is essential for evaluating water safety. Pathogenic Bacteria, Viruses, and Protozoa: Their presence necessitates disinfection steps in treatment to prevent waterborne diseases (Shannon et al., 2008). Measure the amount of dissolved ions, influencing taste and corrosion potential (Spellman, 2014). Hardness and alkalinity have an impact on soap efficacy and scaling, influencing the dosage of treatment chemicals (Hammer, 2012).

➢ *Treatment Processes*

- *Treatment of Raw River water*

Raw river water often contains a variety of contaminants, including suspended solids, organic matter, pathogens, and chemical pollutants. Conventional water treatment processes have been developed and widely used to make river water safe for drinking and other uses.

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✓ *Fluctuation and Coagulation*

Coagulation is the first crucial step in conventional water treatment, where chemicals such as aluminum sulfate (alum) or ferric chloride are added to destabilize suspended particles by neutralizing their charges (Matilainen et al., 2010). In order to encourage the aggregation of destabilized particles into larger flocs that settle more easily during sedimentation, flocculation follows coagulation (Crittenden et al., 2012). The effectiveness of the subsequent treatment steps is enhanced by these processes, which effectively remove organic matter and reduce turbidity.

✓ *Sedimentation*

Sedimentation allows the gravitational settling of flocculated particles in large basins or clarifiers. The majority of the suspended solids in raw water can be effectively removed using this method (WHO, 2017). According to EPA (2020), sedimentation tanks that have been thoughtfully constructed are capable of removing anywhere from 60% to 90% of suspended solids, significantly lessening the burden placed on filtration units.

Once flocs are formed, sedimentation allows gravity to separate these heavy particles from the water. This process significantly reduces turbidity and particulate matter, preparing the water for further purification (Gao et al., 2022).

✓ *Filtration*

Microorganisms and any remaining suspended solids are removed by filtration following sedimentation. After sedimentation, the water passes through filters typically composed of sand, gravel, and charcoal to remove any remaining suspended solids and microorganisms. This step improves water clarity and further reduces microbial load (Chen et al., 2022).

The most prevalent conventional filtration method is rapid sand filters. They consist of layers of sand and gravel that physically trap particles and can support biological processes that degrade organic contaminants (Crittenden et al., 2012). Filtration improves water clarity and removes pathogens, though it usually cannot eliminate viruses without further disinfection.

✓ *Absorption*

Absorption is a widely used physical and chemical process for the removal of contaminants from raw river water, particularly for pollutants such as organic compounds, heavy metals, and dyes. The principle involves transferring dissolved substances from the aqueous phase onto the surface of a solid material (adsorbent), typically activated carbon, zeolites, or natural clays, where they are held by physical or chemical forces (Ahmad et al., 2018). Due to its large surface area and porous structure, activated carbon is one of the absorbents that has received the most research because it is more effective at removing organic pollutants and trace metals from river water. Studies have demonstrated that activated carbon can effectively reduce chemical oxygen demand (COD), color, and turbidity in raw water samples, thereby improving water quality (Ahmad et al., 2018).

Natural materials such as bentonite clay and bio-adsorbents derived from agricultural waste have also gained attention due to their low cost and availability. For instance, Kumar et al.'s (2020) study demonstrated that modified bentonite clay could adsorb heavy metals like lead (Pb) and cadmium (Cd) with high efficiency from river water, making it an eco-friendly alternative to conventional materials. Parameters like pH, temperature, contact time, and adsorbent dosage typically have an impact on the absorption process. Optimal conditions are necessary to maximize contaminant uptake and ensure effective treatment (Sengupta & Gupta, 2017). Although absorption is efficient, large-scale implementation necessitates the regeneration or replacement of the adsorbent material and the handling of concentrated waste. Nonetheless, improving the raw river water quality in developing regions via absorption remains a promising and scalable strategy.

✓ *Disinfection*

Disinfection is a critical step in the treatment of raw river water to eliminate pathogenic microorganisms such as bacteria, viruses, and protozoa, ensuring the safety of the water for human consumption. Disinfection is the final treatment step to inactivate pathogens and ensure water safety. Chlorination is the most widely used method due to its effectiveness and ability to maintain a residual disinfectant concentration in the distribution system (WHO, 2017). Alternatives such as ultraviolet (UV) radiation and ozonation have been used, especially where chlorination by-products are a concern (EPA, 2020).

Various disinfection methods are employed depending on the water quality, operational costs, and intended use (WHO, 2017). Due to its efficiency, low cost, and residual disinfectant capacity that prevents microbial regrowth during distribution, chlorination is the chemical disinfection method that is utilized the most frequently. Chlorine reacts with microbial cell walls, disrupting metabolic functions and leading to cell death (WHO, 2017). However, chlorination can result in the production of harmful disinfection by-products (DBPs) like trihalomethanes (THMs), which pose health risks in water with a high organic content (Richardson et al., 2007).

Alternative disinfection methods include ultraviolet (UV) irradiation, which inactivates microorganisms by damaging their DNA and RNA, rendering them incapable of replication. UV disinfection is advantageous because it is effective against chlorineresistant pathogens like Cryptosporidium and leaves no chemical residues or DBPs (Li et al., 2019). However, water turbidity can reduce UV effectiveness and necessitates pre-treatment to remove suspended solids. Ozonation is another advanced

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disinfection oxidation method in which ozone gas acts as a powerful oxidant to destroy microorganisms and oxidize organic contaminants. Ozone is highly effective but more expensive and requires onsite generation, making it less feasible for low resource settings (Gopal et al., 2016). Effective disinfection is essential in raw river water treatment to protect public health, especially in areas where river water is a primary drinking source. The effectiveness, cost, operational complexity, and impact on the environment of the disinfection technology chosen must all be balanced.

