GREYWATER MANAGEMENT IN EDUCATIONAL FACILITIES : A CASE STUDY OF BISHOP SECONDARY SCHOOL, MUKONO

BISMARK CHEPTOEK

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

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ABSTRACT

Greywater management in educational institutions presents a viable solution to water scarcity and sustainability challenges. This research focuses on design and implementation of a greywater treatment system for Bishop Secondary School, Mukono. The research assessed the sources, volumes and characteristics of greywater generated within the school identifying key physical chemical and biological parameters. Preliminary tests indicated high COD, BOD, TSS, E.coli and TP values in comparison to the national standards.

The main objective of this research and the design were achieved. The design consists of a batch treatment system using kaolin clay as an adsorbent followed by filtration through a sand and gravel column. This will ensure that the greywater is treated to the required standards before reuse supplementing non drinking water needs such as toilet flushing and cleaning.

The use of natural Kaolin clay enhanced the treatment process with high percentage reduction in all quality i.e. BOD, COD, TSS, E.coli and TP with percentage reductions between 10% and 55%.

DECLARATION

I CHEPTOEK BISMARK hereby declare that this research proposal is my original work and has never been submitted to any institution for any award. Any other sources of information referred to are herein duly acknowledged.

Signature: ………………………………… Date: ……………………………….

APPROVAL

This is to certify that this research titled, "greywater management in educational facilities" was carried out under my supervision as the academic supervisor and is now ready for submission for examination.

Mr. Job Gava

Signature: ……………………… Date: …………………………………… Supervisor.

ACKNOWLEDGEMENT

First of all, I would like to thank the ALMIGHTY GOD for enabling me complete my final year research and design project successfully.

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DEDICATION

This report is dedicated to my beloved parents and the family members who were very patient with me during the course of this research. Thank you very much for the continued words of encouragement and financial support towards the completion of my final year project research and design.

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LIST OF ABBREVIATIONS

BOD – Biochemical Oxygen Demand

COD – Chemical Oxygen Demand

TSS – Total Suspended

Solids

TP– Total Phosphorous

mg/L – milligrams per litre

NWSC – National Water and Sewerage Cooperation

NEMA – National Environmental Management Authority

WHO – World Health Organization

UN – United Nations

CHAPTER ONE: INTRODUCTION

1.1Background and Introduction

Water resources sustainability has become a prime issue for almost all the educational institutions across the globe, and so is water reuse technologies and practices. With growing awareness towards environmental protection, schools are implementing several ways of greening their environment, one of them is greywater management. Greywater can be described as the wastewater originating from washbasins, showers, sinks, and kitchens which are neither toilets nor urinals and it is considered safe for use in irrigation and toilet flushing. Such a process is referred to as recycling of greywater and is very important in achieving the water targets in educational facilities as it greatly reduces water use, saves money and encourages acceptable environmental practices (Vigneswaran et al., 2017).

Making use of water recycling systems allows educational establishments to be more environmentally friendly. Schools are water-intensive environments that sometimes use excessive amounts of water, especially in such areas as bathrooms, kitchens, and hostels. Because of the worldwide water crisis, and also the rising cost of doing business, many educational institutions have adopted the use of greywater recycling systems in place (Leong et al., 2019). Greywater management in educational facilities is not just an option for water conservation….

1.2 PROBLEM STATEMENT

Greywater treatment for reuse is an important topic in the context of sustainable water management, especially in areas facing water scarcity (Misra, 2020). Greywater is wastewater that comes from household activities excluding sewage. It typically contains a lower level of pathogens and contaminants than black water, making it less hazardous to treat and reuse for non-potable purposes such as irrigation, toilet flushing, and gardening (Al-Jayyousi, 2016).

With growing environmental awareness and increasing water demand, treating greywater at the institutional level can help reduce freshwater consumption, lower utility bills, and ease pressure on municipal wastewater systems (Eriksson et al., 2019). By reusing greywater, institutions can contribute to water conservation, especially in regions where water resources are limited1.3OBJECTIVES

1.3.1Main Objective

To design a sustainable grey water management system for educational facilities with a focus on Bishop Secondary School, Mukono.

1.3.2 Specific Objectives

1. To determine the sources and volumes of grey water generated per capita per day.

2. To assess the physical, chemical, and bacteriological properties of grey water.

3. To determine the optimum dosage of kaolin clay powder in treatment of greywater

4. To develop a grey water treatment system design

1.3.3 Research Questions

1. What are the sources and daily volumes of grey water generated at Bishop Secondary School?

2. What are the physical, chemical, and bacteriological characteristics of the grey water?

3. How can a sustainable grey water treatment system be designed to satisfy the school's needs?

1.4 JUSTIFICATION

The global rise in fresh water demand and the decline in available water resources increase the demand for sustainable water management strategies, especially in water-stressed regions. Like many developing countries, Uganda faces challenges related to water availability, accessibility, and quality (Nsubuga et al., 2014). The high population in schools increases domestic water consumption and generation of greywater. Taking an approximate daily water use of 30,000 liters per day at Bishops Secondary School Mukono, 24,000 liters a day would be greywater. Although this is a huge amount, the school currently manages greywater using soak pits, which may lead to environmental contamination and loss of the opportunity for water reuse.

The existing greywater disposal practices using soak pits are inadequate in removing pollutants, hence contaminating the groundwater and creating health hazards. If not appropriately treated, greywater contains a high amount of contaminants in the form of BOD, COD, suspended solids, and microbial pollutants (Al-Hamaiedeh & Bino, 2010). The World Health Organization and Ugandan standards dictate that such contaminants should be brought within permissible limits for any kind of safe reuses (WHO, 2017). However, the greywater from Bishop Secondary School, Mukono, is untreated, which may pose health risks to the students and staff. There is a dire need, therefore, for an efficient treatment of wastewater. In other related literature, the application of natural adsorbents like clays was found effective in reducing both organic and inorganic pollutants in wastewater (Sun et al., 2019). Kaolinite, a clay mineral with a high cation exchange capacity and large specific surface area, has demonstrated significant removal efficiencies for key contaminants like BOD, COD, and suspended solids in various wastewater contexts (Iqbal et al., 2021). Nevertheless, research on the practical application of kaolinite for greywater treatment in institutional settings in developing countries remains limited. Most of the literature focuses on synthetic grey water under ideal laboratory conditions but does not consider real systems that could face different characteristics of water and operational issues.

Furthermore, the economic feasibility of adapting kaolinite-based greywater treatment systems into resource-constrained settings is relatively unexplored, as reported by Ghaitidak & Yadav (2013). Bishops Secondary School Mukono currently uses about 10 million UGX a month on its water expenses, hence the rationale for cheap ways of reducing water consumption. Treated greywater can be reused for non-potable purposes such as toilet flushing, compound cleaning, and irrigation, which would substantially reduce the school's reliance on piped water supplied by the National Water and Sewerage Corporation.

1.5 Geographical Scope

The scope of the study is Bishop Secondary School, Mukono, The natural Kaolin clay were obtained from Buwambo deposit 27km north of Kampala.

CHAPTER TWO: LITERATURE REVIEW

2.1 Waste water

Water, which makes up three-quarters of the earth's surface, is one of the necessary components for human survival. Despite this abundance, only around 1% of fresh water is available. By 2030, the world's water demand is predicted to have increased from 4200 Bm3 in 2015 to 6900 Bm3(Nivesh et al., 2023). Many contaminants and dangerous substances of various types and compositions are introduced by industrial and other human-caused activities(Kathalingam et al., 2023).

Wastewater is water that has been used in homes, businesses, manufacturing facilities, and farms. Any groundwater or storm water that enters the sewer system is also included(Victoria, 2024). Water is composed of two hydrogen atoms and one oxygen atom, it is not these constituents that make water important but the contaminants in it. Taking an example of any chemical reaction, we would be satisfied at a reaction purity yield of 99% as most reactions yield 70% to 90% purity. However, for water, even 1% impurity is unacceptable. Many contaminants that we consider insignificant in other products like food can prevent us from using water. In other instances, a slight deviation in the quantity of the right compound can render the water unpalatable or useless for many aquatic purposes(Russell, 2019).

Waste is an inevitable byproduct of human activity. Wastewater will be produced from a large portion of this garbage. Numerous factors influence wastewater's amount and quality. Not every industry or person generates the same quantity of waste. The behavior, way of life, and standard of living of the residents, as well as the legal and technical environment in which they live, all have an impact on the quantity and kind of trash generated in households(Henze and Comeau, 2008).

There are different types of grey water as shown below

Table 3.1 Wastewater types

Wastewater from society	Wastewater generated internally in treatment plants
Domestic wastewater	Thickener supernatant
Wastewater from institutions	Digester supernatant
Industrial wastewater	Reject water from sludge dewatering
Infiltration into sewers	Drainage water from sludge drying beds
Stormwater	Filter wash water
Leachate	Equipment cleaning water
Septic tank wastewater	

1

Adopted from: 2008 Mogens Henze. Biological Wastewater Treatment: Principles Modelling and Design.

Households and residential areas are the source of domestic wastewater, sometimes referred to as municipal sewage. Water from showers, bathtubs, sinks, toilets, dishwashers, and washing machines is included (Noutsopoulos et al., 2018). Nutrients (nitrogen and phosphorus from urine and detergents), Microorganisms (bacteria, viruses, and parasites), Organic materials (food particles, human waste, soap residues), q+and Chemicals (cleaning agents, personal care items) are all present in this effluent (Hatley et al., 2024). When released into natural water bodies, improperly treated household wastewater can lead to environmental contamination and waterborne illnesses. Before being discharged or utilized again, it is typically treated in sewage treatment facilities (Ilyas et al., 2019).

Wastewater from Institutions: This category of wastewater originates from public buildings, offices, hospitals, schools, and universities. Similar to domestic wastewater, it may contain higher levels of organic matter and chemical pollutants because of the following: pharmaceuticals and biomedical waste from hospitals and clinics; food waste and grease from institutional cafeterias; cleaning agents and disinfectants from extensive sanitation processes; and laboratory discharges from schools, research facilities, and hospitals. The treatment of wastewater in hospitals is complicated by the presence of microorganisms, medications, and radioactive elements. To avoid contaminating water sources, special handling and treatment procedures are needed (Vlková et al., 2016, Castiglioni et al., 2018).

Industrial wastewater is produced by factories, manufacturing plants, and processing industries. Its components vary by industry, but usually consists of the following: Chemical pollutants (solvents, acids, and dyes from textile and chemical plants); Heavy metals (lead, mercury, and arsenic from metal processing and electronics industries); Oils and grease (from food processing and petroleum industries); and high-temperature wastewater (from power plants and refineries). Industrial wastewater is more toxic than domestic wastewater hence it requires particular treatment prior reuse or disposal (Ahmed et al., 2021). Many industries including those in Uganda pre-treat their wastewater before releasing it into municipal sewage systems to avoid damaging sewer infrastructure and treatment plants (Godswill, 2017).

Rainwater or groundwater that seeps into sewer pipes via fractures, joints, or faulty connections is referred to as infiltration from sewers (Zeydalinejad et al., 2024). Old, aging sewer pipes with fractures and leaks, pipelines that are damaged or poorly linked, high groundwater levels that push water into sewer systems, and tree roots that get into sewer pipes are some of the causes of infiltration. Sewage treatment facilities may become overloaded due to infiltration, which would increase wastewater volume and treatment expenses. Additionally, it may result in sewage system breakdowns, which could contaminate groundwater and surface water through overflows (Lundberg, 2021).

Rainwater or melted snow that runs off of parking lots, roadways, rooftops, and other impermeable surfaces is known as stormwater (Kostina et al., 2022). Stormwater is not produced by human activity like wastewater from homes or businesses, but it can contain a range of contaminants, including: Heavy metals (lead, zinc, and copper from tires and industrial areas); oil and grease (from roads and vehicle emissions); pesticides and fertilizers (from agricultural runoff); and sediments and debris (sand, leaves, and plastic waste)(Pamuru et al., 2022). If stormwater is not adequately managed, it can contaminate rivers, lakes, and groundwater because it bypasses sewage treatment facilities. Retention ponds and stormwater drainage systems are used by many communities to prevent flooding and remove contaminants from water before it enters natural bodies (Ferzoco and McCauley, 2024).

The liquid that emerges from landfills, known as leachate, contains suspended and dissolved elements from decomposing garbage. Rainwater seeping into solid trash and dissolving pollutants is how it forms(Yaashikaa et al., 2022). When organic garbage breaks down, it releases liquids that contain high levels of germs and poisons. Hazardous and industrial waste also releases chemicals into nearby water sources. Ammonia and nitrogen compounds from decomposing organic waste, heavy metals from batteries, electronic waste, and industrial byproducts, and toxic organic compounds from pesticides, solvents, and medications are frequently found in leachate (Teng et al., 2021). Leachate from landfills can contaminate drinking water supplies by leaking into groundwater if improperly handled. In order to avoid harming the environment, landfills usually employ leachate collecting and treatment systems (Wijekoon et al., 2022).

Wastewater gathered and treated from individual septic systems used in rural and unsewered areas is referred to as septic tank wastewater, or on-site wastewater (Ghangrekar, 2022). By separating solids from liquids, a septic tank enables heavier materials to settle as sludge. Anaerobic bacterial digestion is used to partially remediate wastewater. discharges liquid wastewater into a drain field, where leftover impurities are filtered off by soil and microorganisms (Almomani, 2016). Pathogens (bacteria, viruses, and parasites from human waste), nutrients (phosphorus and nitrogen, which can contaminate groundwater), and organic matter that needs to be broken down further by soil microbes are all still present in septic wastewater. Sewage backups, unpleasant smells, and groundwater contamination can result from poorly maintained septic systems. In order to avoid system breakdowns, routine pumping and inspection are required (Haider et al., 2023).

2.1.1 Legislation on wastewater

The six's United Nations Sustainable Development Goal (SDG) to ensure availability and sustainable management of water and sanitation for all is being threatened by the enormous amount of waste water generated and improperly managed. Target 6.3 of this SDG, "to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" is greatly affecting the general realization of the SDG-6. This arises from the increasing world population and industrialization which is proportional to the amount of waste water generated(United Nations, 2016).

The United Nations advocates for the continuous improvement in the management of all types of waste water. In the 2022 release of the United Nations Secretary-Generals' Advisory Board on Water & Sanitation (UNSGAB) which stated: In an increasingly urbanized world, severe health and pollution problems are caused by human sewage, industrial and agricultural pollution, and city storm waters. According to rough estimates, 80–90% of wastewater in developing nations is dumped straight into rivers, lakes, and oceans, resulting in water-borne illnesses, impeding travel and economic growth, and seriously harming the ecosystem. Sustainable finance mechanisms and a cost-effective strategy are necessary for wastewater management and pollution control. Preventing pollution must be a part of the economic equation since it can increase agricultural and industrial production. Due to its reusability and potential as a source of "new" water, treated water can lessen the environmental impact of cities, farms, and industry. Urban wastewater that has been properly treated can be used again for peri-urban farming and industry. Wastewater can be converted into energy. Green jobs are produced by all of these initiatives(United Nations, 2022).

The main laws controlling wastewater management in East Africa are usually found in each nation's "Water Act," which contains rules for water use, protection, and management. These laws include provisions for wastewater discharge and treatment standards, which are frequently enforced by the national environmental protection agency of that country. Important features include the requirement for effluent discharge permits and compliance with certain water quality standards when releasing wastewater into the environment(Parliament of Kenya, 2016, Order of the Government, 2020).

The "Water Act, 1995" (Cap 152), which is the main law governing wastewater in Uganda, contains specific rules about waste discharge through the "Water (Waste Discharge) Regulations, 1998" under Section 107 of the Water Act. The National Environment Management Authority (NEMA) is in charge of enforcing these rules and standards for effluent discharge into water bodies. In this law, “a person wishing to discharge wastewater is supposed to apply to the director for a waste discharge permit in the prescribed manner”(Parliament of Uganda, 1997).

2.1.2 Wastewater Treatment Methods

Treatment of wastewater is a critical process to clean water used for domestic, industrial, and agricultural activities prior to release to the environment or re-use. The primary reasons for wastewater treatment are to protect public health through the elimination of pathogens and toxic chemicals, preventing water pollution of natural watercourses, conserving freshwater resources through recycling, and addressing environmental needs (Metcalf & Eddy, 2014; WHO, 2017). Wastewater can be categorized into three broad types: domestic (municipal) wastewater, which is generated in homes, schools, and offices and contains organic matter, nutrients, and detergents; industrial wastewater, which is generated by refineries and factories and can have heavy metals and poisonous chemicals; and agricultural wastewater, which is generated in farms and animal operations and tends to be high in organics and nutrients (Tchobanoglous et al., 2014; Ahmed et al., 2021; Mateo-Sagasta et al., 2017).

