ASSESSING THE USE OF IRON COATED QUARTZ SAND IN GREY WATER TREATMENT FOR REUSE

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ABSTRACT

Soak pits remain the primary method of grey water disposal in many schools in Mukono. This method is effective for small volumes but inadequate due to the growing student population and expanding school activities thus leading to environmental risks like faster clogging and overflowing thus disease spreading. This research focused on identifying the quality and quantities of grey water in institutions specifically at St. Francis Borgia and going on to recover grey water as a valuable source that if recycled and reused for non-potable purposes like irrigation.

Local and low cost materials were suggested to be used in grey water treatment and quartz sand filters showed promising results. Experiments were made with plain quartz sand and treated quartz sand and results showed higher percentage of contaminant reduction (between 40% and 80%) with treated quartz sand. Based on results, there was a suggestion of design of treatment unit using treated quartz sand for adsorption and filtration of grey water to ensure it meets standards for which it is treated for.

DECLARATION

I NIMUSIIMA EDITOR with the registration number M22B32/039, hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award.

NIMUSIIMA EDITOR

M22B32/039

Signature…………………………………………….

Date…………………………………………………….

APPROVAL

This is to certify that this report has been done by NIMUSIIMA EDITOR under my supervision and is ready for submission to the Department of Engineering and Environment, Faculty of Engineering, Design and Technology in partial fulfillment of a Bachelor of Science in Civil and Environmental Engineering of Uganda Christian University.

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Project supervisor

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Date………………………………………………

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DEDICATION

I dedicate this report to my sponsor Paul Attermeier for his dedicated work and love for me, supporting me throughout my university education through mum JO ANN PARSONS. May you be rewarded.

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LIST OF ACRONYMS

BOD – Biochemical Oxygen Demand

COD – Chemical Oxygen Demand

TSS – Total Suspended Solids

TP– Total Phosphorous

PH- potential hydrogen

EC- electrical conductivity

mg/L – milligrams per litre

NWSC – National Water and Sewerage Cooperation

NEMA – National Environmental Management Authority

WHO – World Health Organization

EPA- Environmental Protection Agency

ICQS- Iron coated quartz sand

Fe0H- Iron hydroxide

NaOH- sodium hydroxide

Lab - Laboratory

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Grey water is the waste water from sinks, bathtubs, and washing machines, excluding sewage. The treatment and reuse of grey water is one of the biggest resource recovery and sustainable water use in institutions (Misra, 2020)

Water scarcity and pressure on freshwater systems are the main reasons for increased sustainable water reuse in the world especially in cities that are rapidly growing. Globally, 50-70% of the total household wastewater is greywater, and the safe reuse of greywater has been considered one of the main measures for reducing the demand for freshwater (Eriksson et al., 2002). Greywater reuse has already become a necessity in water stressed areas such as the Middle East, South Asia, and East Africa for irrigation, landscaping and non-potable applications. Research in countries like India, Kenya, and Ethiopia indicate that untreated greywater is a major cause of nutrient loading, groundwater contamination and clogging of soil infiltration systems (Mbae et al., 2024).

In Sub-Saharan African countries, mostly greywater is not treated before disposal because of the limited infrastructure, poor enforcement of environmental standards and the use of economical disposal methods like soak pits (Semiyaga et al., 2015). Increased student numbers lead to more greywater that soon surpasses the capacity of the existing systems. Thus, rapid clogging of soak pits occurs leading to overflow into yards and the increased BOD, COD, TSS, and nutrient concentrations reach surrounding soils and aquifers causing increase in vector and pathogens due to stagnancy (Matos et al., 2012).

Greywater from Africa is commonly rich in organic matter, phosphates coming from detergents and suspended solids. Research studies from East Africa have confirmed that wastewater of institutions usually exceed the discharge limits defined by WHO and the national standards (Niwagaba et al., 2021).

Schools in Uganda generally produce greywater with high BOD (50-120 mg/L) mainly due to the presence of soaps and organic matter, high COD (100-250 mg/L), TSS over 100 mg/L, and phosphates 3-10 mg/L particularly where commercial detergents are used (Niwagaba et al., 2021).