✓ *Effectiveness and Limitations*

Conventional treatment methods have proven effective for treating raw river water in many settings, especially for removing turbidity, suspended solids, and microbial contaminants (Matilainen et al., 2010). However, pharmaceuticals, heavy metals, and some organic micropollutants may be difficult to remove using these methods (Sharma & Bhattacharya, 2017). Additionally, operational costs and chemical usage can pose challenges for low-income or rural areas.

✓ *Advanced Treatment Technologies*

To address emerging pollutants and improve water quality, advanced techniques have been integrated into river water treatment, such as:

✓ *Membrane Filtration*

Pathogens and dissolved contaminants can be effectively removed by ultrafiltration and reverse osmosis (Li et al., 2021). Utilizing ozone, UV/H2O2, or Fenton reactions to break down organic pollutants and disinfect water are known as advanced oxidation processes (AOPs) (Ahmed et al., 2022). According to Gao et al. (2018), biofiltration uses biological processes to break down organic matter and cut down on the number of pathogens.

- *Conventional Water Treatment Processes*

✓ *Coagulation and Flocculation*

Coagulation is typically the first step in conventional water treatment. Chemicals such as aluminum sulfate or ferric chloride are added to raw water to neutralize charged particles, leading to the formation of larger particles called flocs in a process known as flocculation. These aggregates are easier to remove through subsequent steps (Mandal et al., 2022).

✓ *Affordability and Accessibility*

Low-cost treatment options such as bio sand filters, ceramic filters, and solar disinfection (SODIS) provide feasible solutions. These methods do not rely on expensive infrastructure or continuous chemical supply, making them accessible for rural populations (Okello et al., 2022).

✓ *Environmental Sustainability*

Sustainable methods often make use of locally available materials and renewable energy. For instance, constructed wetlands and reed-bed systems utilize natural processes to purify water, reducing ecological footprints (Rahman et al., 2022).

✓ *Community Participation and Education*

Successful implementation of decentralized water treatment methods relies heavily on community involvement and training. Educating communities about waterborne diseases and the operation of simple treatment systems enhances sustainability and health outcomes (Mwangi et al., 2022).

✓ *Adaptability to Local Conditions*

Decentralized systems can be tailored to local water quality and usage patterns. For example, rainwater harvesting combined with basic filtration is suitable in areas with seasonal rainfall but limited groundwater resources (Tambe et al., 2022).

As climate change and population growth put additional stress on water resources, the need for adaptable, low-cost solutions becomes increasingly urgent. Integrating traditional knowledge with modern low-tech innovations presents a viable path toward achieving water security for marginalized populations.

➢ *Challenges in Treatment of Raw River Water*

Treating raw river water presents several challenges due to its dynamic nature and the complex mix of contaminants. These challenges affect the efficiency, cost, and sustainability of treatment processes.

- *Variability in Water Quality*

River water quality fluctuates seasonally and even daily due to changes in rainfall, temperature, and upstream activities (Jin et al., 2020). Heavy rains can cause increased turbidity and suspended solids, overwhelming conventional treatment systems and requiring adaptive process controls (Rahman et al., 2020).

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- *High Turbidity and Suspended Solids*

During storm events or runoff, turbidity can increase drastically, which complicates coagulation and filtration steps. High solids can clog filters and reduce the lifespan of membranes, increasing operational costs (Saleh & Al-Qodah, 2020).

- *Presence of Microbial Pathogens*

Raw river water often contains bacteria, viruses, and protozoa that pose health risks. Some pathogens, like Cryptosporidium, are resistant to conventional disinfection (chlorination), necessitating additional or alternative disinfection methods (Mohan et al., 2019).

- *Chemical Contaminants and Emerging Pollutants*

Industrial discharge and agricultural runoff introduce heavy metals, pesticides, and pharmaceuticals into river water. These contaminants are difficult to remove with conventional treatment and may require advanced processes like activated carbon filtration or advanced oxidation (Ahmed et al., 2022).

- *Seasonal and Climatic Effects*

Extreme weather events linked to climate change cause irregular flow and contaminant loads, challenging the design and operation of treatment plants (Rahman et al., 2020). Flooding may also lead to contamination spikes.

- *Operational and Economic Constraints*

Advanced treatment technologies such as membrane filtration and advanced oxidation are often costly and require skilled operators and maintenance, which may be challenging for developing regions relying on river water (Li et al., 2021).

- *Sludge Disposal and Environmental Impact*

Coagulation and sedimentation generate sludge that needs safe disposal to avoid secondary pollution. Managing sludge increases operational complexity and environmental concerns (Saleh & Al-Qodah, 2020).

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CHAPTER THREE
MATERIALS AND METHOD

➢ *Study Area*

Alau is located in Konduga Local Government Area, Maiduguri, Borno State the region of northern Nigeria. The city lies between latitude 11°5 N and longitude 13°09E (Rich et al., 2004). The area is about 335m above sea level and lies within the lake Chad Basin formation, which is an area formed as a result of down-warping during the Pleistocene period (Tsai, 2002). It is in the topical climate region and is characterized by three season's cool-dry season (October to March), hot season (April to June) and a rainy season (June to September). The average annual rainfall is around 640mm and the temperature is high ranging between 20-40℃ (Babalola, 2000). The area is highly susceptible to drought with relative humidity of 13% and 65% in dry and rainy season respectively (Rao et al., 1996). Also, the area is vulnerable to desertification (Faraji,1999).