The treatment process is typically divided into initial, primary, secondary (biological), and tertiary (refined) stages, each for different types of pollutants.

Initial treatment focuses on the removal of big debris and solids through screening and grit removal to protect downstream equipment. Screening, however, involves passing wastewater through bar racks or fine screens in an effort to screen out materials like plastics and rags, while grit chambers practice sedimentation or aeration to eliminate sand and gravel (Metcalf & Eddy, 2014). Flow equalization is also utilized in industrial processes for equalizing discharge fluctuations in wastewater and to prevent shock loads on biological treatment plants (EPA, 2000).

Primary treatment follows preliminary processes and primarily involves sedimentation, where the wastewater is retained in large tanks to allow settleable solids to settle and floatables like oils and grease to float to the surface for scraping off. Primary clarifiers, which are rectangular or circular, can remove 50–70% of suspended solids and 25–40% of biochemical oxygen demand (BOD) (Tchobanoglous et al., 2014). A alternative to sedimentation is dissolved air flotation (DAF), in which minute air bubbles are supplied to induce floating of suspended solids on the top and is particularly effective for oily wastewater (Rubio et al., 2002).

Secondary treatment involves breaking down dissolved and colloidal organic matter through biological processes. The process used most frequently is the activated sludge process, whereby the aerobic bacteria break down organic pollutants in aeration tanks before separation from the treated water and biomass in secondary clarifiers. It eliminates 85–95% BOD and is used most frequently in municipal treatment plants (Metcalf & Eddy, 2014). Other biological treatment methods are trickling filters, through which wastewater is passed over biofilm-covered media, and rotating biological contactors (RBCs), which utilize rotating discs as a place for microbial growth. These are simpler and have lower energy requirements but are not as efficient as activated sludge, taking out an average 70–90% of BOD (EPA, 2000). Membrane bioreactors (MBRs) combine biological treatment with ultrafiltration membranes to produce high-quality effluent for reuse, but their cost hinders widespread use (Judd, 2011). Anaerobic digestion is another biological process used on high-strength industrial wastewater, where microorganisms break down organic matter in the absence of oxygen, producing biogas as a by-product (Appels et al., 2008).

Tertiary treatment further processes the effluent to meet strict discharge standards or enable reuse. Filtration techniques, such as sand filtration and membrane systems (microfiltration, ultrafiltration, nanofiltration, and reverse osmosis), remove remaining suspended solids, bacteria, and dissolved contaminants (Shannon et al., 2008). Disinfection is needed to remove pathogens and can be achieved through chlorination, UV light, or ozonation, each with various benefits and drawbacks (EPA, 1999). Remineralization or nutrient removal, particularly for nitrogen and phosphorus, might be necessary in an effort to prevent eutrophication of receiving waters. Biological nitrification-denitrification denitrifies ammonia to nitrogen gas, and chemical precipitation or enhanced biological phosphorus removal (EBPR) reduces the phosphate content (Metcalf & Eddy, 2014). Advanced oxidation processes (AOPs), e.g., ozone/hydrogen peroxide and Fenton's reagent, oxidize stable organic pollutants by extremely reactive hydroxyl radicals (Oller et al., 2011).

Sludge produced during treatment also must be treated to reduce volume and stabilize organic material. Thickening of the sludge, digestion (either anaerobic or aerobic), and dewatering (either filter pressing or centrifugation) are standard practices, and the resulting biosolids can either be land-applied as fertilizer, burned to recover energy, or landfilled (EPA, 2000; Tchobanoglous et al., 2014). New technologies such as microbial fuel cells (MFCs), wherein electricity is generated from wastewater treatment, and algae systems, which trap nutrients in lieu of biomass production for biofuels, are bright prospects for energy-neutral and sustainable wastewater treatment (Logan et al., 2006; Park et al., 2011).

2.1.3 Decentralized Wastewater Treatment Systems

It is some of the present trends in wastewater management to see growing interest in decentralized treatment for rural areas, small towns, and developing nations where centralized systems are not feasible or economically impossible (Massoud et al., 2009). Some of these include package treatment plants, constructed wetlands, and septic tank effluent filtration, which can be made specifically to suit the requirement of a given community. Decentralized systems do offer advantages like lower cost of infrastructure, reduced energy requirements, and potential reuse of water locally (Libralato et al., 2012). There are limitations in some aspects like the requirements for maintenance, reliability in operation, and regulation control, particularly in places where technical capability is low (Tilley et al., 2014). Among some of the new technologies in this field are the development of smart decentralized systems with remote monitoring and automated control capabilities in order to enhance treatment performance and minimize operator action (Rahman et al., 2020).

2.1.4 Climate Change Impacts on Wastewater Treatment

Climate change causes significant threats to the wastewater treatment sector by increasing rainfall intensity, rising sea level, and climate temperature fluctuations (Mills et al., 2020). These changes can lead to hydraulic overload of treatment operations, reduced efficiency of treatment by temperature-sensitive biological processes, and damage to infrastructure due to extreme weather (Delgado et al., 2022). It has been reported through studies that the biological nutrient removal processes are the most temperature-sensitive, with nitrification efficiency greatly compromised below 15°C (Gori et al., 2013). Adaptation strategies under investigation include the development of climate-resilient treatment technologies, such as hybrid constructed wetlands with adjustable flow paths and the integration of sophisticated monitoring systems to identify and respond to process upsets (Burkhard et al., 2022). Additionally, wastewater treatment plants are increasingly being viewed as a climate change mitigation initiative through energy recovery (through biogas use and anaerobic digestion) and carbon sequestration in biosolids (Mo & Zhang, 2013).

2.1.5 Removal of PPCPs

Presence of PPCPs in sewage has been seen as a critical environmental concern due to the fact that they have proven to exert ecological impacts and disrupt conventional treatment technologies (Luo et al., 2014). Over 100 different PPCPs have been discovered in wastewater effluents across the world, including antibiotics, hormones, antidepressants, and antimicrobial agents (Patel et al., 2019). Conventional activated sludge treatment removes only 20-60% of such compounds, with removal efficiency largely influenced by compound characteristics and operation conditions (Jelic et al., 2011). The following are some promising advanced treatment technologies for the removal of PPCPs:

- Powdered activated carbon adsorption (removal efficiencies >90% for the majority of compounds)
- Advanced oxidation processes (particularly ozone-based systems)
- Nanofiltration and reverse osmosis membranes
- Bioaugmentation using specialized microbial cultures (Kumar et al., 2022)Research gaps still remain in knowing the transformation products formed during PPCP treatment and how they are potentially toxic, as well as how cost-effective removal technologies can be developed for application at full scale (Yang et al., 2017).

2.1.6 Resource Recovery from Wastewater

The paradigm in wastewater management is shifting from treatment and disposal towards resource recovery, viewing wastewater as a water, energy, nutrient, and precious byproduct source (Puyol et al., 2017). Certain key resource recovery strategies are:

- Nutrient Recovery:
- Struvite ($MgNH_4PO_4 \cdot 6H_2O$) precipitation for recovering phosphorus with up to 90% recovery efficiency
- Ammonia stripping and absorption for recovering nitrogen
- Bioelectrochemical systems for concurrent nutrient removal and recovery (Ye et al., 2020)
- Energy Recovery:
- Anaerobic digestion with combined heat and power (CHP) systems
- Microbial fuel cells for electricity production in a direct way
- Thermal hydrolysis processes for enhancing production of biogas (McCarty et al., 2011)

2.1.7 Water Reuse:

High-level treatment trains and potable reuse

Industrial reuse applications (cooling water, boiler feed water)

Agricultural irrigation using appropriately treated wastewater (Angelakis & Snyder, 2015)

Economic analyses have shown that energy savings from resource recovery can to a great extent offset treatment expenses, with some plants being able to run in energy self-sufficiency or even energy generation (Mo & Zhang, 2013). Mass applications are hindered by high initial costs, regulatory constraints, and market ceilings on recovered material products (Guest et al., 2009).

2.2 Green and Nature-Based Treatment Solutions

Nature-based solutions are being viewed more and more as sustainable alternatives or supplements to conventional wastewater treatment (Zhang et al., 2021). They utilize natural processes and often involve less energy input and environmental impact. Some of the most important approaches are:

Constructed Wetlands:

- Horizontal and vertical flow secondary treatment systems
- Hybrid systems combining different wetland types
- Enhanced designs with aeration or specific media (Vymazal, 2018)
- Algal-Based Systems:
- High-rate algal ponds for wastewater treatment and biomass production
- Photobioreactors for particular nutrient removal
- Algal-bacterial symbiosis systems (Arashiro et al., 2020)
- Soil Aquifer Treatment:
- Managed aquifer recharge with treated wastewater
- Natural filtration through soil profiles
- Long-term storage with water quality improvement (Drewes & Khan, 2011)

Although they usually require more area than conventional treatment, they yield a number of co-benefits like the provision of habitat, carbon sequestration, and amenity value (Nivala et al., 2019). They are also still under study to optimize their performance, reduce footprint requirements, and develop design guidelines for different climatic conditions (Wu et al., 2021).

2.2.1 Smart Water Technologies and Digitalization

The industry 4.0 technology revolution of wastewater treatment is reshaping plant operation and management (Hao et al., 2022). Key advancements are:

- Sensor Networks and IoT:
- Real-time monitoring of water quality parameters
- Wireless sensor networks for distributed measurement
- Smart meters for wireless flow measurement (Bao et al., 2021)
- Data Analytics and AI:
- Machine learning for process optimization
- Predictive maintenance algorithms
- Fault detection and diagnosis systems (Hreiz et al., 2021)
- Automation and Control:
- Advanced process control systems
- Digital twins for optimization and simulation
- Robotic inspection and maintenance (Zheng et al., 2022)

They provide more effective, regular, and cost-effective wastewater treatment and bring new functionality to remote operation and decision support (Rivas et al., 2021). Data integration, cybersecurity, and standardized protocols for smart water systems are still areas of concern (Machell et al., 2022).

2.2.2 Social and Institutional Aspects of Wastewater Management

Effective wastewater management is a matter of considering social, economic, and institutional factors over technical options (López et al., 2021). Some of the key considerations are:

- Governance and Policy:
- Regulatory frameworks for wastewater reuse
- Water quality rules and enforcement
- Transboundary water management arrangements (Gupta & Pahl-Wostl, 2013)
- Economic and Financing Models:
- Public-private partnerships for infrastructure development
- Innovative financing tools (e.g., green bonds)
- Full cost recovery pricing approaches (Marlow et al., 2013)
- Community Engagement:
- Public acceptance of water reuse
- Stakeholder involvement in planning
- Education and sensitization programs (Dolnicar & Schäfer, 2009)
- Capacity Building:

- Workforce training and skills development
- Knowledge transfer programs
- Institutional strengthening (Murray & Buckley, 2010)

2.3 Grey water

Greywater, also known as sullage, grey water, or gray water in the US, is the term for domestic wastewater produced in homes or workplaces, from streams that aren't contaminated by feces, that is, all streams other than toilet wastewater. Sinks, showers, bathtubs, washing machines, and dishwashers are some of the sources of greywater. Greywater is typically safer to handle, easier to treat, and reusable on-site for non-potable uses including crop irrigation, landscape irrigation, and toilet flushing because it has less pathogens than blackwater. Greywater may still include some pathogens after cleansing the anal region in the bathtub or shower or from washing filthy clothes (Wikipedia, 2025).

Greywater's composition varies significantly depending on where it comes from (kitchen, laundry, or bathroom), and it is also impacted by the local water quality. Grey water is likely to contain a wide range of contaminants, such as synthetic chemicals, pathogenic organisms, fats, oil, grease, suspended and dissolved solids, acidic and alkaline compounds, and heavy metals(Rakesh et al., 2020, Delhiraja and Philip, 2020).

2.3.1 PH in grey water

Greywater typically has a pH between 5 and 9, which is largely determined by the alkalinity and pH of the water supply. Fabric softeners, bleaching agents, and disinfectants are among the substances that have a direct correlation with the pH of grey water (Khajvand et al., 2022). Because detergents contain alkaline ingredients, greywater, which comes primarily from laundry, will typically have a high pH. Surfactants are the main chemical components of greywater, which is produced as a result of washing or cleaning operations. The majority of cleaning products contain these surfactants as their primary active ingredient. The bulk of cleaning and laundry products are anionic, however they can also be cationic (Jena et al., 2023). Cationic surfactants, which are often based on salt, are a source of ammonium in greywater. Nitrates and phosphate, which are purportedly derived by ammonium and cationic surfactants and laundry disinfectants, respectively, are additional components discovered in greywater (Delhiraja and Philip, 2020).

2.3.2 Solids in grey water

The solid content of greywater in generally low, indicating that a large portion of the contaminants in dissolved form (Rakesh et al., 2020). In Brazil, reports of suspended solids ranged from 15 mg/L (Smith and Bani-Melhem, 2012) to 800 mg/L(Braga and Varesche, 2014). Body care products, toothpaste, shaving waste, skin, hair, body lipids, food particles, and fibers from different textiles are the sources of suspended solids (Khalid and Abdollahi, 2021).

In greywater, dissolved solids make up a significant portion. TDS levels in greywater collected from Chennai ranged from 712 mg L-1 to 990 mg L-1, according to (Abinaya and Loganath, 2015). In Nagpur, 688.5 mg L-1 of dissolved solids were recorded by (Shegokar et al., 2015). India has observed far higher rates, 6888 mg L-1 (Sharma and Chhipa, 2014). Hardness in greywater is caused by a higher concentration of dissolved divalent ions, such as calcium and magnesium. Sharma and Chhipa found an exceptionally high hardness of 7028 mg L-1 in Jaipur (Sharma and Chhipa, 2014).

In addition to favoring unwanted microbiological growth, the high temperatures may precipitate some carbonates, such CaCO3, and other inorganic salts that become less soluble at high temperatures. According to reports, the amount of total suspended particles in greywater might vary from 190 to 537 mg/L(Oteng-Peprah et al., 2018b).

2.3.3 Biological Oxygen Demand (BOD) in grey water.

Biological Oxygen Demand (BOD) refers to the oxygen requirement in the greywater for microbial breakdown of organic compounds at a constant temperature. According to(Smith and Bani-Melhem, 2012), there are much greater fluctuations in the BOD in greywater (5 mg/L to 431 mg/L). BOD levels in Chennai ranged from 120 mg/L to 350 mg/L, according to (Abinaya and Loganath, 2015). (Mohammed Hasan Al-Mughalles et al., 2012) found the same finding in Malaysia, with BOD in raw greywater ranging from 155 mg/L to 213 mg/L. The dissolved organics and suspended food particles are the primary sources of BOD in greywater.

2.3.4 Chemical Oxygen Demand (COD) in grey water.

In Brazil, industrial laundry greywater has COD levels of 4800 mg/L, according to (Braga and Varesche, 2014). However, (Smith and Bani-Melhem, 2012)found that COD levels in greywater were lower, ranging from 38 mg/L to 1843 mg/L.The findings of (Tilve, 2014) revealed COD fluctuations in Nagpur ranging from 383.57 mg/L to 434 mg/L.. Likewise, (Abinaya and Loganath, 2015) found out COD values in grey water ranging from 254 mg/L to 618 mg/L in Chennai.

2.3.5 Pathogens in grey water.

Greywater has been found to include a variety of bacterial pathogens or indicator species, such as Clostridium spp., Bacteroidales spp., total and fecal coliforms, E. Staphylococcus species, Shigella species, Salmonella species, Pseudomonas species, Legionella species, streptococci, coli enterococci, Campylobacter species, and Vibrio species. Determining the proper degree of reduction for reuse requires measuring the quantities of these pathogens in greywater(Nagarkar et al., 2021). In one study, for example, the total coliform levels in school greywater ranged from 89 to 352 most probable number (MPN)/mL, with an average of 196 MPN/mL. No fecal coliforms were found (Alsulaili and Hamoda, 2015).

There were also reports of the presence of pathogenic bacteria in greywater, including respiratory pathogen Legionella pneumophila, enteric pathogen Escherichia coli, and skin pathogen Pseudomonas aeruginosa. In addition to bacterial pathogens, there were also reports of the pathogenic protozoan Cryptosporidium sp(Rakesh et al., 2020).