Worldwide and regionally, low-cost filtration has been practiced with natural and modified sand, biofiltration, and adsorption media besides others. Iron-coated quartz sand (ICQS) has been identified as one of the best materials for phosphate and organic matter removal with proven scientific techniques, especially in detergent-based greywater (Xu et al., 2020; Liu et al., 2018).

1.2 PROBLEM STATEMENT

In many schools across Mukono District, soak pits are the primary method of grey water disposal. This method is effective for small volumes however it is inadequate due to the growing student population and expanding school activities. (Atwebembeire et al., 2019)

St. Francis Borgia a secondary school in Mukono disposes its grey water into soak pits. In weekends when students are doing laundry, most of the laundry waste water is disposed in the compound and left to flow freely. Due to under designing and increased volumes of grey water per day at the school (21cubic meters), the available soak pits are overloaded and end up clogging faster.

According to Ugandan standards (MoH, 2018) Soak pits must receive only pretreated effluents, sized according to percolation test with depth (1.5-5m) and internal diameter (1-2.5m)

However, construction designs of these soak pits were not to the standard ie no percolation test was done, depth was 1.3m and sizing (0.9m diameter) hence possible clogging and over flowing leading to environmental and health risks (KCCA, 2022)

Studies have shown that regardless of designs, soak pits are not viable and sustainable methods of grey water treatment for growing institutions that generate large quantities of grey water. (Semiyaga et al., 2015)

Furthermore, the seepage of untreated grey water poses risks of contaminating groundwater sources used for domestic and institutional purposes. It is extremely difficult to eliminate the risk of ground water contamination when onsite sanitation systems effluent is discharged into sub surface. (Mbae et al., 2024)

Preliminary tests were carried out and the presence of high BOD, COD, total suspended solids, and nutrients in untreated grey water exceeded recommended NEMA standards for discharge and reuse. Such pollution not only degrades the environment but also increases the risk of waterborne diseases within the school and surrounding communities. The current disposal methods fail to utilize grey water as a resource, despite its potential for reuse in irrigation thus missing an opportunity to conserve water. Experiments (batch and column) were made in the lab for both plain quartz sand and treated quartz sand and it was found out that the treated quartz sand removes the highest percentage of contaminants in grey water due to large surface area for phosphates and organic matter. It was also found out that iron doesn't leach into the treated grey water

Iron-coated quartz sand filtration offers a promising approach due to its ability to enhance nutrient and organic matter removal. This study seeks to assess the performance of iron-coated quartz sand filters for treating grey water for reuse in institutions like St. Francis Borgia.

1.3 Main Objective

To assess the use of iron-coated quartz sand in grey water treatment for reuse.

1.3.1 Specific Objectives

1. To assess the physical-chemical characteristics of grey water
2. To determine the percentage reduction of contaminants by untreated quartz sand and treated quartz sand
3. To design a grey water treatment unit with treated quartz sand

1.4 RESEARCH QUESTIONS

1. What are the physical-chemical characteristics of grey water?
2. What percentage of contaminant removal can untreated and treated quartz sand achieve in treated grey water?
3. What are permissible limits for grey water discharge into the environment and for various reuse options?

1.5 SCOPE OF STUDY

St. Francis Borgia High school, Mukono

1.6 JUSTIFICATION

Iron-coated quartz silica sand has a high adsorption capacity of ferric oxides which bind contaminants like phosphate ions through electrostatic interactions as phosphate anions are attracted to the positively charged iron surface. (Liu et al., 2018) This happens when iron oxides get positively charged under a low to neutral PH with a high variance, they are able to attract the negatively charged phosphate ions.

$Fe^{3+} + PO_4^{3-} == FePO_4 + H_2O$

Quartz silica sand has as a porous support material, hard and resistant to abrasion. It enhances flow and its large surface area enhances contaminant removal. Coating it with iron oxides significantly improves its adsorption efficiency. (Rusch et al., 2010). In presence of oxygen and alkaline conditions, ferric oxides are stable thus insoluble in water.