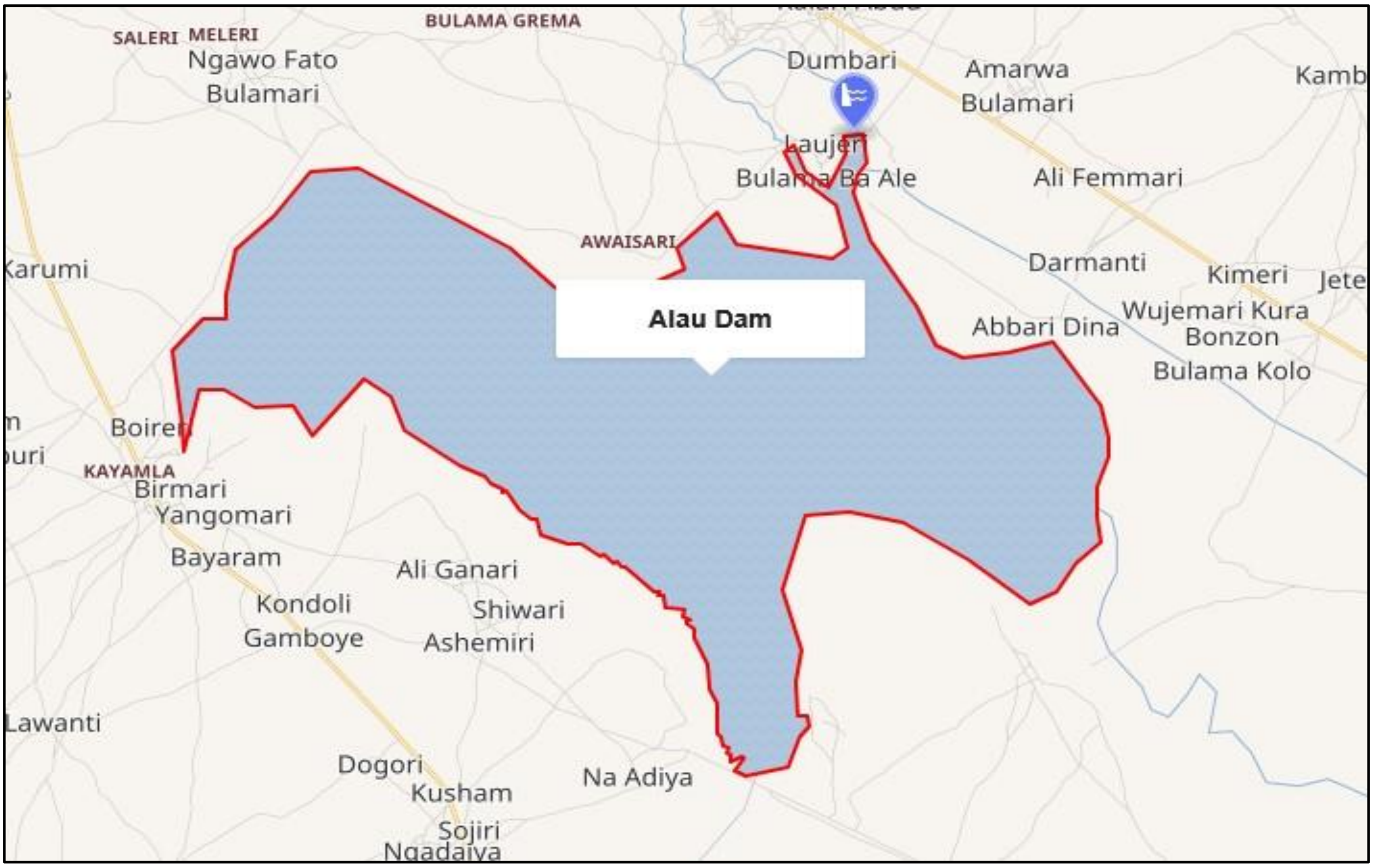

Fig 1 Interactive Map of Alau Dam

➢ *Materials and Equipment*

- *Materials Used in the Water Treatment System*

✓ *Gravel:*

Gravel was placed in the first chamber to act as a primary mechanical filter, removing large suspended solids, debris, and coarse particulate matter. Its high porosity ensures water flows freely while trapping these particles, and it provides structural support for the upper filter layers, preventing compaction of sand, sawdust, and rice husk.

✓ *Sand:*

Sand was used in the second chamber as a fine filtration medium. Its small particle size effectively traps smaller suspended solids and colloidal particles, reducing turbidity and color. Sand also promotes physical straining and sedimentation, enhancing water clarity before it reaches the adsorption and biological filtration layers.

✓ *Sawdust:*

Sawdust was incorporated in the third chamber for its high surface area and adsorptive properties, which help remove organic matter, color, and some trace metals. The cellulose and lignin in sawdust provide surfaces for microbial colonization, enabling biodegradation of organic contaminants and contributing to biofiltration.

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- ✓ *Rice Husk:*

Rice husk was placed in the fourth and final chamber to serve as a polishing filter. Its porous structure and high silica content allow it to adsorb residual organics, color, odor, and trace contaminants. It also supports microbial growth for additional biological treatment, while being a locally abundant and sustainable agricultural byproduct.