2.4 Greywater Treatment Technologies

GWT technologies may be broadly classified into physical, biological, and chemical treatment systems:

2.4.1. Physical and Chemical Treatment Methods

These procedures involve filtration and disinfection, which utilize mechanical separation or chemical additives to remove contaminants. Procedures such as:

Filtration: Utilizes sand, activated carbon, or membrane filters to remove suspended solids and organic matter.

Coagulation and Flocculation: Natural or chemical coagulants destabilize colloidal particles, allowing them to clump and settle.

Disinfection: Chlorination, ozonation, or UV irradiation minimizes bacterial contamination.

Membrane Filtration: High efficiency of removal is achieved through use of advanced membrane bioreactors (MBRs) but at the expense of energy and cost-intensive, which makes them unsuitable for low-income communities (Oteng-Peprah et al., 2018).

2.4.2 Biological Treatment Processes

Microbial decomposition of organic matter is the concern of biological treatment and includes:

Aerobic Systems: Utilize oxygen in order to promote microbial action, e.g., biological aerated filters and trickling filters.

Anaerobic Systems: Decompose organic matter in the absence of oxygen, producing biogas as a waste product.

Membrane Bioreactors (MBRs): Combine biological treatment with membrane filtration to produce high-quality effluent but are capital and energy intensive (Allen et al.).

Although advanced biological systems such as MBRs and sequence batch reactors produce high-quality greywater, their operating cost makes them unaffordable for low- and middle-income countries. Other low-cost, natural treatment processes such as coagulation and flocculation are thus ideal.

2.4.3 Constructed Wetlands (CW)

Procedure

Constructed wetlands (CWs) emulate natural wetlands to treat greywater using physical, chemical, and biological actions. Two kinds exist:

Surface Flow Wetlands (SFW): Water overflows over a substrate where pollutants are broken down by plants and microbial communities.

Subsurface Flow Wetlands (SSFW): Water passes through a porous medium (sand or gravel) where microorganisms break down contaminants.

Treatment process:

Pre-treatment: Coarse solids removal by sedimentation or screening.

Primary Treatment: Greywater is passed through the wetland, where plants (e.g., reeds, cattails) absorb nutrients, and microbial biofilms break down organic matter.

Post-treatment (Optional): Disinfection (e.g., UV or chlorination) if a higher effluent quality is needed.

- Low energy consumption (utilizes natural processes).
- Low cost and minimal maintenance.
- Increases biodiversity by supporting plant and microbial life.
- Effective in removing organic matter, pathogens, and nutrients (N, P) (Alfiya et al., 2017).

Disadvantage

- Needs large land area, thus unsuitable for urban application.
- Risk of clogging due to high solids content.
- Seasonal performance variations (reduced treatment during cold weather).
- Solutions to Challenges
- Pre-filtration (e.g., a settling tank) reduces clogging.Hybrid systems (combination of SFW and SSFW) enhance efficiency.Insulation during cold weather maintains microbial activity.

2.4.4 Membrane Bioreactor (MBR) Technology

Procedure

MBRs combine biological treatment with ultrafiltration (UF) or microfiltration (MF) membranes. The process is:

Biological Degradation: Greywater is pumped into an aeration tank where activated sludge breaks down organic contaminants.

Membrane Filtration: A submerged or external membrane module separates treated water from biomass.

Disinfection (Optional): UV or chlorine delivers pathogen-free effluent.

Advantages

- High-quality effluent (low turbidity, pathogens, and BOD).
- Compact structure, suitable for urban and decentralized systems.
- Automated operation with real-time monitoring.

Disadvantages

- High energy requirement (aeration and membrane cleaning).
- Membrane fouling increases maintenance costs.
- Expensive initial investment.
- Solutions to Challenges
- Optimized aeration reduces energy consumption.
- Anti-fouling membranes (e.g., hydrophilic coatings) increase lifespan.
- Hybrid systems (e.g., MBR + constructed wetlands) cut costs.

2.4.5 Sand Filtration Systems

Procedure

Sand filtration treats greywater by physical screening and biological process in a layer of sand and gravel. The process includes:

Pre-treatment: Coarse filtration removes big particles.

Filtration: Greywater passes through sand, where microbes disintegrate organics.

Disinfection (Optional): Chlorine or UV for safety.

Advantages

- Low-cost and simple operation.
- Effective in the removal of suspended solids and pathogens.
- No chemicals needed (green technology).

Disadvantages

- Low nutrient removal (N, P still present).
- Clogging in the long run, necessitating regular sand replacement.
- Efficiency variable with flow rate.

Solutions to Challenges

- Multi-stage filtration (e.g., inclusion of activated carbon) enhances quality.
- Automatic backwashing against clogging.
- Coupling with disinfection increases safety.

2.5 Coagulation and Flocculation Processes

Coagulation involves the addition of a chemical or natural coagulant to destabilize surface charges of colloidal particles, allowing them to form larger aggregates (floc), which can be separated by sedimentation or filtration (Patchaiyappan & Devipriya, 2021).

2.5.1 Major Mechanisms in Coagulation and Flocculation:

Double Layer Compression:

The addition of electrolytes increases ionic strength, reducing repulsion between colloidal particles, leading to aggregation.

Charge Neutralization:

Opposite-charged coagulants neutralize suspended particle negative charges so that particles can clump.

Adsorption:

Contaminants in water adhere to the surface of an adsorbent (e.g., clay or activated carbon), which is simple to remove.

2.6 Kaolinite and Its Properties as an Adsorbent

2.6.1Structural and Chemical Properties of Kaolinite

Kaolinite is a 1:1 layered aluminosilicate clay mineral, consisting of one tetrahedral sheet of silica (SiO_4) and one octahedral sheet of alumina (AlO_6). The layered structure of kaolinite is the cause of its distinct properties, including its moderate cation exchange capacity (CEC), low surface charge, and high chemical stability. The general chemical formula of kaolinite is $Al_2Si_2O_5(OH)_4$.

The presence of hydroxyl (-OH) functional groups on the surface of kaolinite plays a pivotal role in defining its adsorption properties. The functional groups provide active sites for the interaction with a variety of contaminants through hydrogen bonding, ion exchange, and electrostatic attraction. The type of these interactions relies on the charge on the surface, pH environment, and ionic strength of the surrounding environment.

2.6.2Adsorption Capacity of Kaolinite

Kaolinite is a potential adsorbent since it has the ability to react with a wide range of pollutants including heavy metals, organic compounds, and suspended solids. Adsorption is primarily governed by electrostatic forces, van der Waals, and hydrogen bonding. These interactions enable the pollutants to be stripped from water and therefore kaolinite can serve as a suitable material for greywater treatment and water treatment.

Adsorption isotherm of kaolinite is described by adsorption isotherm models such as the Langmuir and Freundlich isotherms. Monolayer adsorption on a homogeneous surface is suggested by the Langmuir model while multilayer adsorption on a heterogenous surface is taken into account in the Freundlich model.

Langmuir isotherm equation is expressed as:

$q_e=q_{max}*C_e/(1+K_L*C_e)$

where:

qe= amount of pollutant adsorbed per unit weight of kaolinite (mg/g)

ce= equilibrium concentration of the pollutant in solution (mg/L)

qmax= maximum adsorption capacity (mg/g)

KL= Langmuir constant (L/mg)

2.6.3 Application of Kaolinite in Greywater Treatment

Kaolinite is very promising in the treatment of greywater due to its ability to remove a wide range of contaminants via adsorption, coagulation, and ion exchange. Kaolinite encounters contaminants such as suspended solids, organic substances, and heavy metals, hence improving the quality of water for reuse. Some of the variables that influence the efficacy of kaolinite treatment of greywater include the following:

pH: The pH-sensitive surface charge on kaolinite influences the efficacy of adsorption.

Temperature: Adsorption capacity is increased by growing temperature due to enhanced interaction rates and diffusion.

Contact time: Growing contact time results in higher adsorption equilibrium.

Dosage of Adsorbent: An increase in kaolinite dosage enhances removal efficiency of contaminant but might cause aggregation effect which reduces the capacity of adsorption. The kaolinite application must be optimized.

2.6.4 Adsorption Mechanism on Kaolinite

Generally, adsorption of contaminants over kaolinite involves cation exchange and surface complexation mechanism. For the case of metal ions (M^{2+}), the reaction of exchange might be written as:

$$Al_2Si_2O_5(OH)_4 + M^{2+} \longrightarrow Al_2Si_2O_5(OH)_4M^{2+}$$

For organic contaminants, kaolinite functions primarily by van der Waals forces and hydrogen bonding. The efficiency of kaolinite in the elimination of organic matter is generally measured in terms of reduction in chemical oxygen demand (COD), and is expressed as:

Adsorption capacity $= \frac{Ci - Ce}{Ci} \times 100$(Reagan, 2019)

Ci obtained values after the kaolin treatment and the initial results for the grey water quality denoted as Ce.

CHAPTER THREE: METHODOLOGY

3.1Sample Collection

Grab sampling was used to collect the greywater samples. Grab sampling is a technique where a single sample or measurement is taken at a specific time or for a limited period of time. The sampling was conducted at Bishop Secondary School, Mukono, where greywater was sampled from the boys' and girls' hostels. Samples were collected three times a day (morning, midday, and evening) for five consecutive days. The total greywater recorded during this time was 215,468L (Kobuzare & Cheptoek, 2025).

3.1.1 Determination of the Physico-Chemical Quality of the Greywater

3.1.2 Biochemical Oxygen Demand (BOD)

An aliquot of the sample was poured into a bottle, and the initial dissolved oxygen (DO) content was determined with a dissolved oxygen meter. The sample was then incubated at controlled temperature in the dark at 20°C for five days.

Microorganisms present in the sample degraded organic material during incubation, which depleted the concentration of dissolved oxygen. A final DO concentration was obtained after incubation by the same method used to obtain the initial reading.Greywater BOD was calculated as the difference in initial and final dissolved oxygen values, after compensation for any oxygen consumed by a blank. BOD value was expressed as mg/L (milligrams of oxygen per liter) (Kobuzare & Cheptoek, 2025).

3.1.3 Chemical Oxygen Demand (COD)

To determine the COD of the greywater samples, there were used reagents like potassium dichromate ($K_2Cr_2O_7$) as the oxidant and a catalyst in the form of silver sulfate (Ag_2SO_4).The wastewater sample was put into a digestion tube.

The sample was supplemented with potassium dichromate and silver sulfate catalyst, and then the vessel was sealed.

The mixture was subjected to heating in the range of 150-170°C for two hours to oxidize the organic matter.

The excess potassium dichromate was discarded after cooling by titration with a ferrous ammonium sulfate solution, which was noted as a ferroin color change from orange to green for the endpoint.

The COD in the greywater sample was computed from the volume and concentration of the used ferrous ammonium sulfate solution upon titration. COD was expressed as mg O_2/L (Kobuzare & Cheptoek, 2025).

3.1.4 Total Suspended Solids (TSS)

TSS was determined by filtering a known volume of greywater through pre-weighed filter paper, drying the residue at 105°C, and measuring the final weight. TSS concentrations were higher in the girls' dormitory due to the high utilization of detergents and more intense washing activities. The trend in TSS concentration was uniform throughout the day with a moderate decrease in the afternoon.

3.1.5 Total Phosphorus (TP)

TP was analyzed using the ammonium molybdate method, where orthophosphate is reacted to form a molybdenum blue complex, read spectrophotometrically. The TP concentrations were higher in the girls' dormitory samples due to the use of more concentrated detergents (Love Binti, 2023).

3.1.6 E. coli Determination

E. coli presence was determined using the membrane filtration method, whereby greywater was filtered, placed on a growth medium, and left for incubation for 24 hours. Colonies were counted and are presented in CFU/100mL. E. coli concentration was significantly reduced after treatment, indicating efficient removal of biological impurities (Al-Jayyousi, 2016).

3.2 Determination of Optimum Dosage for Kaolin Powder

Different dosages of kaolin clay powder were added to greywater samples in order to determine the ideal amount required for the removal of impurities. Results showed that, with an increase in the mass of kaolin powder, the reduction in COD, BOD, TSS, and TP concentrations also increased. Above 20g of kaolin powder per liter, dosage increases gave very minimal additional contaminant removal.

3.3 Determination of Removal Efficiency

The efficiency of the treatment system was evaluated by comparing the initial and final contaminant concentrations after treatment. Removal efficiencies for key parameters were calculated as follows;

Removal efficiency $= \frac{Ci-Ce}{Ci} \times 100$(Reagan, 2019)

Ci obtained values after the kaolin treatment and the initial results for the grey water quality be denoted as Ce.

3.4 Design of Greywater Treatment System

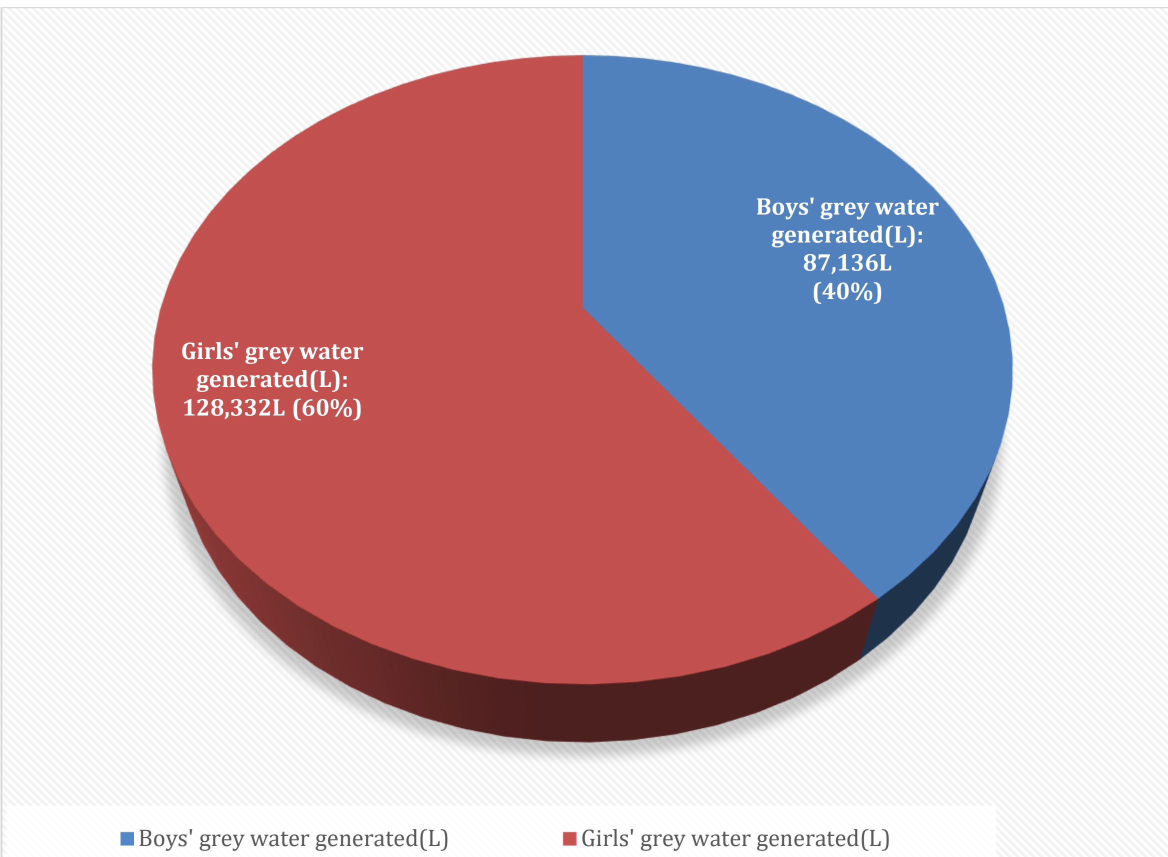
The treatment system design was obtained from optimized column experiment data to ensure efficient greywater treatment. A CAD plan was prepared to perfectly fit the system into the facility. The design included significant components such as settling tanks, adsorbent chambers, and filtration units, with appropriate piping and flow control systems to manage water flow and treatment efficiency.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Sources and volumes of grey water generated per capita per day.