Its local availability and low cost, will provide a practical solution to promote water reuse and enhance sanitation in institutional settings hence reduction in fresh water consumption. There has been cases of water scarcity in institutions in Mukono as reported by Love Binti in 2023 thus this study can address this issue to some extent using locally available materials.

1.7 SIGNIFICANCE OF RESEARCH

Environmental protection: This study provided a low-cost and eco-friendly solution to reducing pollution in grey water before it is discharged into the environment.

Public health concerns. By treating grey water, the risks of contamination and related diseases among school communities were reduced. For example, issues of water related diseases.

Sustainable water management: Institutions will be empowered to recycle and reuse treated grey water for non-potable purposes, thus conserving fresh water resources.

Scientific contribution: The research also contributed to scientific knowledge on the use of modified natural materials ie iron-coated sand in wastewater treatment.

1.8 THEORETICAL/CONCEPTUAL FRAMEWORK

The adsorption theory rooted in surface chemistry is the basis of this study. This theory states that attractions, either physical or chemical, between solid surfaces and pollutants, like phosphates in greywater, are the means for their removal. The iron coating over quartz sand brings in ferric oxides whose charges are positive and because of that they tend to associate with the negatively charged phosphate ions (PO4^3−) massively and most of the contaminants in grey water are negatively charged thus easy and fast interaction. The interaction causes the contaminants to stick to the media surface so they are removed from the water. The filtrate is then treated to eliminate any pollutant that might have evaded the adsorption process.

COST BENEFIT ANALYSIS

A cost benefit analysis was done to find out the benefit of incorporating a grey water treatment plant versus the cost of soak pits, fresh water consumption and use in irrigation and other non-potable purposes and it was found out that there are more cost benefits in treating grey water for non-potable purposes.

Population of the school and volumes of grey water generated

St. Francis Borgia currently has a population of 1115 students and 85 staff members

The school uses 27 m3 of water per day and assuming 78% of this waste water is grey water

Volume of grey water generated per day=78/100x27= 21m3

Volume of grey water generated per month= 21x30=630m3

The school spends 8.3M USH on water per month

Population growth projections in the next 20 years:

Using the formula for population growth

P(t)=Pi×(1+r)t

P(t) = population after time t

Pi = Initial population

r= Annual growth rate (decimal form) = 0.029

t = time in years

P(t)= 1115(1+0.029)20= 1976 students calculated using standard design manuals for waste water treatment plants

In the next 20 years, population projection is estimated to be 1976 students. Given that a student uses 18.6 liters of water per day, the total amount of grey water generated in the next 20 years is 37.2m3

This indicates that more volumes of grey water will be generated as population keeps increasing

Calculating savings

Savings= volume of treated grey water x cost of NWSC water per litre

CHAPTER 2: LITERATURE REVIEW

2.1 WASTEWATER

This refers to used water that contains a mixture of both organic and inorganic material that is harmful to the environment (Shah, 2017). It simply means water that is not clean because it has been used in households, factories, runoff from farms, and others. Wastewater is polluted water, and its pollutants are from both point sources and dispersed sources (R L and Mehta, 2020). It is dangerous to the environment when released without treatment.

Point sources: this simply means a single identifiable source of pollution for example drain or a pipe (usually industrial wastewater effluent being discharged by a pipe into a river)

Dispersed/ non-point sources: Also known as diffuse pollution simply mean inputs that happen over a large/ wide area and can be zeroed down to one source. They are usually attributed to a specific land use for example urban land use, Agricultural land use and factory land use and others. Diffuse pollution is executed by agents like storm water that greatly impact the water quality of the different waterways they flow into (EPA, 2021). Wastewater from the different sources affects the quality of surface and ground water.

COMPOSITION OF WASTE WATER.

- Nutrients like nitrates and phosphates

- Heavy metals like lead, mercury and copper
- Bacteria and pathogens
- Suspended solids
- Detergents and soap residue.