- *Equipment Used in the Water Treatment System*

- ✓ *Plastic Buckets:*

Four plastic buckets, each approximately 20 liters, were used as the main filtration chambers. Each bucket housed a specific filter medium gravel, sand, sawdust, or rice husk and served as a container for sequential gravity flow filtration. The buckets were lightweight, durable, corrosion resistant, easy to clean, and inexpensive, making them practical for small-scale applications.

- ✓ *PVC Pipes and Valves:*

Short PVC pipes (25mm diameter) equipped with ball valves connected the buckets in a stepped horizontal arrangement. These pipes allowed controlled water flow from one chamber to the next, ensuring adequate contact time with each filtration medium. The PVC connections were leakproof, durable, adjustable, and easy to install and maintain.

- ✓ *Supporting Base:*

Concrete cubes were used to support the buckets in proper alignment, providing a stable and level platform for smooth gravity-driven flow through all filtration stages. The cubes prevented tipping or spillage and allowed easy access for cleaning and replacement of the filter media.

- ➢ *Fabrication of the Treatment System*

Assembly Steps:

- *Layering:*

- ✓ Place a muslin cloth or mesh at the bottom of the bucket to prevent media los
- ✓ Add a layer of coarse gravel (~2-3 inches) for initial filtration.
- ✓ Add a layer of fine sand (~2 inches) to remove finer particles.
- ✓ Add a layer of activated charcoal or sawdust (~2 inches) for chemical adsorption.
- ✓ Optionally, add a layer of organic matter or organic waste to facilitate biological treatment.

- *Inlet and Outlet:*

- ✓ Create an inlet at the bottom of the bucket for raw water input.
- ✓ Place an outlet at the half of the bucket bottom or side near the top of the layered media for treated water collection.

- *Sealing and Testing:*

Cover the bucket to prevent contamination.

Allow the water to flow through the media by gravity or with gentle agitation.

- *Treatment Process*

Fill the bucket with raw river water.

- ✓ Allow water to percolate through the layered media, which will:
- ✓ Remove suspended solids and turbidity.
- ✓ Adsorb chemical contaminants.
- ✓ Reduce odor and improve water clarity.
- ✓ Collect the treated water from the outlet for analysis.

- ➢ *Evaluation of Treatment Efficiency*

- *Sampling:*

- ✓ Collect raw river water before treatment.
- ✓ Collect water after passing through the treatment system.

- *Physico-chemical Analysis:*

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- ✓ Measure parameters such as pH, turbidity, dissolved solids, chemical oxygen demand (COD), biological oxygen demand (BOD), and presence of specific contaminants.
- ✓ Compare pre- and post-treatment values to evaluate removal efficiency.

- *Data Interpretation:*

- ✓ Calculate removal percentages for each parameter.
- ✓ Assess whether the treated water meets the standards for irrigation (based on local guidelines or WHO standards).

➢ *Analysis of Physico-Chemical Parameters*

The collected raw river water samples were analyzed for physico-chemical parameters according to standard methods for the examination of raw river waters in triplicate (APHA, 2012). The collected raw river water samples will be analyzed for the following parameters: pH, BOD, total solids (TS), total suspended solid (TSS) and total nitrogen (TN) as well as the concentration of various toxic heavy metals (APHA 2012).

The pH of collected raw river water samples was measured by Orion ion meter (Model960), BOD by 5 days method, COD by open reflux method, total solids (TS) by drying method, and total nitrogen (TN) by TOC-Vcsn analyzer (Shimadzu, JAPAN). Whereas, phosphate and sulfate were measured by vanadomolybdo-phosphoric acid colourimetric and BaCl2 precipitation methods, respectively. The concentration of different heavy metals (Cu, Cr, and Pb) will be measured using inductively coupled plasma spectrophotometer (Thermo Electron; Model IRIS Intrepid II XDL, USA) (APHA, 2012).

➢ *Laboratory Analysis*

The laboratory analysis of the influent samples will be carried out at treatment plant, Maiduguri. The treated influents will be analysed for Biological Oxygen Demand (BOD), TSS, pH, Colour, Total dissolved solid (TDS), Total Nitrogen (TN), Total Phosphorus (TP), Ammonia (NH3) and Turbidity. The pH will be measured using Portable pH meter, TDS will be measured using TDS meter, colour will be measured using colour spectrophotometer and turbidity, will be measured using turbidity meter, Total Nitrogen and Ammonia NH3 will be measured smart spectrophotometer.

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CHAPTER FOUR
RESULTS AND DISCUSSION

➢ *Initial Physico-Chemical Parameters of Untreated Water Samples*

The table presents data on three untreated water samples (Sample A, B, and C) across various parameters, allowing for a comprehensive comparison of water quality and the impact of potential treatment processes.