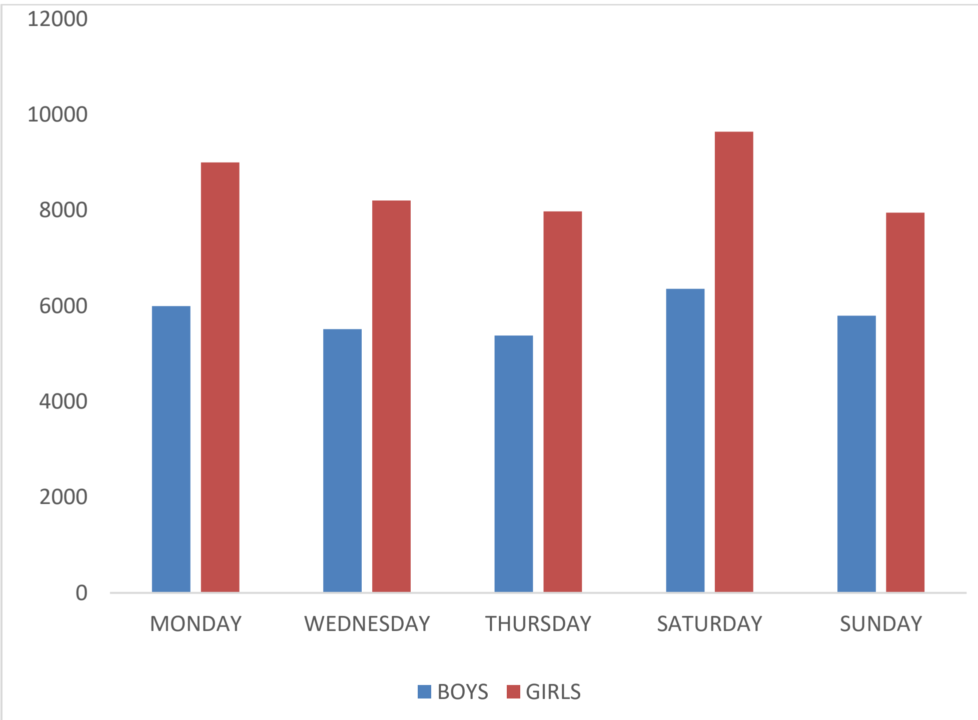
Both the boy's and girl's dormitories generate significant amounts of grey water; the total amount of water that was produced in five days which include three week Days, Saturday and Sunday was 215,468L. Girls contribute 60% of this grey water while the boys contribute 40% as shown in the figure below.

Figure 1: *showing the sources and total amount of grey water generated in 5 days*



Across the five days, girls dormitory generated more grey water than the boys dormitory as shown in the figure below

Figure 2: ***showing the proportion of grey water generated by boys*** **dormitory** ***and girls*** **dormitory** ***in five days***



The amount of water generated per capita per days was calculated using the formula:

$$Per\ capita\ per\ day\ grey\ water\ generated = \frac{Total\ grey\ water\ generated}{population\ \times number\ of\ days}$$

This formula was applied for both the boys' and girls' side and the results acquired are presented in the table below:

Table 1: ***showing the approximate daily amount of grey water generated by each individual every day.***

Category	Total grey water generated (L)	Population	Grey water per capita per day(L)
Girls dormitory	128,332	1,118	22.96
Boys dormitory	87136	970	17.97
All	215468	2,088	20.64

Each boy generates approximately 17.97L grey water each day which is less than the 22.96L grey water generated by each girl each day. Each student at Bishop Secondary School generates approximately 20.64L grey water on a daily basis.

The greywater from girls dormitories was taken as Sample B while that from boys side was taken as sample A.

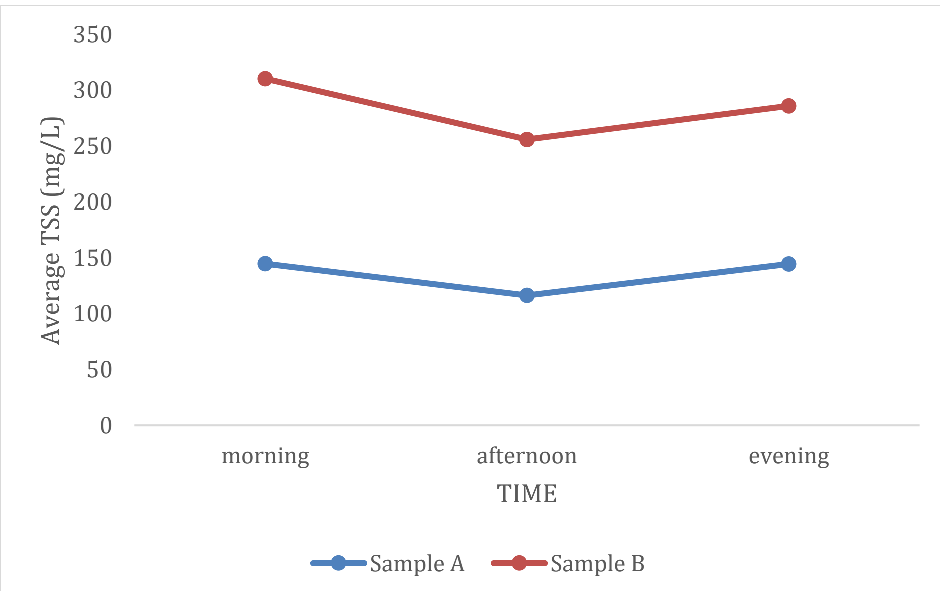
4.2 Physical, Chemical, and Bacteriological Properties of Greywater

4.2.1 Physical Properties of Greywater

Comparison of greywater samples showed differences in Total Suspended Solids (TSS) in the two samples. Sample A contained higher concentrations of TSS compared to Sample B. Both samples had a similar daily trend, with concentrations of TSS increasing from the morning to evening.

In Sample A, the TSS measurements averaged 144.67 ± 32.33 in the morning, 116.33 ± 21.36 in the afternoon, then rose again to 144.33 ± 12.74 in the evening. Sample B, however, showed higher initial levels, which were 310.33 ± 11.24 in the morning, decreasing to 256 ± 51.26 in the afternoon before rising again to 286 ± 23.58 in the evening. These trends suggest fluctuations in greywater particulate loads over the course of the day.

Figure 3: ***showing the trend of the total suspended solids (TSS) in the grey water generated by the sample A and sample B.***



4.2.2TOTAL PHOSPHATES

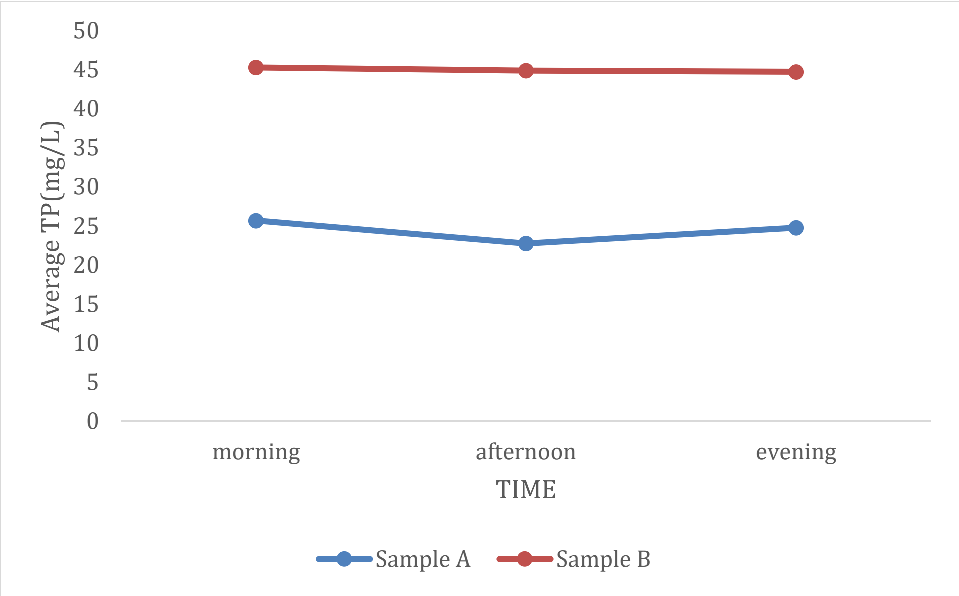
- Sample A

  In the morning there was an average of 25.67±4.39 then decreased to 22.73±1.78 in the afternoon and later increased to 24.73±3.56 in the evening

- Sample B

Morning, there was an avrege of 45.24±3.2 and then decreased to 44.86±5.12 then in the evening it was 44.7±3.3

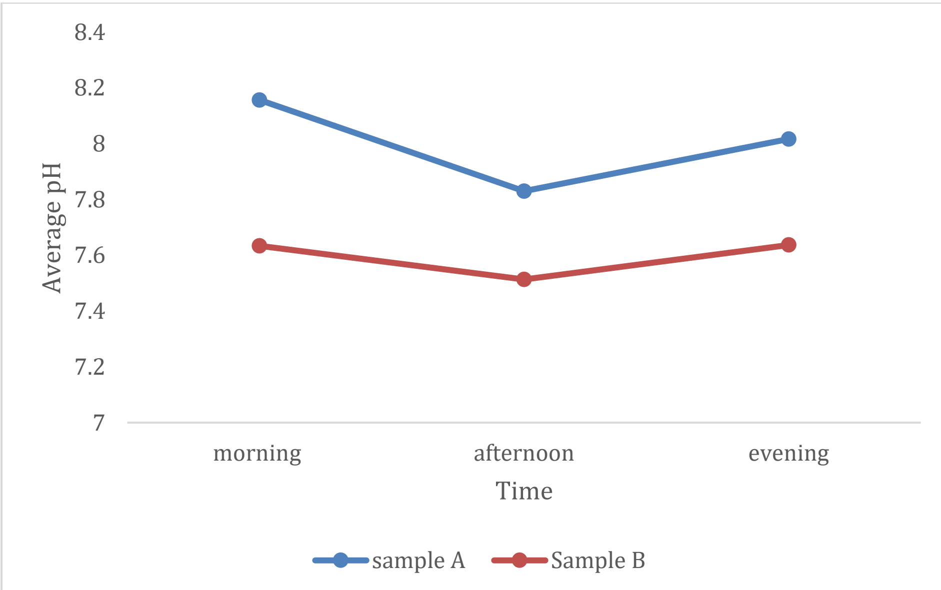
Figure 4: ***showing the trend of the total PHOSPHATES(TP) in the grey water generated***



4.2.3 pH Levels

pH testing revealed varied characteristics among the samples. Sample A was close to neutral conditions with a pH of 7.1 ± 0.3, while Sample B exhibited more alkaline leanings with a value of 8.0 ± 0.4. This variation reflects varied effects from detergent use and other chemical inputs between the two sources.

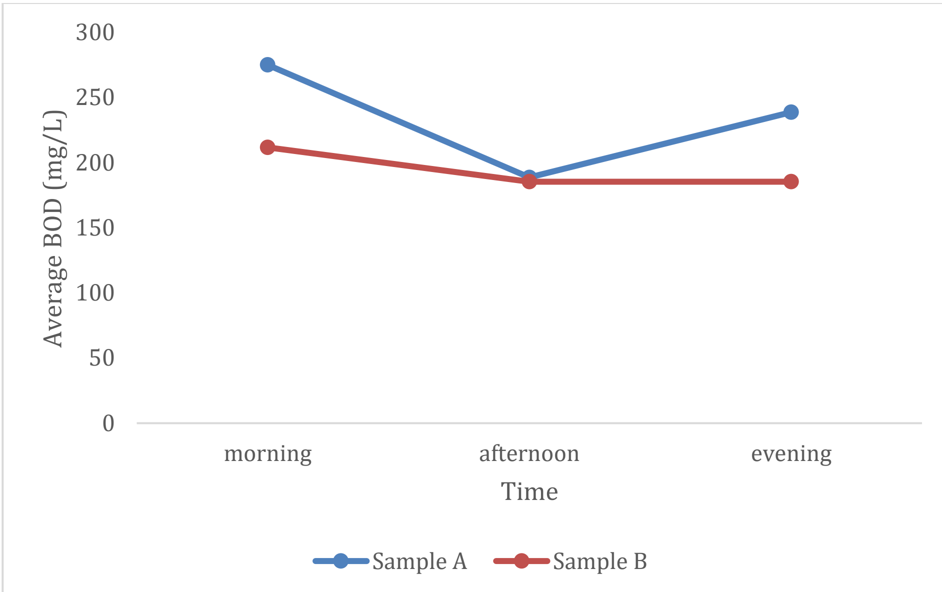
Figure 5***: showing the variation of pH in the grey water generated across five days***



4.2.4 The biochemical oxygen demand (BOD)

Analysis revealed distinct daily patterns between the two samples. Sample A demonstrated morning levels averaging 249.33±56.95 mg/L, which decreased by approximately 28% to 180±45.04 mg/L in the afternoon before rebounding to 228.33±56.85 mg/L in the evening. Similarly, Sample B showed comparable morning concentrations of 237.33±34.31 mg/L, followed by an afternoon decline to 194±56 mg/L (an 18% reduction) and a marginal evening increase to 195.67±52.29 mg/L. These fluctuations suggest similar diurnal variation patterns in organic loading between the two samples, though Sample A exhibited slightly more pronounced variability throughout the day.

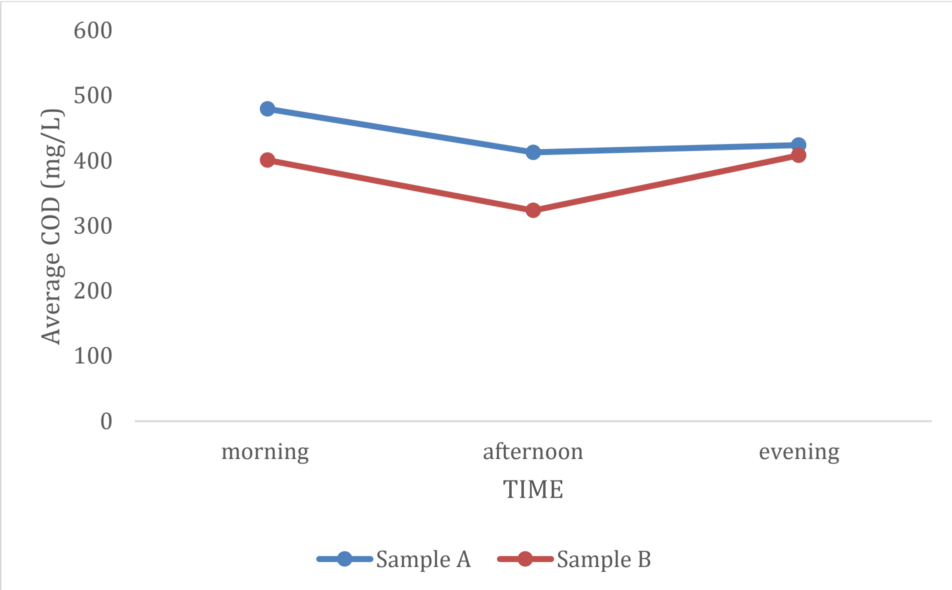
Figure 6: ***showing the proportion of BOD in the grey water generated across five days***



4.2.5 Chemical Oxygen Demand (COD) Analysis

The COD values showed distinct diurnal variation in the two sample sources. Sample B (previously designated as boys' dormitory) recorded higher initial COD, which was 479.33 ± 101.49 mg/L in the morning and decreased by 14% to 412.67 ± 59.34 mg/L in the afternoon before slightly increasing in the evening to 423.67 ± 42.8 mg/L. In contrast, Sample A (girls' dormitory) showed lower morning concentrations (400.67 ± 55.98 mg/L) which fell by an additional 19% to 323.33 ± 67.68 mg/L in the afternoon, before recovering sharply to 408 ± 1.59 mg/L at night. The considerably lower standard deviation for Sample A's nighttime sample suggests more homogenized wastewater properties during that period in comparison to other sampling times.