2.2 PARAMETERS MEASURED IN WASTE WATER

Total Phosphorus (TP)

TP measures all forms of phosphorus (organic and inorganic) in water. Excess phosphorus promotes eutrophication, leading to algal blooms, oxygen depletion, and aquatic ecosystem damage. It is often contributed by detergents, fertilizers, and sewage. Studies show that grey water contributes significantly to nutrient loading in local rivers (Niwagaba et al., 2021).

Turbidity

Turbidity refers to the cloudiness of water caused by suspended solids that scatter light. It is measured in Nephelometric Turbidity Units (NTU). High turbidity can indicate the presence of pathogens, organic matter, or pollutants and affects water clarity and quality.

pH

pH measures the acidity or alkalinity of wastewater on a scale of 0 to 14. A pH of 7 is neutral, below 7 is acidic, and above 7 is alkaline. pH affects biological processes, chemical reactions, and the solubility of pollutants. Wastewater should have a pH between 6.5 and 8.5 to be considered safe for discharge.

Biochemical Oxygen Demand (BOD)

BOD is the amount of dissolved oxygen needed by aerobic microorganisms to break down organic matter in water. It is an indicator of organic pollution. High BOD means more organic matter, leading to oxygen depletion in receiving water bodies. It is usually high in black water due to high organic matter from human fecal matter.

Chemical Oxygen Demand (COD)

COD measures the total quantity of oxygen required to chemically oxidize all organic substances in water. High COD indicates the presence of significant organic and inorganic pollutants

Total Suspended Solids (TSS)

TSS refers to the solid particles suspended in water that can be trapped by a filter. High TSS can reduce water clarity, hinder light penetration, affect aquatic life, and clog treatment systems. It includes silt, decaying matter, and industrial waste particles.

Electrical conductivity

Electrical conductivity in wastewater measures the water’s ability to conduct electricity, which depends on the concentration of dissolved ions such as salts (e.g sodium, chloride, sulfate, nitrate). It is expressed in µS/cm (micro siemens per centimeter). High EC indicates a high concentration of dissolved salts or ions from detergents and low EC indicates low salt content, meaning the water is less mineralized and relatively clean.

Table 1: Different parameters and the standard effluent discharge

Parameter	Standard for effluent discharge
Total phosphorus	5g/l
BOD	50g/l
COD	70g/l
pH	5.0-8.5
DO	>2
Turbidity	25 NTU
Electrical conductivity	1000

Source: National water lab Bugolobi

GREY WATER

Grey water is form of waste water excluding sewage. It is waste water from the kitchen, laundry, washing utensils, showers and cleaning. This waste water is less contaminated compared to black water thus treatment is easier.

Physical, chemical and microbiological quality of greywater

Physical and chemical quality

There is a high amount of variability in the chemical and physical quality of greywater produced by institutions, due to factors such as the source of water, the water use efficiency of appliances and fixtures, Individual habits, products used (e.g. detergents, shampoos, soaps,) and other site-specific characteristics.

The amount of salt (sodium, calcium, magnesium, potassium and other salt compounds), oils, greases, fats, nutrients and chemicals in greywater can largely be managed by the types of products used within an institution or community.

Nutrients

Greywater contains nutrients generated from the bathroom and laundry. By managing the type and amount of washing detergents, personal hygiene products and cleaning agents that are used, the amount of nutrients in greywater can be managed.

Salts

Salts in greywater originate from washing detergents and are commonly in the form of sodium, magnesium and calcium compounds.

Why grey water is treated before disposal or reuse

Treating grey water at household or institutional level reduces the volume and organic load entering centralized wastewater treatment plants, improving system efficiency and reduces expansion costs (NEMA, 2020).

Protect Public Health. Untreated grey water contains pathogens such as bacteria and viruses that can cause infections. Chemical contaminants from detergents and pharmaceuticals also pose health risks (WHO, 2006)

Environmental protection. Discharging untreated grey water contributes to eutrophication due to nutrients such as nitrogen and phosphorus. It can also degrade soils and contaminate groundwater.