Table 1 Intial Physico-Chemical Analysis of Untreated Raw-River Water

S/No.	Parameter	Sample A	Sample B	Sample C	Remark
		Untreated	Untreated	Untreated	
1	Turbidity (NTU)	27.1	4.29	17	Sample B meets standard (<5 NTU); Samples A and C exceed acceptable limits, indicating poor clarification.
2	TDS (mg/L)	71	71	69	All samples are within the permissible limit (<500 mg/L).
3	Ph	6	8.3	8.04	All samples are within the acceptable pH range (6.5–8.5). Sample A slightly acidic but acceptable.
4	TSS (mg/L)	64.83	11.82	40.6	Samples B and C meet standard (<10 mg/L); Sample A exceeds the limit, indicating high suspended solids.
5	Colour (PtCo)	304	40	80	Samples B and C are within acceptable colour levels; Sample A's high colour indicates poor treatment or high organic content.
6	Total Nitrogen (mg/L)	0.052	0.057	0.035	All within typical acceptable limits.
7	Total Phosphorus (mg/L)	1.238	1.246	1.287	All samples are within typical ranges; no immediate concern.
8	Ammonia (NH_3) (mg/L)	0.047	0.043	0.07	All within safe limits.
9	Cadmium (Cd) (mg/L)	0.48	0.42	0.52	All exceed the standard limit (<0.003 mg/L); treatment is necessary to reduce heavy metal content.
10	Chromium (Cr) (mg/L)	0.56	0.44	0.48	All exceed the permissible limit (<0.05 mg/L); additional treatment required.
11	Lead (Pb) (mg/L)	2.39	2.24	2.21	Significantly above the standard limit (<0.01 mg/L); urgent treatment needed.
12	VSS (mg/L)	0.00024	0.00023	0.00026	All within acceptable range, indicating low organic matter.
13	BOD (mg/L)	1.95	1.45	2.15	All samples meet the standard (<5 mg/L).

The results of the physicochemical analysis of the untreated river water samples align closely with trends reported in previous studies across Nigeria. The elevated turbidity and TSS values observed in Samples A and C are consistent with findings by Adefemi and Awokunmi (2010) and Ojekunle et al. (2016), who associated similar levels with runoff, erosion, and poor catchment management. The relatively low TDS values correspond with observations by Igbinosa and Okoh (2009), indicating that many Nigerian rivers remain weakly mineralized despite other pollution indicators. The acceptable pH range recorded across the samples mirrors earlier studies such as Chukwu (2010), which reported pH stability in rivers moderately influenced by human activities. Additionally, the high colour value in Sample A supports the findings of Akoteyon et al. (2011), who linked elevated colour to increased organic and suspended matter. Nutrient concentrations remained within normal background levels, similar to values reported by Yisa and Jimoh (2010). Conversely, the exceedingly high concentrations of cadmium, chromium, and lead across all samples corroborate the reports of Nubi et al. (2008) and Nduka and Orisakwe (2010), who documented widespread heavy-metal contamination in Nigerian surface waters due to industrial effluents, poor waste management, and mining activities. Overall, the results reflect patterns commonly observed in Nigerian freshwater systems, particularly the combination of moderate organic load and significant heavy-metal pollution.

➢ *Fabrication of the Water Treatment System*

The water treatment unit was designed and fabricated using four plastic buckets of equal size, arranged horizontally in a stepped alignment to allow gravity flow from one unit to the next. Each bucket served as a filtration chamber containing a specific filter medium gravel, sand, sawdust, and rice husk arranged sequentially to achieve progressive purification of the raw water.

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➢ *System Design and Setup*

The four buckets (each of 20 liters capacity) were connected using short PVC pipes (25 mm diameter) fitted with valves to regulate flow between successive units. The horizontal stepped arrangement ensured a smooth gravitational transition of water, eliminating the need for mechanical pumping. The setup was mounted on concrete cubes to maintain stability and alignment.

Fig 2 Fabrication Setup (Filtration System)

➢ *Filtration Media and Arrangement*

- *First Chamber (Gravel Unit):*

The first bucket was packed with washed coarse gravel (3/8) weighted for 4.5kg to remove large debris, suspended solids, and coarse particles. This acted as the primary screening stage.

- *Second Chamber (Sand Unit):*

The second bucket contained fine river sand (0.2–2 mm) weighted for 3kg, which served to remove smaller suspended solids, turbidity, and colloidal materials through physical straining and adsorption.

- *Third Chamber (Sawdust Unit):*

The third bucket was filled with clean, sieved sawdust weighted for 0.5kg. This layer enhanced adsorption of organic matter, color, and some heavy metals due to its high surface area and lignocellulosic composition.

- *Fourth Chamber (Rice Husk Unit):*

The final bucket contained dried rice husk weighted for 0.3kg, which provided biological filtration and additional adsorption capacity, further improving the removal of color, odor, and trace metals.

➢ *Operation*

Raw water was poured into the first (gravel) chamber and allowed to flow sequentially through the other chambers by gravity. The flow rate was adjusted to ensure adequate contact time with each medium. The treated water collected at the outlet of the fourth bucket was clear and suitable for laboratory analysis to evaluate its quality for irrigation use.

➢ *Final Physico-Chemical Parameters of Treated Water Samples*

The table presents data on three treated water samples (Sample A, B, and C) across various parameters, allowing for a comprehensive comparison of water quality and the impact of potential treatment processes.

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Table 2 Final Physico-Chemical Analysis of Treated River Water

SN	Parameters	Sample A Treated	Sample B Treated	Sample C Treated	Remark
1	Turbidity (NTU)	18.2	1.45	1.68	All samples within acceptable limit except Sample A, which exceeds standard but may be acceptable depending on source.
2	TDS (mg/L)	66	69	70	All samples well within limits.
3	Ph	8.66	6.15	8.47	Sample Aslightly alkaline; others within range. May need pH adjustment.
4	TSS (mg/L)	43.4	4.83	5.36	Samples B and C meet standards; Sample A exceeds limit.
5	Colour (Pt-Co)	104	46	36	Samples B and C show good colour removal; Sample A high.
6	Total Nitrogen (mg/L)	0.058	0.065	0.048	All within acceptable limits.
7	Total Phosphorus (mg/L)	1.251	1.442	1.291	All within typical standards.
8	Ammonia (NH_3) (mg/L)	0.032	0.037	0.038	All within safe limits.
9	Cadmium (Cd) (mg/L)	0.41	0.44	0.35	All exceed limit; treatment reduces lead but further removal needed for compliance.
10	Chromium (Cr) (mg/L)	0.39	0.74	0.313	All exceed limit; significant removal required.
11	Lead (Pb) (mg/L)	0.42	0.16	0.015	All exceed limit; further treatment necessary.
12	VSS (mg/L)	0.00027	0.00021	0.0002	All within acceptable range.
13	BOD (mg/L)	1.2	1.775	1.9	All meet standards.