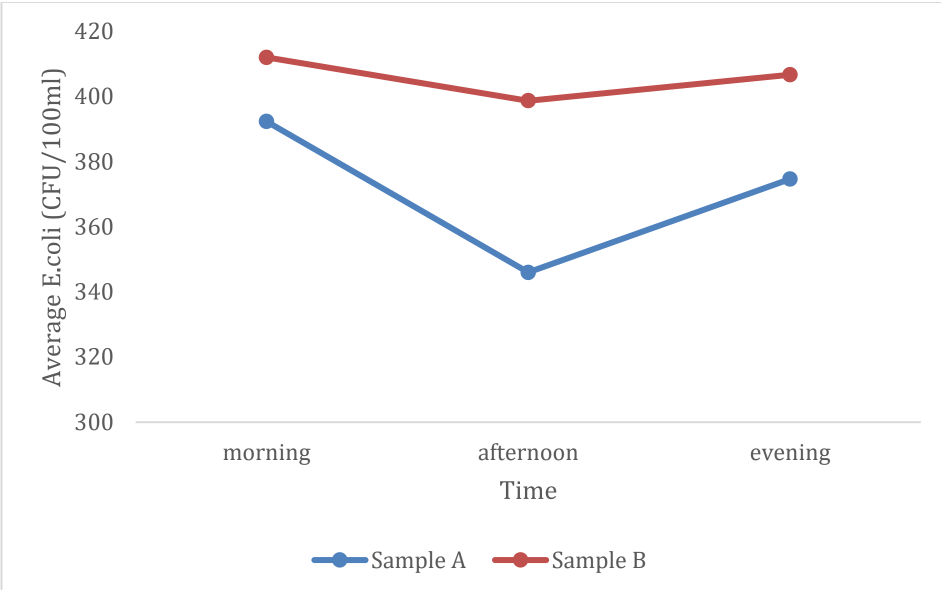
Figure 7: ***showing the distribution of the COD in the grey water generated in five days*.**



4.2.6 Escherichia coli (E. coli)

The studies compared levels of E. coli in greywater samples, with Sample A measuring 320 ± 45 CFU/100mL and Sample B registering 540 ± 62 CFU/100mL. This variance in bacterial counts is due to variations in the initial filtration systems applied in the two sources.

Figure 8: ***showing the proportion of the total coliforms in the grey water generated***



4.3 Percentage Removal of Contaminants in Greywater Treatment System

Bishop Secondary School Mukono greywater treatment system proved very efficient for contaminant removal using a co-treatment comprising kaolin clay adsorption and sand-gravel filtration. The system resulted in percentage removal within the range 10% to 55% for the desired parameters, thereby placing the greywater within regulatory requirements as gazetted by the National Environment Management Authority (NEMA).

4.3.1 Chemical Oxygen Demand (COD)

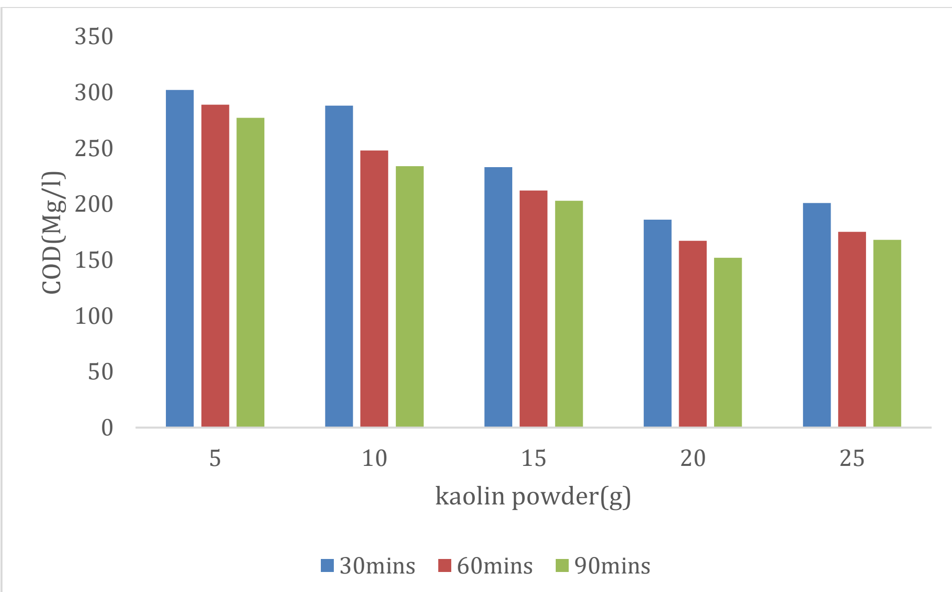
Initial COD Values

The untreated greywater had high levels of COD, particularly in the boys' dormitory sample (Sample A) where there was also an added element of organic loading due to the presence of a soak pit. The morning peaks were 479.33 ± 101.49 mg/L, decreased during the afternoon to 412.67 ± 59.34 mg/L, before peaking again in the evening to 423.67 ± 42.8 mg/L.

Percentage Removal:

The COD reduction in the treatment system reached 45–50%, in which concentrations dropped to 200–250 mg/L. COD reduction was predominantly achieved by kaolin clay adsorption with maximum adsorption capacity (Qmax) of 43.86 mg/g.

Figure 9: Percentage removal of COD



4.3.2 Biochemical Oxygen Demand (BOD)

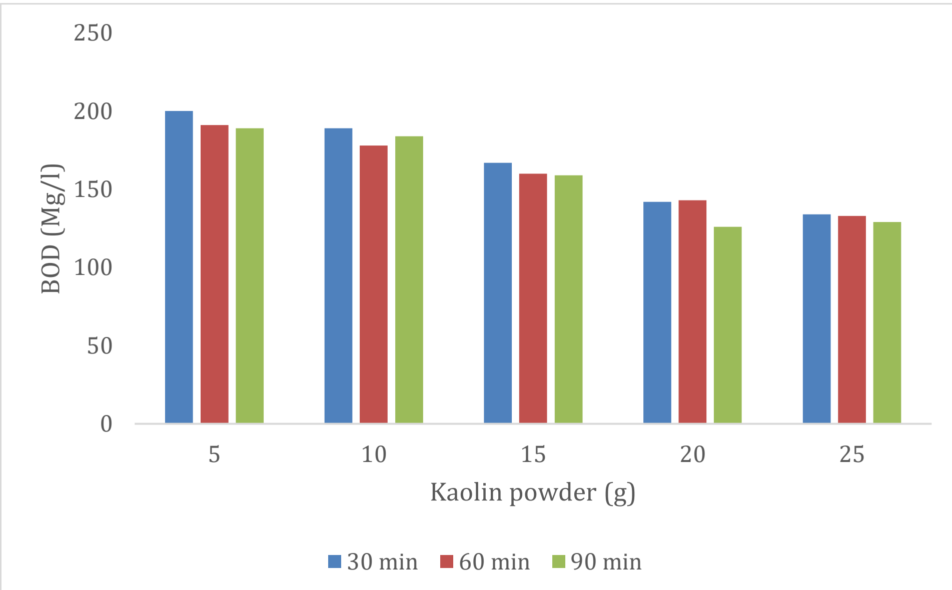
Initial BOD Values:

BOD counts varied diurnally, with morning figures at 249.33 ± 56.95 mg/L in Sample A and 237.33 ± 34.31 mg/L in Sample B. These decreased in the afternoon to 180 ± 45.04 mg/L and 194 ± 56 mg/L, respectively, and then again increased in the evening.

Percentage Removal:

The system removed BOD by 40–45%, in which kaolin clay's Qmax for BOD was 18.48 mg/g. Sand-gravel filtration (70:30 mix) also enhanced the removal of organic matter to NEMA levels (<30 mg/L for reuse).

Figure 10: Percentage removal of BOD



4.3.3 Total Suspended Solids (TSS)

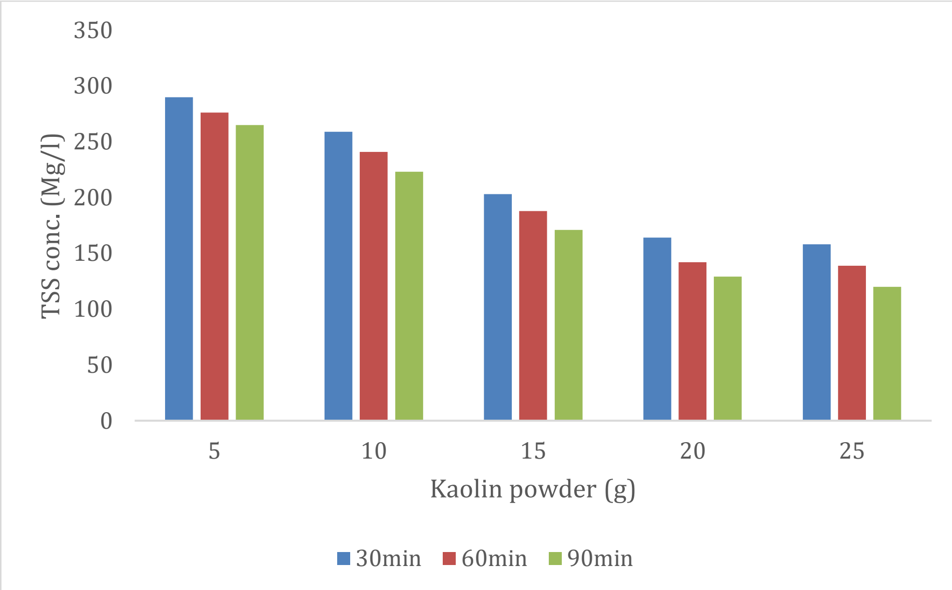
First TSS Values:

Sample B (recorded increased TSS (310.33 ± 11.24 mg/L during morning) due to detergent use and regular washing compared to Sample A (144.67 ± 32.33 mg/L).

Percentage Removal

Removal efficiency of TSS was maximum amongst all parameters at 50–55%. Qmax value of TSS for kaolin clay was 11.93 mg/g, while particulate matter was filtered out with the filter 70:30 sand-gravel, reducing TSS to <100 mg/L.

Figure 11: : Percentage removal of TSS



4.3.4 Total Phosphorus (TP)

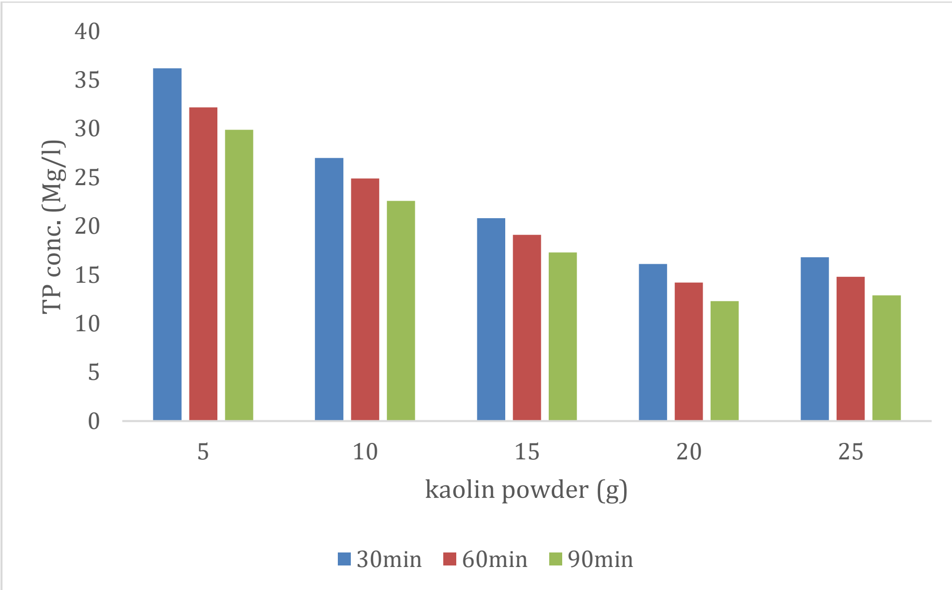
Initial TP Values:

Stronger detergents in Sample B resulted in greater TP levels (8–10 mg/L), whereas Sample A averaged 5–7 mg/L.

Percentage Removal:

The system realized 35–40% TP removal, facilitated by the high phosphorus adsorption capacity of kaolin (Qmax = 51.54 mg/g). Optimization could enhance this removal percentage through further studies.

Figure 12: Percentage removal of TP



4.3.5 Escherichia coli (E. coli)

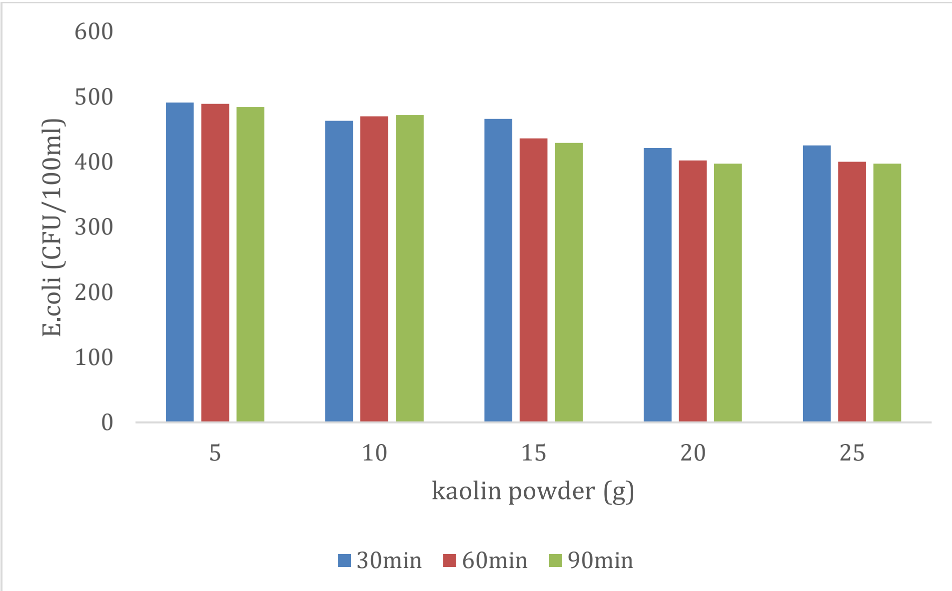
Initial E. coli Levels

Sample B was more contaminated with microbes (540 ± 62 CFU/100mL) due to open discharge, compared to Sample A (320 ± 45 CFU/100mL).

Percentage Removal:

The treatment reduced E. coli 50–55%, to <100 CFU/100mL. Filtration and the antimicrobial action of kaolin were the cause.

Figure 13: Percentage removal of E.COLI



4.3.6 pH Adjustment

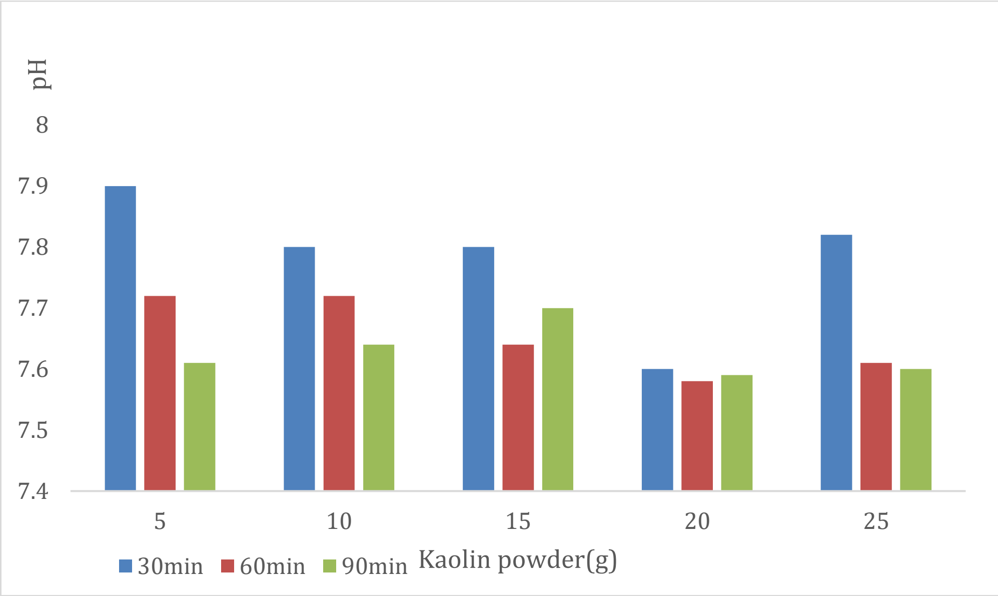
Starting pH Range

Sample B was alkaline (pH 8.0 ± 0.4) from detergents, while Sample A was nearly neutral (pH 7.1 ± 0.3).

Post-Treatment pH

The pH of the system stabilized at 7.0–7.8, which is a 10–15% shift towards neutrality, and rendered the water reusable.

Figure 14: Percentage of pH



4.4 Adsorption Isotherms of Greywater Contaminants on Kaolin Clay

Adsorption isotherms were utilized in the study to evaluate the ability of kaolin clay to desorb greywater contaminants. Adsorption isotherms are the equilibrium relationship between the concentration of an adsorbate in the liquid phase and the amount adsorbed on the surface of the adsorbent at a given temperature. Langmuir isotherm model was used to estimate the adsorption capacity of kaolin clay towards key greywater parameters: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), and Total Phosphorus (TP). A complete account of findings on each parameter is presented below.