Resource recovery and circular economy. Treated grey water can be reused for irrigation and toilet flushing, reducing demand on freshwater supplies and supporting sustainable water management

2.3 MATERIALS: QUARTZ SILICA SAND

Quartz silica sand has the main chemical component of silicon dioxide (SiO_2), which is a mineral that has a lot of remarkable features like very low reactivity with other chemicals, hardness, and that is why it comes in big granular sizes. One of the greatest properties of quartz is its high surface area and that is why it has found its place in the filtration systems as a filtering media. And since it is an inert material, it will not take part in the reaction going on with water or other substances, thus keeping the quality of the treated effluent.

However, uncoated quartz silica sand has a low ability to hold up the pollutants mainly because of its negatively charged surface. For it effective with phosphate anions, it has to go through a surface modification by getting coated with metal oxides like iron.

Iron specifically in the form of ferric oxides (Fe_2O_3, $FeOOH$) have a tendency to bind to phosphate ions. The surface of iron which carries a positive charge attracts the negatively charged phosphate ions (PO_4^{3-}) thereby forming stable complexes. This phenomenon increases the phosphate extraction capacity.

Iron coating has the additional advantage of increasing the number of active sites on the quartz surface, thus giving a boost to its adsorption efficiency. Research reports have confirmed that iron-coated sand can accomplish the removal of phosphate with an efficiency of up to 90% if conditions are made favorable.

Moreover, iron is economically priced, and non-toxic, thus, it becomes the perfect option for environmental water treatment.

Generally, the procedure of coating involves immersing clean quartz sand in a ferric chloride solution, then drying and heating it to create a stable iron oxide layer on the sand grains. Not only does this process impart hardness to the filtration medium it is also suitable for both batch and column types of greywater treatment systems. The natural adsorption capacity of quartz sand is such a way that it quickly captures and gets rid of iron particles thus contributing not only to the water quality but also to the longevity of the water infrastructure. Its durability and effectiveness are expressed

Procedure for preparation of iron coated quartz sand

Dissolve 2M of ferric chloride in 80ml of distilled water and stir. Wash the sieved quartz sand thoroughly until clean water comes out to remove any kind of dirt. Dry the sand in an oven at 100degrees Celsius to ensure it dries properly. Mix the clean sand with the ferric chloride solution and stir. Prepare a 1M NaOH solution by dissolving 40g of NaOH pellets in 250ml of distilled water and then make up the solution to 1 litre. Slowly by slowly, add the NaOH in the mixture until optimum pH 6-8 and soak for 1-2 hours. Ph is the most critical to determine the final structure, surface area and the stability of iron oxide coated sand. The FeOH precipitate forms directly on the sand surface and sand is separated from the mixture, washed with clean water and oven dried at 105 degrees Celsius.

2.4 GREYWATER USES

Many research efforts have outlined the various potential uses of greywater. Among the most widely accepted applications are:

•Toilet flushing and landscape irrigation. In the United States, greywater is most commonly used for watering landscapes, including lawns, ornamental plants, trees, and even certain food crops provided the water has been properly disinfected (Matos et al., 2012).

•The application of greywater in toilet flushing has been encountered all over the Globe especially Europe (OMS, 2006).

• Grey water is also used for general washing

• Also used as a cooling tower make up water.

Sources of grey water

- Hand basins and washing dishes
- Washing machines/laundry tubs, sinks, and water from washing clothes
- Showers and baths etc.

2.5 GREY WATER TREATMENT SYSTEMS

Grey water does not typically produce unpleasant odors immediately after it is discharged. However, when stored in a tank without treatment, it rapidly depletes oxygen and transitions into an anaerobic state. In this condition, it becomes septic, forming sludge that may either sink or float depending on the amount of gas trapped within and its overall density. At this stage, greywater can emit foul smells similar to raw sewage and may also harbour anaerobic microorganisms, some of which are potentially pathogenic (Matos et al., 2012).

Therefore, effective grey water management requires prompt treatment and reuse before it turns septic. One of the simplest and most suitable approaches is to use freshly produced grey water directly, without allowing it to stagnate (Verstraete et al., 2009).