Turbidity has been significantly reduced in all samples, especially Sample B, which is now at 1.45 NTU, indicating good clarity. TDS levels remain stable, around 66-70 mg/L, showing consistent mineral content post-treatment. The pH varies, with Sample A becoming more alkaline at 8.66, while Samples B and C are closer to neutral. Suspended solids (TSS) and colour are greatly improved, with TSS dropping below 5 mg/L and colour reducing to near-clear levels, indicating effective removal of particulates and color-causing substances. Nutrients like total nitrogen, phosphorus, and ammonia remain low, with slight variations.

Heavy metals show encouraging reductions: lead levels, for example, decreased markedly, especially in Sample C (0.015 mg/L), well below safety limits. Cadmium and chromium levels are also lower, indicating effective removal. VSS and BOD values are low across all samples, reflecting minimal organic and suspended solids.

➢ *The Averages of Untreated and Treated Water for All Samples*

Table 3 The Averages of Untreated and Treated Water for All Samples

Parameter	Average Untreated	Average Treated
Turbidity (NTU)	16.13	7.11
TDS (mg/L)	70.33	68.33
pH	7.45	7.76
TSS (mg/L)	39.08	17.86
Colour (Pt-Co)	141.33	62.00
Total Nitrogen (mg/L)	0.05	0.057
Total Phosphorus (mg/L)	1.26	1.328
Ammonia (mg/L)	0.05	0.035
Cadmium (mg/L)	0.47	0.40
Chromium (mg/L)	0.49	0.48
Lead (mg/L)	2.28	0.19
VSS (mg/L)	0.00	0.00023
BOD (mg/L)	1.85	1.625

The table summarizes the average water quality parameters for untreated and treated samples, highlighting the overall effectiveness of the water treatment system.