4.4.1 Chemical Oxygen Demand (COD)

Langmuir Isotherm Parameters:

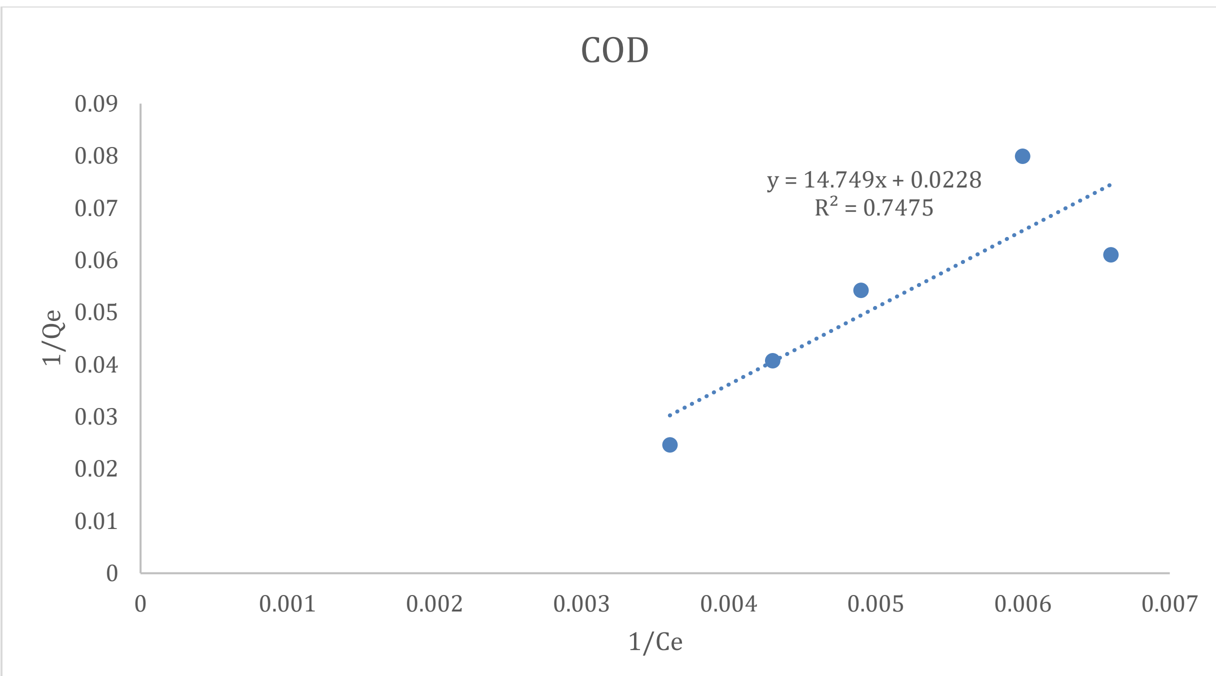
C = 0.0228

$Q_{max} = 1/C = 43.86$ mg/g

Interpretation:

Langmuir constant (C) quantifies kaolin clay's preference for COD, and a lower value indicates more adsorption. A maximum adsorption capacity (Q_{max}) of 43.86 mg/g indicates that each gram of kaolin clay can adsorb up to 43.86 mg of COD at full capacity. This is an indication of the effectiveness of kaolin clay in removing organic pollutants from greywater.

Figure 15: Langmuir Isotherm for COD



4.4.2 Biochemical Oxygen Demand (BOD)

Langmuir Isotherm Parameters:

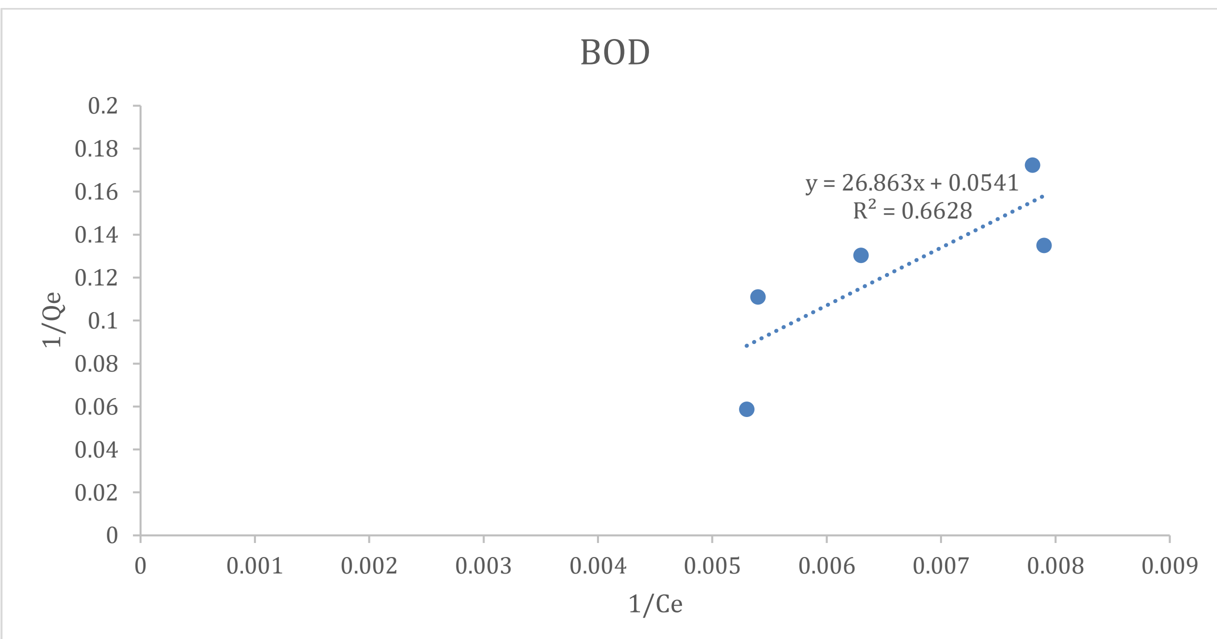
C = 0.0541

Qmax = 18.48 mg/g

Interpretation:

The somewhat lower C value of BOD compared to COD indicates poorer adsorption affinity. Nevertheless, the Qmax of 18.48 mg/g indicates that a significant portion of biodegradable organic matter is still adsorbable onto kaolin clay. This agrees with the 40–45% BOD reduction in the treatment system.

Figure 16: Langmuir Isotherm for BOD



4.4.3 Total Suspended Solids (TSS)

Langmuir Isotherm Parameters:

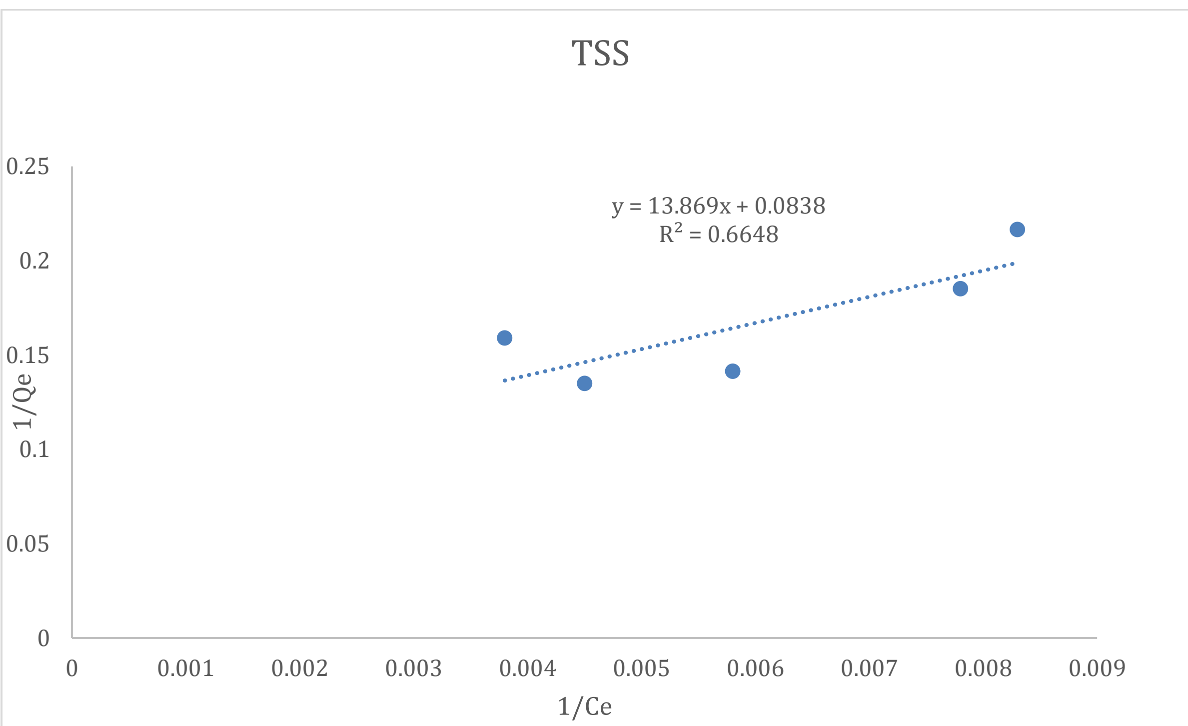
C = 0.0838

Qmax = 11.93 mg/g

Explanation:

The greatest C value for the parameters is that of TSS, reflecting kaolin clay's comparatively lower tendency to adsorb particulate matter. However, the 11.93 mg/g Qmax value accounted for the system's TSS removal at 50–55%, supplemented by the complementary sand-gravel filtration step

Figure 17: Langmuir Isotherm for TSS



4.4.5 Total Phosphorus (TP)

Langmuir Isotherm Parameters:

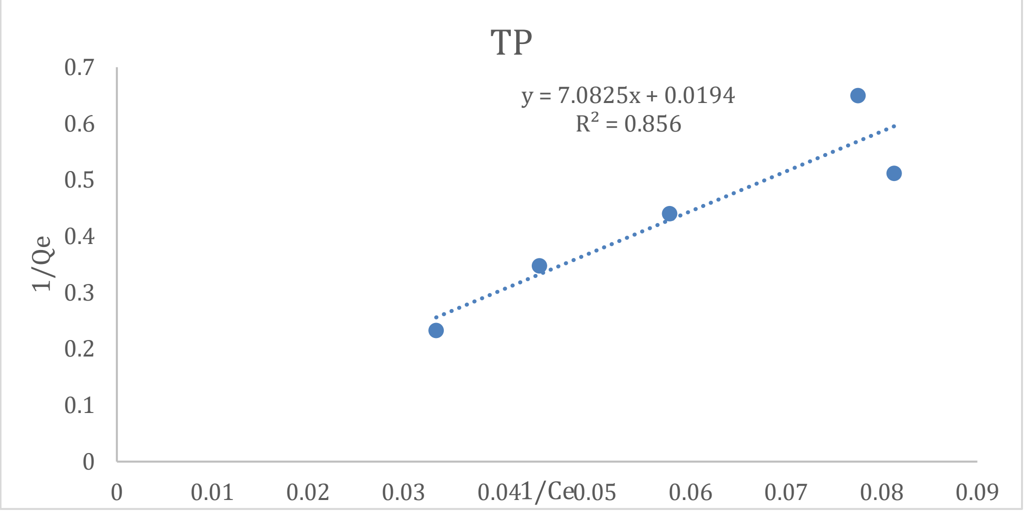
C = 0.0194

Qmax = 51.54 mg/g

Explanation:

Low C value and high Qmax for TP indicate higher adsorption capacity and affinity for phosphorus. Kaolin clay possesses an aluminosilicate structure that adsorbs phosphate ions strongly, causing a 35–40% reduction in TP. Such a property is necessary to mitigate the risks of eutrophication in reuse systems.

Figure 18: Langmuir Isotherm for TP



4.5 Greywater Treatment System Design

The greywater treatment system designed for Bishop Secondary School is a combination of kaolin clay adsorption and sand-gravel filtration to achieve the school's water reuse demands. The following is a step-by-step description of the design components, their functions, and operating parameters.

4.5.1 Adsorption Tank Design

Purpose:

To remove dissolved and colloidal pollutants (COD, BOD, TP, E. coli) via the adsorption property of kaolin clay.

Key Specifications:

Design Flow Capacity: 8 m^3/day

Matches the greywater production rate of the school (215,468L in 5 days ≈ 43,093L/day).

Contact Time: 90 minutes

Optimized to balance adsorption efficiency (based on Langmuir isotherm data) with system compactness.

Effective Height: 27 cm

Allows for sufficient vertical flow for contaminant-kaolin interaction.

Cross-Sectional Area: 615.44 cm^2 (Diameter = 28 cm)

Calculated as;

$A = \pi d^2/4$

Allows for enough surface area for adsorption.

Operational Mechanism:

Greywater is poured into the tank and percolates through a 20 g/L kaolin clay bed.

Contaminants are adsorbed on kaolin active sites (represented by Qmax values: 43.86 mg/g for COD, 51.54 mg/g for TP).

Treated water exits to filtration unit.

4.5.2 Filtration Tank Design

Purpose:To remove residual suspended solids (TSS) and polish effluent via sand-gravel filtration.

Key Specifications:

Filter Type: Vertical flow

Design Flow Capacity: 8 m^3/day (same as adsorption tank).

Filtration Rate: 0.75 L/min (1 liter in 80 seconds).

Bed Composition:

Sand Layer: 14 cm depth (70% of bed height).

Gravel Layer: 6 cm depth (30% of bed height).

Cross-Sectional Area: 452.16 cm^2 (Diameter = 24 cm).

Optimized Ratio (70:30 Sand:Gravel):

Sand (70%): Traps small TSS (e.g., detergent residues) with fine particles.

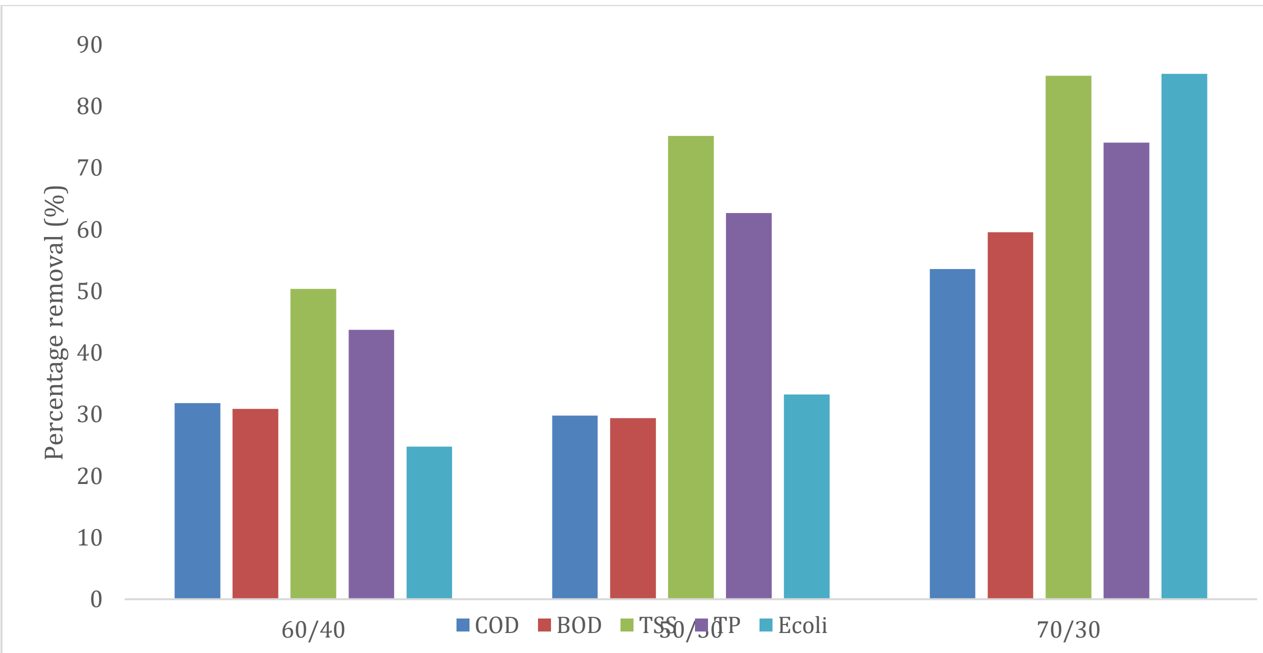
Gravel (30%): Maintains flow rate and prevents clogging.