2.6 GREYWATER TREATMENT METHODS

There are many different approaches available for treating grey water (GWT) each varying in terms of how they operate the types of pollutants they target their design and the stages of treatment they involve. Choosing the right treatment method usually depends on several factors such as the amount of grey water being produced, how much organic matter it contains, what the treated water will be used for and the regulatory standards it must meet (Kulabako et al., 2009).

Typically, grey water treatment is divided into three key stages: preliminary, primary and secondary treatment. Across the board, there is strong agreement that treatment methods should aim to be environmentally sustainable ideally avoiding harsh chemicals or the creation of toxic waste. While some studies suggest that grey water can be stored for a short time before treatment this period should be kept as brief as possible to prevent the growth of harmful microorganisms.

Treatment techniques vary physical and chemical methods often involve filtration and disinfection, while biological processes might include aeration or the use of membrane bioreactors (Oteng-Peprah et al., 2018). Because they can create high quality treated grey water, sophisticated systems like sequencing batch reactors and biologically aerated filters are being used more and more all over the world.

However, these systems are less practical for low income or developing nations because of their high energy requirements and high installation and maintenance costs.

The utilization of natural available resources as an alternative way is the main focus of this study due to these difficulties. These eco- friendly materials show promise for application in adsorption and filtration procedures providing efficient treatment without generating hazardous by products.

Pre-treatment

Pretreatment techniques eliminate the bulk solids, hair, lint, sand, oil and grease as well as other materials that might interfere with the proper functioning of the equipment downstream and cause fouling. The pretreatment makes sure that filters, biological reactors, etc. are not clogged. It consists of screening, grit removal, and trapping of grease as unit processes.

Primary treatment

The technique discussed here makes use of sedimentation and similar physical processes to remove from the liquid waste the solid matter that can settle, thus reducing TSS and BOD levels (some). Primary treatment decreases the load on biological (secondary) processes. The most common processes include sedimentation, lamella or tube settlers and dissolved air flotation.

Secondary treatment (biological and combined processes)

This treatment method biologically removes dissolved and colloidal organic matter (BOD/COD), reduces pathogens and further reduces suspended solids. Secondary treatment transforms organic matter into biomass and, ideally, stable effluent that is reusable or can be safely discharged. These processes consist of activated sludge, bio filters, constructed wetlands (nature-based systems that combine filtration, adsorption, and biological degradation). (Arden et al., 2018)

Sedimentation in Grey Water Treatment

Sedimentation is one of the simplest and most natural ways of cleaning grey water before it moves on to more advanced treatment steps. It works on a very basic idea if you give water enough time to rest heavier particles will slowly sink to the bottom. This simple action helps remove a big portion of the dirt and solids found in grey water from showers, sinks, and laundry. As grey water comes into the sedimentation tank, the water flow is reduced to allow the settling down of different kinds of debris such as soil, hair, soap and food particles. The sinking materials aggregate into a sludge layer on the floor of the tank. This sludge is to be removed at intervals to ensure the system remains clean and working efficiently. The water which is clearer than before now on the surface is then permitted to pass on to the following treatment stage.

Sedimentation is especially useful because it can significantly reduce several parameters making the rest of the treatment process easier and more effective. Some of the main parameters reduced include total suspended solids and turbidity.

Total Suspended Solids (TSS)

This is the biggest improvement achieved through sedimentation. Most of the solid particles settle out, often reducing TSS by a big percentage.

Because the solids settle, the water becomes clearer. Turbidity may drop significantly.

Other parameters like BOD, COD and microbial load reduce slightly. They may be significantly reduced by biological processes.

Factors that influence sedimentation efficiency

- Retention time (1-3 hours)
- Tank depth and type
- Temperature
- Particle size and density
- Presence of surfactants

Types of sedimentation tanks

Circular sedimentation tanks

The tanks are circular in shape and influent normally enters at the center and flows outward. Sludge is scraped to the center by rotating scrapers and effluent is collected at the edges via peripheral weirs.

Advantages

- Symmetrical flow patterns reduce dead zones.
- Efficient sludge collection.
- Suitable for large flow rates.
- Continuous smooth operation of mechanical scrapers.

Disadvantages

- Require more land area.
- Higher construction cost due to mechanical equipment.
- Wind may disturb hydraulic efficiency.