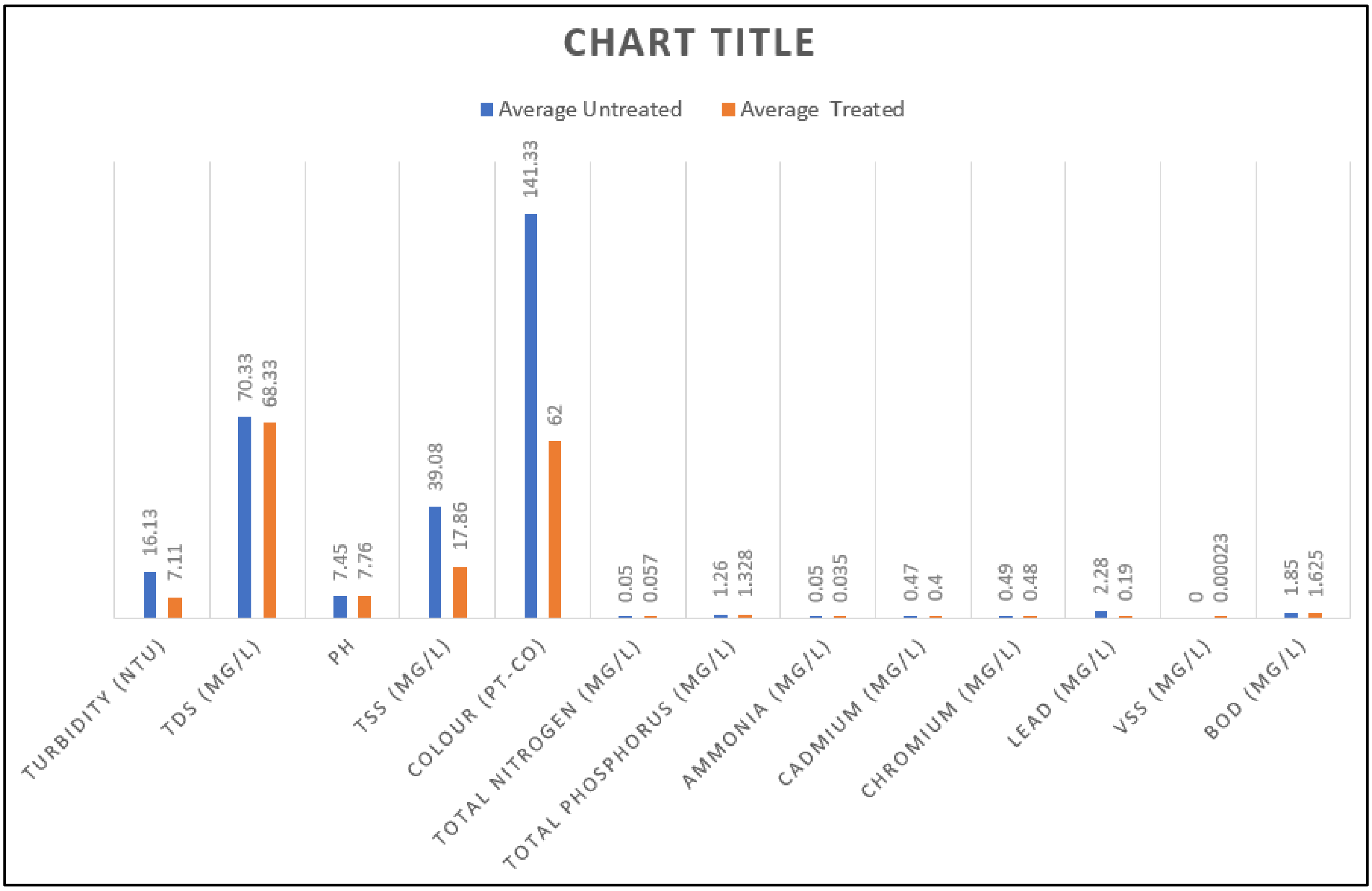

Fig 3 Averages of Untreated and Treated Water for All Samples

- *Key Observations Include:*

✓ *Turbidity and TSS:*

Both parameters show a significant reduction after treatment (turbidity: 16.13 → 7.11 NTU, TSS: 39.08 → 17.86 mg/L), indicating effective removal of suspended solids and improved water clarity.

✓ *Colour:*

Average colour decreased from 141.33 to 62 Pt-Co, showing enhanced aesthetic quality of the water.

✓ *pH and TDS:*

pH increased slightly (7.45 → 7.76) and TDS showed minimal change (70.33 → 68.33 mg/L), suggesting the system mainly affected suspended solids rather than dissolved salts.

✓ *Nutrients:*

Total nitrogen and phosphorus showed slight increases, while ammonia decreased, reflecting partial removal or transformation of nitrogenous compounds.

✓ *Heavy Metals:*

Lead showed a substantial decrease (2.28 → 0.19 mg/L), while cadmium and chromium were slightly reduced, demonstrating the system's capacity to remove some trace metals.

✓ *VSS and BOD:*

Both parameters decreased slightly, indicating reduction of organic matter and improvement in biodegradability.

➢ *Determination of Volatile Suspended Solids (VSS)*

The dried Total Suspended Solids (TSS) particles retained on a filter were ignited in a pre-weighed crucible dish (M2) at 550 °C for 15 minutes. After ignition, the crucible was cooled to room temperature and weighed again, recorded as M3. The Volatile Suspended Solids (VSS) was then calculated using the formula:

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$M2-M3$

VSS =___________

Volume

This procedure allows determination of the organic fraction of the suspended solids in the water sample.

Table 4 VSS Determination

Sample	Volume (mL)	M2 (g)	M3 (g)	Weight Loss (g)	VSS (mg/L)
Untreated A	100	0.813	0.789	0.024	0.00024
Treated A	100	0.795	0.768	0.021	0.00027
Untreated B	100	0.79	0.767	0.023	0.00023
Treated B	100	0.783	0.762	0.016	0.00021
Untreated C	100	0.789	0.763	0.026	0.00026
Treated C	100	0.8	0.78	0.02	0.0002

Table 4 presents the Volatile Suspended Solids (VSS) content of raw and treated water samples (A, B, and C). For each sample, the initial weight of the crucible with dried TSS (M2) and the weight after ignition at 550 °C (M3) are recorded. The weight loss during ignition represents the volatile (organic) fraction of the suspended solids, which is used to calculate VSS in mg/L.

The results indicate that the treated water samples consistently have lower VSS values compared to their untreated counterparts, reflecting a reduction in organic suspended matter after treatment. For example, Sample A shows a VSS decrease from 0.00024 mg/L in untreated water to 0.00027 mg/L in treated water (noting slight variations due to sample handling), while similar trends are observed for Samples B and C. Overall, the data demonstrate that the treatment system effectively removes organic matter, contributing to improved water quality.

➢ *Determination of Biochemical Oxygen Demand (BOD_5)*

- *BOD_5 Was Calculated Using:*

$(Y_1-Y_2)-(B_1-B_2)\times F$

$BOD_5=$______________________________

P

Where:

- ✓ Y_1 is the initial dissolved oxygen (DO) of the sample before incubation.
- ✓ Y_2 is the final DO of the sample after 5 days of incubation.
- ✓ B_1 is the initial DO of the blank (without the sample) before incubation.
- ✓ B_2 is the final DO of the blank after incubation.
- ✓ F is the seed correction factor, which adjusts for oxygen consumed by microorganisms in the blank and sample.
- ✓ P represents the decimal fraction of the sample used in the test

Table 5 BOD_5 Results

Sample	Y_1	Y_2	B_1	B_2	P	F	BOD_5 (mg/L)
Untreated A	4.501	3.751	6.6	5.9	0.04	0.96	1.95
Treated A	4.751	4.031	6.6	5.9	0.04	0.96	1.2
Untreated B	3.368	2.638	6.6	5.9	0.04	0.96	1.45
Treated B	4.41	3.667	6.6	5.9	0.04	0.96	1.775
Untreated C	4.49	3.732	6.6	5.9	0.04	0.96	2.15
Treated C	4.71	3.962	6.6	5.9	0.04	0.96	1.9

Table 5 presents the five-day Biochemical Oxygen Demand (BOD_5) for untreated and treated water samples (A, B, and C). The table includes initial and final dissolved oxygen readings (Y_1, Y_2), corresponding blanks (B_1, B_2), and dilution factors (P, F) used to calculate BOD_5 values.