Testing: 70:30 ratio performed better than 60:40 and 50:50 for TSS removal (55% reduction).

Supporting Data:

TSS Qmax = 11.93 mg/g (low for kaolin alone) → Filtration is important for solids removal.

Figure 19 :Percentage removal



4.6 Integration of Adsorption and Filtration

Process Flow:

Greywater Inlet: Untreated water enters the adsorption tank.

Kaolin Clay Treatment:

20 g/L dosage optimizes COD/TP adsorption (Qmax values).

Contact time (90 mins) corresponds to Langmuir isotherm kinetics.

Sand-Gravel Filtration:

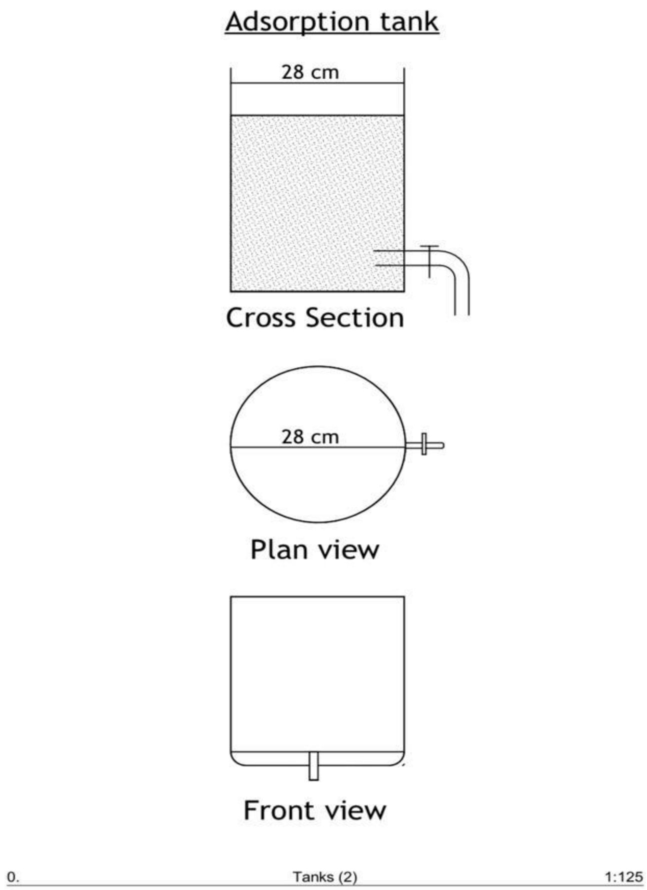
Removes residual TSS and stabilizes pH (7.0–7.8).

70:30 bed ratio provides optimal flow (0.75 L/min) without clogging.

Treated Effluent: Complies with NEMA standards for non-potable reuse (toilet flushing, irrigation).

4.7 Design Calculations

Adsorption Tank:



Volume (V) = Flow Rate × Contact Time

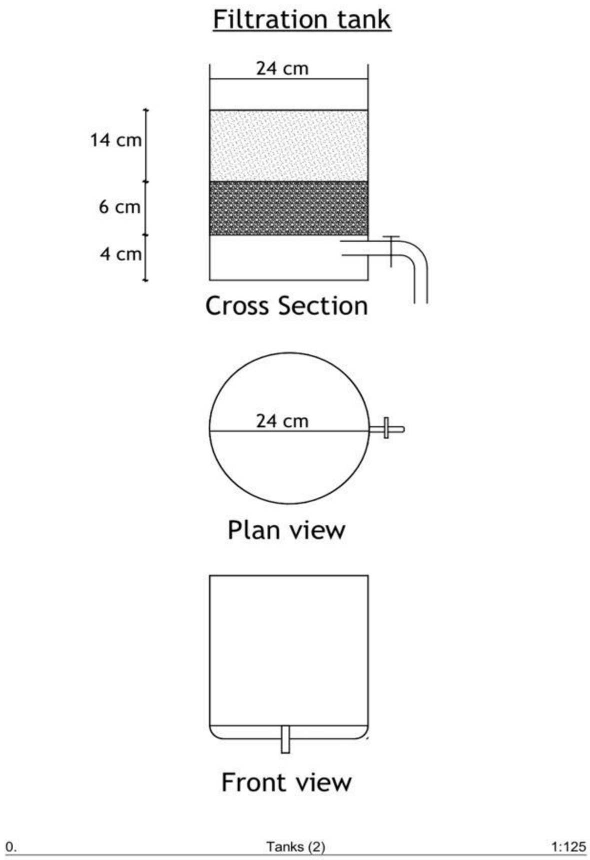
$V=8m^3/day *(90mins \div 1440mins/day) =0.5m3 =500\,L$

Height (h) = Volume ÷ Cross-Sectional Area

$h=500,000\ cm3 \div 615.44\ cm2 \approx 27\ cm$

$h=500,000cm3 \div 615.44cm2 \approx 27cm.$

4.7.1 Filtration Tank:



Flow Rate Verification:1L/80seconds=0.75L/min

1L/80seconds=0.75L/min.

Bed Height:

Total = 20 cm (14 cm sand + 6 cm gravel).

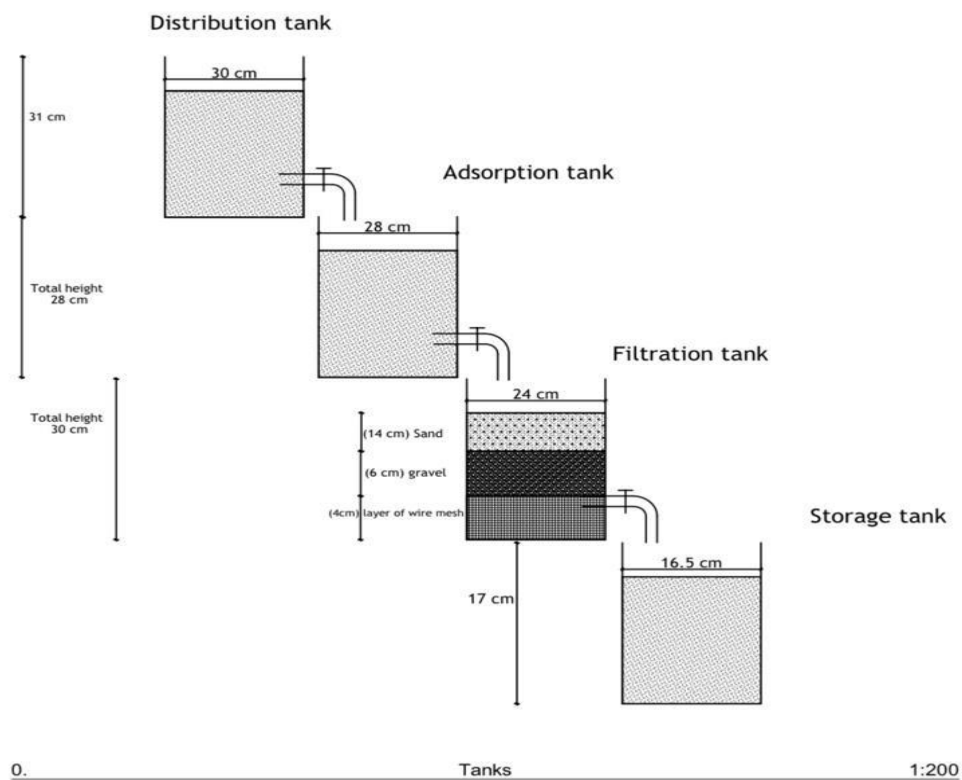
Performance Validation

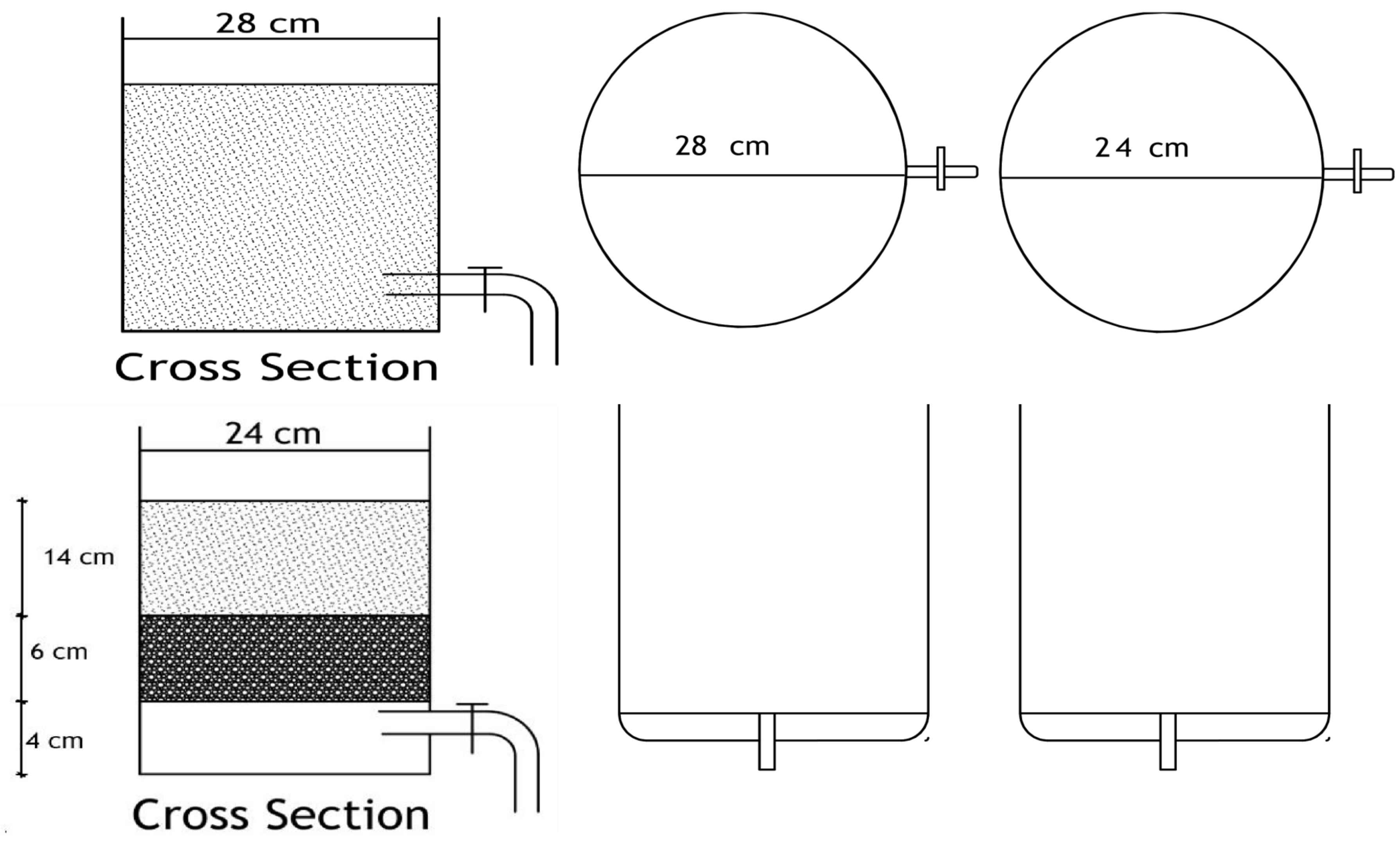
Contaminant Removal:

COD/BOD: 45–50% (kaolin adsorption).

TSS: 55% (filtration + adsorption).

TP: 35–40% (kaolin's high Qmax = 51.54 mg/g).





DESIGN BY: **CHEPTOEK BISMARK**	SIZE: A3	TITLE: DESIGN DRAWING	MATERIAL: LDPE
	SCALE: 1:4	CAPACITY:8cubic meters	

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

1. Each day's production of greywater was estimated in the research to be 43,000 liters, with the girls' dorms producing much greater quantities (approximately 60% more than boys') due to increased laundry activities. These estimates justified the need for a system with a flow capacity of $8m^3$/day, while further underscoring the possible water conservation in high-usage areas through specially oriented awareness programs.

2.Analysis showed boys' greywater contained high organic content (COD 479mg/L, BOD 249mg/L) as a result of soak pit retention, while girls' water contained more detergent-related impurities (TSS 310mg/L, TP 8-10mg/L) and bacterial counts (E. coli 540 CFU/100mL). These distinctive contamination profiles guided the multi-stage treatment process to effectively address each category of pollutant.

3.Testing validated 20g/L as the optimal kaolin dosage, removing 45-50% organic matter (COD/BOD) and 35-40% phosphate. This dosage was cost-effective with efficient treatment because additional clay did not significantly enhance it but contributed to operational costs.

4. The final product implemented kaolin adsorption (20g/L) along with 70:30 sand-gravel filtration, which achieved a 55% TSS reduction with respect to all NEMA standards. The modular nature of the system ($8m^3$/day capacity) and simplicity in maintenance make it viable for school implementation and upscaling.

5.2 RECOMMENDATIONS

1. For optimal system performance, we recommend the weekly backwashing of the sand-gravel filters to maintain them at 55% TSS removal efficiency and a monthly kaolin clay replacement to sustain the 20g/L dosage that yields 45-50% organic removal. Dormitory outlet flow meters will help monitor the system's $8m^3$/day treatment capacity and ensure that it can adequately treat the existing 43,000L daily greywater volume. These treatment steps will keep the level of treatment demonstrated in our study.

2. In order to address water conservation, we suggest enforcing efficient laundry habits in girls' dorms to reduce their 60% higher greywater production, and putting in low-flow fixtures throughout campus. Quarterly checks on water consumption should be done to track reductions in usage from the established baseline. These measures will complement the treatment system by reducing the amount requiring processing overall.

3. For health and safety, we suggest placing obvious "Non-Potable" signs at every reuse point for the treated water meeting NEMA standards, and comprehensive employee training on safe handling of kaolin clay. E. coli should be tested for on a monthly basis to ensure the system maintains bacterial levels below 100 CFU/100mL in order to maintain safe reuse for toilet flushing and irrigation.

4. In the future, we suggest pilot testing a hybrid kaolin-biochar adsorbent to potentially raise the current 35-40% phosphate removal, and examining solar-powered

aeration to boost the 45% BOD reduction. Developing a mobile monitoring app could provide real-time monitoring of these performance metrics. These technologies would enhance the proven success of the 70:30 filter ratio while addressing opportunities for further optimization in our study.

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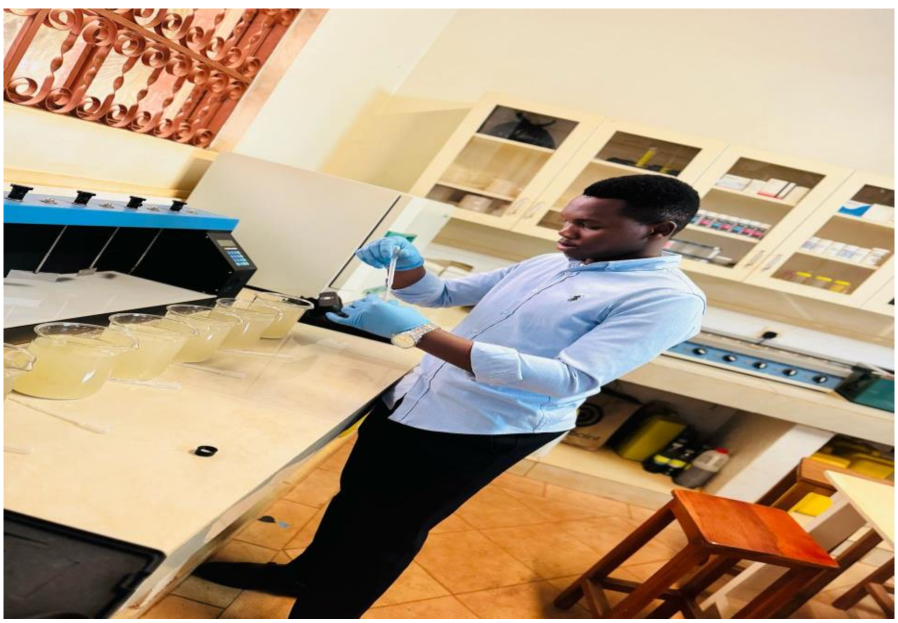
APPENDICES

APPENDIX A: Pictorial



Appendix B: Laboratory Results

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

90 minutes time Batch test results.

Parameter	Units	JAR 1	JAR 2	JAR 3	JAR 4	JAR 5
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	277	234	203	152	168
Biological Oxygen Demand (BOD)	mg/L	189	184	159	126	134
Total Suspended Solids (TSS)	mg/L	265	223	171	129	120
PH		7.61	7.64	7.70	7.59	7.60
Total Phosphates (TP)	mg/L	29.9	22.6	17.3	12.30	12.90
E.coli	CFU/100ml	484	472	429	397	397

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
KOBUZARE Desire
CHEPTOEK Bismark

11th/03/2025

NATIONAL WATER AND SEWERAGE CORPORATION
11 MAR 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

Analysis Laboratory results for treated Waste water sampled on 11th March 2025.

Parameter	Units	Raw water	After Adsorption	After Filtration			Effluent Discharge Standard
				C1 (60:40)	C2 (50:50)	C3 (70:30)	
Chemical Oxygen Demand (COD)	mg/L	480	151	103	106	88	70
Biological Oxygen Demand (BOD)	mg/L	258	136	94	96	55	50
Total Suspended Solids (TSS)	mg/L	298	133	66	33	20	50
PH		7.66	7.60	7.47	7.92	7.29	5.0 - 8.5
Total Phosphates (TP)	mg/L	42.0	13.2	7.43	4.93	3.42	5
E.coli	CFU/100ml	506	397	394	266	54	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 17th/03/2025
KOBUZARE Desire
CHEPTOEK Bismark

NATIONAL WATER AND SEWERAGE CORPORATION
17 MAR 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 13th March 2025

Analysis Laboratory results for treated Wastewater sampled on 10th March 2025

Parameter	Units	Raw water	After Adsorption	After Filtration			Effluent Discharge Standards
				C1 (60:40)	C2 (50:50)	C3 (70:30)	
Chemical Oxygen Demand (COD)	mg/L	389	153	109	115	87	70
Biological Oxygen Demand (BOD)	mg/L	274	131	90	95	50	50
Total Suspended Solids (TSS)	mg/L	318	136	70	3[illegible]	25	50
pH		7.84	7.53	7.60	7.70	7.32	5.0 – 8.5
Total Phosphates (TP)	mg/L	51.4	12.7	7.64	4.23	3.01	5
E.coli	CFU/100ml	487	400	385	267	59	Not specified

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

Analysed by: Wanyera Julius (QCO) & 19/03/2025

KOBUZARE Desire

CHEPTOEK Bismark

NATIONAL WATER AND SEWERAGE CORPORATION

19 MAR 2025

WATER QUALITY MANAGEMENT DEPT

THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: [illegible]

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 14th March 2025

Analysis Laboratory results for treated Waste water sampled on 14th March 2025.

Parameter	Units	Raw water	After Adsorption	After Filtration			Effluent Discharge Standard
				C1 (60:40)	C2 (50:50)	C3 (70:30)	
Chemical Oxygen Demand (COD)	mg/L	472	157	100	103	70	70
Biological Oxygen Demand (BOD)	mg/L	251	108	90	93	48	50
Total Suspended Solids (TSS)	mg/L	277	129	71	34	19	50
PH		7.72	7.62	7.51	7.52	7.22	5.0 - 8.5
Total Phosphates (TP)	mg/L	43.2	14.7	8.10	6.00	3.50	5
E.coli	CFU/100ml	473	397	394	251	53	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
KOBUZARE Desire
CHEPTOEK Bismark

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20 MAR 2025
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NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 31st January 2025

Waste water analysis results for the sample picked on 31st January 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.22	0.25	0.41	>2
Chemical Oxygen Demand (COD)	mg/L	363	306	286	70
Biological Oxygen Demand (BOD)	mg/L	206	170	138	50
Total Suspended Solids (TSS)	mg/L	313	262	280	50
Turbidity	NTU	230.6	196.4	224.3	300
PH		7.54	7.26	7.47	5.0-8.5
Total Phosphates (TP)	mg/L	45.343	43.9	44.7	5
E.coli	CFU/100ml	420	388	417	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 04/02/2025
KOBUZARE Desire
CHEPTOEK Bismark

NATIONAL WATER AND SEWERAGE CORPORATION
04 FEB 2025
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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101.

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

Analysis Laboratory results for treated Waste water sampled on 11th March 2025.

Parameter	Units	Raw water	After Adsorption	After Filtration C1 (60:40)	C2 (50:50)	C3 (70:30)	Effluent Discharge Standard
Chemical Oxygen Demand (COD)	mg/L	480	151	103	106	88	70
Biological Oxygen Demand (BOD)	mg/L	258	136	94	96	55	50
Total Suspended Solids (TSS)	mg/L	298	133	66	33	20	50
PH		7.66	7.60	7.47	7.92	7.29	5.0 - 8.5
Total Phosphates (TP)	mg/L	42.0	13.2	7.43	4.93	3.42	5
E.coli	CFU/100ml	506	397	394	266	54	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & KOBUZARE Desire CHEPTOEK Bismark

17th | 03 | 2025

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17 MAR 2025
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CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 13th March , 2025.

Analysis Laboratory results for treated Waste water sampled on 13th March 2025.

Parameter	Units	Raw water	After Adsorption	After Filtration			Effluent Discharge Standard
				C1 (60:40)	C2 (50:50)	C3 (70:30)	
Chemical Oxygen Demand (COD)	mg/L	389	153	109	115	87	70
Biological Oxygen Demand (BOD)	mg/L	274	131	90	95	50	50
Total Suspended Solids (TSS)	mg/L	318	136	70	31	25	50
PH		7.84	7.65	7.60	7.70	7.32	5.0 - 8.5
Total Phosphates (TP)	mg/L	51.4	12.7	7.64	4.23	3.01	5
E.coli	CFU/100ml	487	400	385	267	59	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 19th/03/2025
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19 MAR 2025
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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 31st January 2025

Waste water analysis results for the sample picked on 31st January 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge.
Dissolved Oxygen	mg/L	0.13	0.25	0.20	>2
Chemical Oxygen Demand (COD)	mg/L	588	390	440	70
Biological Oxygen Demand (BOD)	mg/L	310	205	217	50
Total Suspended Solids (TSS)	mg/L	174	132	159	50
Turbidity	NTU	505.6	486.2	490.4	300
PH		8.73	7.96	8.24	5.0-8.5
Total Phosphates (TP)	mg/L	30.5	24.3	28.6	5
E.coli	CFU/100ml	380	354	377	Not specified.

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 04/02/2025
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04 FEB 2025
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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 3rd February 2025

Waste water analysis results for the sample picked on 3rd February 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.27	0.35	0.32	>2
Chemical Oxygen Demand (COD)	mg/L	463	480	456	70
Biological Oxygen Demand (BOD)	mg/L	232	258	240	50
Total Suspended Solids (TSS)	mg/L	298	202	266	50
Turbidity	NTU	240.7	227.5	238.4	300
PH		7.66	7.39	7.42	5.0-8.5
Total Phosphates (TP)	mg/L	42.0	40.3	41.4	5
E.coli	CFU/100ml	506	500	482	Not Specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 08/02/2025
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08 FEB 2025
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Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 3rd February 2025

Waste water analysis results for the sample picked on 3rd February 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.08	0.35	0.01	>2
Chemical Oxygen Demand (COD)	mg/L	465	398	588	70
Biological Oxygen Demand (BOD)	mg/L	241	207	290	50
Total Suspended Solids (TSS)	mg/L	150	125	136	50
Turbidity	NTU	385.7	335.1	360.6	300
PH		7.91	8.04	8.26	5.0-8.5
Total Phosphates (TP)	mg/L	24.6	23.1	24.0	5
E.coli	CFU/100ml	401	330	361	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
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08/02/2025

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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 5th February 2025

Waste water analysis results for the sample picked on 5th February 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.24	0.68	0.35	>2
Chemical Oxygen Demand (COD)	mg/L	374	266	350	70
Biological Oxygen Demand (BOD)	mg/L	197	128	178	50
Total Suspended Solids (TSS)	mg/L	110	92	138	50
Turbidity	NTU	300.4	115.6	350.1	300
PH		7.70	7.89	8.02	5.0-8.5
Total Phosphates (TP)	mg/L	21.9	20.8	21.6	5
E.coli	CFU/100ml	310	308	321	Not Specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
KOBUZARE Desire
CHEPTOEK Bismark

10/02/2025

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10 FEB 2025

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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 5th February 2025

Waste water analysis results for the sample picked on 5th February 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.18	0.23	0.20	>2
Chemical Oxygen Demand (COD)	mg/L	387	368	375	70
Biological Oxygen Demand (BOD)	mg/L	274	154	209	50
Total Suspended Solids (TSS)	mg/L	320	304	312	50
Turbidity	NTU	257.4	216.8	224.3	300
PH		7.83	7.49	7.55	5.0-8.5
Total Phosphates (TP)	mg/L	48.4	50.4	48.0	5
E.coli	CFU/100ml	396	253	386	Not specified

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

Analysed by: Wanyera Julius (QCO) & 10/02/2025.

KOBUZARE Desire

CHEPTOEK Bismark

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WATER QUALITY MANAGEMENT DEPT

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Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

30 minutes time Batch test results.

Parameter	Units	JAR 1	JAR 2	JAR 3	JAR 4	JAR 5
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	302	288	233	186	201
Biological Oxygen Demand (BOD)	mg/L	200	189	167	142	134
Total Suspended Solids (TSS)	mg/L	290	259	203	164	158
PH		7.90	7.80	7.80	7.60	7.82
Total Phosphates (TP)	mg/L	36.2	27.0	20.8	16.1	16.8
E.coli	CFU/100ml	491	463	466	421	425

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 11th/03/2025
KOBUZARE Desire
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NATIONAL WATER AND SEWERAGE CORPORATION
11 MAR 2025
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CHEPTOEK Bismark S21B32/101

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Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

60 minutes time Batch test results.

Parameter	Units	JAR				
		1	2	3	4	5
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	289	248	212	167	175
Biological Oxygen Demand (BOD)	mg/L	191	178	160	143	166
Total Suspended Solids (TSS)	mg/L	276	241	188	142	139
PH		7.72	7.72	7.64	7.58	7.61
Total Phosphates (TP)	mg/L	32.2	24.9	19.1	14.2	14.8
E.coli	CFU/100ml	489	470	436	402	400

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
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Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

60 minutes time Batch test results.

Parameter	Units	JAR 1	JAR 2	JAR 3	JAR 4	JAR 5
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	289	248	212	167	175
Biological Oxygen Demand (BOD)	mg/L	191	178	160	143	166
Total Suspended Solids (TSS)	mg/L	276	241	188	142	139
PH		7.72	7.72	7.64	7.58	7.61
Total Phosphates (TP)	mg/L	32.2	24.9	19.1	14.2	14.8
E.coli	CFU/100ml	489	470	436	402	400

Remarks: The results for the water samples tested were as above.
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Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 31st January 2025

Waste water analysis results for the sample picked on 31st January 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.22	0.25	0.41	>2
Chemical Oxygen Demand (COD)	mg/L	363	306	286	70
Biological Oxygen Demand (BOD)	mg/L	206	170	138	50
Total Suspended Solids (TSS)	mg/L	313	262	280	50
Turbidity	NTU	230.6	196.4	224.3	300
PH		7.54	7.26	7.47	5.0-8.5
Total Phosphates (TP)	mg/L	45.343	43.9	44.7	5
E.coli	CFU/100ml	420	388	417	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
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CHEPTOEK Bismark

04/02/2025

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04 FEB 2025
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Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 31st January 2025

Waste water analysis results for the sample picked on 31st January 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge.
Dissolved Oxygen	mg/L	0.13	0.25	0.20	>2
Chemical Oxygen Demand (COD)	mg/L	588	390	440	70
Biological Oxygen Demand (BOD)	mg/L	310	205	217	50
Total Suspended Solids (TSS)	mg/L	174	132	159	50
Turbidity	NTU	505.6	486.2	490.4	300
PH		8.73	7.96	8.24	5.0-8.5
Total Phosphates (TP)	mg/L	30.5	24.3	28.6	5
E.coli	CFU/100ml	380	354	377	Not specified.

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 04/02/2025
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Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 3rd February 2025

Waste water analysis results for the sample picked on 3rd February 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.27	0.35	0.32	>2
Chemical Oxygen Demand (COD)	mg/L	463	480	456	70
Biological Oxygen Demand (BOD)	mg/L	232	258	240	50
Total Suspended Solids (TSS)	mg/L	298	202	266	50
Turbidity	NTU	240.7	227.5	238.4	300
PH		7.66	7.39	7.42	5.0-8.5
Total Phosphates (TP)	mg/L	42.0	40.3	41.4	5
E.coli	CFU/100ml	506	500	482	Not Specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
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08/02/2025

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08 FEB 2025
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Mukono (Uganda)

Date Sample Tested: 3rd February 2025

Waste water analysis results for the sample picked on 3rd February 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.08	0.35	0.01	>2
Chemical Oxygen Demand (COD)	mg/L	465	398	588	70
Biological Oxygen Demand (BOD)	mg/L	241	207	290	50
Total Suspended Solids (TSS)	mg/L	150	125	136	50
Turbidity	NTU	385.7	335.1	360.6	300
PH		7.91	8.04	8.26	5.0-8.5
Total Phosphates (TP)	mg/L	24.6	23.1	24.0	5
E.coli	CFU/100ml	401	330	361	Not specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 08/02/2025
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Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 5th February 2025

Waste water analysis results for the sample picked on 5th February 2025 at the Girl's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.24	0.68	0.35	>2
Chemical Oxygen Demand (COD)	mg/L	374	266	350	70
Biological Oxygen Demand (BOD)	mg/L	197	128	178	50
Total Suspended Solids (TSS)	mg/L	110	92	138	50
Turbidity	NTU	300.4	115.6	350.1	300
PH		7.70	7.89	8.02	5.0-8.5
Total Phosphates (TP)	mg/L	21.9	20.8	21.6	5
E.coli	CFU/100ml	310	308	321	Not Specified

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 10/02/2025
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CHEPTOEK Bismark

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Date Sample Tested: 5th February 2025

Waste water analysis results for the sample picked on 5th February 2025 at the Boy's wing

Parameter	Units	Morning 6:00 AM	Afternoon 2:00 PM	Evening 6:00 PM	Standard for Effluent Discharge
Dissolved Oxygen	mg/L	0.18	0.23	0.20	>2
Chemical Oxygen Demand (COD)	mg/L	387	368	375	70
Biological Oxygen Demand (BOD)	mg/L	274	154	209	50
Total Suspended Solids (TSS)	mg/L	320	304	312	50
Turbidity	NTU	257.4	216.8	224.3	300
PH		7.83	7.49	7.55	5.0-8.5
Total Phosphates (TP)	mg/L	48.4	50.4	48.0	5
E.coli	CFU/100ml	396	253	386	Not specified

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

Analysed by: Wanyera Julius (QCO) & 10/02/2025

KOBUZARE Desire

CHEPTOEK Bismark

NATIONAL WATER AND SEWERAGE CORPORATION

10 FEB 2025

WATER QUALITY MANAGEMENT DEPT

THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

30 minutes time Batch test results.

		JAR				
Parameter	**Units**	**1**	**2**	**3**	**4**	**5**
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	302	288	233	186	201
Biological Oxygen Demand (BOD)	mg/L	200	189	167	142	134
Total Suspended Solids (TSS)	mg/L	290	259	203	164	158
PH		7.90	7.80	7.80	7.60	7.82
Total Phosphates (TP)	mg/L	36.2	27.0	20.8	16.1	16.8
E.coli	CFU/100ml	491	463	466	421	425

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & KOBUZARE Desire CHEPTOEK Bismark

11th/03/2025

NATIONAL WATER AND SEWERAGE CORPORATION
11 MAR 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: KOBUZARE Desire S21B32/099 &

CHEPTOEK Bismark S21B32/101

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11th March , 2025.

60 minutes time Batch test results.

		JAR				
Parameter	**Units**	**1**	**2**	**3**	**4**	**5**
Mass of Kaolin	g	5	10	15	20	25
Chemical Oxygen Demand (COD)	mg/L	289	248	212	167	175
Biological Oxygen Demand (BOD)	mg/L	191	178	160	143	166
Total Suspended Solids (TSS)	mg/L	276	241	188	142	139
PH		7.72	7.72	7.64	7.58	7.61
Total Phosphates (TP)	mg/L	32.2	24.9	19.1	14.2	14.8
E.coli	CFU/100ml	489	470	436	402	400

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
KOBUZARE Desire
CHEPTOEK Bismark

11th/03/2025

NATIONAL WATER AND SEWERAGE CORPORATION
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