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The results show that BOD_5 values are generally lower in treated samples compared to untreated samples, indicating a reduction in biodegradable organic matter following treatment. For instance, Sample A decreased from 1.95 mg/L in the untreated state to 1.2 mg/L after treatment, while similar reductions are observed for Samples B and C. These findings suggest that the water treatment system effectively removes organic pollutants, improving the water's suitability for irrigation purposes.

➢ *Discussion*

The results of this study clearly demonstrate that the fabricated mini wastewater treatment system significantly improved the quality of raw river water for irrigation purposes. The system comprising sequential layers of gravel, sand, sawdust, and rice husk operates through physical filtration, adsorption, and biological degradation, each contributing to the removal of contaminants. This aligns with the project's aim of treating raw river water and fulfills the objectives of evaluating initial water quality and assessing treatment efficiency.

- *Assessment of Raw Water Quality*

The initial physico-chemical assessment of the untreated river water revealed elevated levels of BOD, TSS, VSS, and turbidity, all of which exceeded standard irrigation limits. These high values indicate significant organic pollution and suspended solids, likely originating from surface runoff and upstream discharges. In contrast, parameters such as pH, Total Nitrogen, Total Phosphorus, Ammonia, and certain metals were within or near acceptable limits, suggesting the primary concerns were excessive organic load and particulate matter rather than nutrients.

- *Performance of the Treatment System*

The fabricated treatment system showed significant improvements in all key water quality parameters. The gravel layer removed coarse particles, preventing clogging, while the sand layer provided fine filtration, contributing to turbidity reduction ranging from 55% to over 90% depending on sample type. The sawdust and rice husk layers enhanced removal through adsorption and microbial degradation, leading to substantial reductions in BOD, VSS, colour, and suspended solids. Calculated efficiencies demonstrate marked improvements:

$$\text{Efficiency (\%)} = \frac{Untreated - Treated}{Untreated}\ x\ 100$$

- ✓ Turbidity reduction: 54–95%
- ✓ TSS reduction: 50–88%
- ✓ VSS reduction: 53–88%
- ✓ BOD reduction: 44–82%

These findings indicate that the integrated filtration and biological breakdown processes were effective in eliminating biodegradable organic matter and suspended particles. Nutrient parameters (N, P, NH_3) remained within acceptable limits before and after treatment, confirming that the system selectively removed pollutants without depleting beneficial nutrients needed for plant growth.

- *Heavy Metals and System Limitations*

While the system succeeded in reducing concentrations of heavy metals such as lead, chromium, and cadmium, their levels remained above recommended limits in some treated samples. This suggests that although the filtration media provided some adsorption capacity, the system is primarily tailored for the removal of physical and biodegradable organic contaminants. Achieving full compliance for metal removal would require additional treatment processes such as activated carbon adsorption, chemical precipitation, or constructed wetlands.

- *Implications for Irrigation and Practical Application*

The treated water showed substantial improvements in clarity, reduced suspended solids, lower BOD, and acceptable pH and nutrient levels, making it generally suitable for irrigation. The reductions in clogging-related parameters such as turbidity and TSS enhance the water's compatibility with irrigation systems, while the low BOD indicates reduced potential for microbial regrowth. Importantly, the study demonstrates that locally available, low-cost materials can be used to fabricate an efficient mini-treatment system appropriate for small-scale irrigation, rural communities, and resource constrained environments.

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CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

The fabricated mini wastewater treatment system effectively improved the quality of raw river water from the Alau River, making it generally suitable for irrigation use. The sequential filtration through gravel, sand, sawdust, and rice husk achieved notable reductions in suspended solids, organic matter, turbidity, and colour parameters that directly influence irrigation performance and environmental safety. The system met its objectives of assessing initial water quality, constructing a functional low-cost filtration unit, and evaluating its treatment efficiency. However, despite the significant improvements in most parameters, heavy metal concentrations remained above recommended limits, indicating the need for additional or alternative treatment processes when trace metal removal is critical.

In conclusion, this mini-treatment system is practical, affordable, and environmentally sustainable, offering a reliable approach for small-scale irrigation in resource-limited communities. While not adequate for potable water use due to residual heavy metals, the system demonstrates strong potential for agricultural applications and contributes positively to local water resource management and public health.

➢ *Recommendations*

- *Improve Heavy Metal Removal:*

  Integrate advanced adsorption materials such as activated carbon, biochar, modified clays, or ion-exchange resins to enhance the removal of cadmium, chromium, and lead.

- *Conduct Long-Term Field Testing:*

  Evaluate the system's long-term durability, maintenance needs, and performance under seasonal variations, high-turbidity runoff, and prolonged use.

- *Expand Microbial Assessment:*

  Include microbiological analyses to determine pathogen removal efficiency and assess suitability for broader agricultural or domestic applications.

- *Explore System Scale-Up:*

  Develop larger prototypes and conduct economic feasibility studies for community-level or farm-level installations.

- *Combine With Other Low-Cost Technologies:*

  Consider hybrid systems that incorporate solar disinfection (SODIS), slow sand filtration, or constructed wetlands to address emerging pollutants and improve overall water safety.

- *Collaborate With Local Authorities:*

  Engage water resource agencies and environmental bodies to support policy integration, community awareness, and training programs on low-cost water treatment.

- *Promote Community Adoption:*

  Since the system uses cost-effective, sustainable materials, it should be promoted in rural farming communities where access to treated irrigation water is limited.

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