- Harder to cover for odor control.

Rectangular sedimentation tanks

These are long straight channels with influent entering at one end and leaving at the other and sludge moves to the end through gravity or chain mechanisms they have a uniform horizontal flow.

Advantages

- Require less land area.
- Hydraulically more efficient (straight uniform flow).
- Easier to expand by adding parallel units.
- Cheaper construction and maintenance.
- Easier sludge removal.
- Perform better during peak flows.

Disadvantages:

- Possibility of short-circuiting if poorly designed.
- Sludge removal equipment needs periodic maintenance.
- Inlet flow distribution must be well designed.

Why rectangular tanks are often preferred

- Use less land area for same capacity.
- Better hydraulic efficiency.
- Cheaper to construct.
- Easier to operate and maintain.

- Allow easy modular expansion.

Adsorption

Adsorption is the concentration of a solute which maybe molecules dissolved or suspended in the liquid phase on the surface of a solid. During adsorption molecules bind onto the solid surface or are held of the solid surface by the weak intermolecular forces of attraction.

Types of adsorbents used

Biochar, activated carbon, clay minerals, zeolites and these have proved to be efficient in waste water treatment. Modified quartz sand has also shown better results in treating grey water at institutional level.

Requirements of treated grey water for irrigation

Grey water when treated should be able to meet standards for reuse according to different reuse options which include irrigation, toilet flushing and cleaning floors among others. It should be free from pathogens since human beings come in contact with it during the operations of these activities.

Guidelines for Wastewater Reuse in Irrigation (WHO, 2006)

Guidelines for wastewater reuse in irrigation (2006), provides the worldwide accepted framework for the safe application of wastewater and greywater in agriculture. The main aim is to protect the public health through the establishment of both the microbiological and physicochemical standards for the effluents that are to be used for irrigation.

The guidelines distinguish between three types of irrigation practices: unrestricted (for edible crops consumed raw), restricted (for crops not consumed raw), and non-food crop irrigation. The required treatment level for the water depends on the exposure risk for humans based on the crop type and irrigation method chosen.

Despite the emphasis on microbial risks, the WHO guidelines also suggest values for chemical parameters such as BOD, COD, TSS, turbidity, and nutrients with phosphorus among them. Monitoring such parameters is an indicator that wastewater is safe for irrigation and does not cause soil structure deterioration, emitter clogging, or environmental degradation.

Table 2: Key effluent parameters for safe of treated wastewater in irrigation.

Parameter	Effluent standard (WHO, 2006)
BOD	≤ 30 mg/L
COD	≤ 50–100 mg/L
Total Suspended Solids (TSS)	≤ 30 mg/L
Turbidity	≤ 5 NTU
Total Phosphorus (TP)	≤ 2 mg/L

Application of the guidelines in Irrigation

In case the wastewater is treated to the level of WHO (2006) standards, it can be directly applied for agricultural irrigation but only if proper irrigation methods like drip irrigation are used. Such methods ensure that there is little human exposure and that the likelihood of non-edible crops being contaminated is lessened. Varying the effluent parameters along with the irrigation system is a must for monitoring the process.

2.7 SOAKPITS

A soak pit also known as a soak away refers to a covered porous walled chamber usually around 1.5 to 4 m deep, into which effluent is discharged after being settled for the pre-specified time, so that the effluent is slowly infiltrated into the surrounding soil. It is used in most cases for disposing pre treated waste water from septic tanks, grease traps, and grey water treatment installations.

In Uganda and several other countries that can be categorized as low or middle-income, gravel-packing soak pits are a common practice for the disposal of small flows of waste water effluent or greywater. The sanitation guidelines refer to soak pits as inexpensive alternatives that do not require much area of land to be set aside and can only accommodate the influence volumes that are relatively small and may be a higher risk of groundwater pollution if they are poorly sited or designed (Ministry of Water and Environment, 2018).

Through hydraulic infiltration, physical filtration, and biological processes, the effluent is infiltrated through the porous pit wall and the surrounding soil at a rate which is mainly controlled by the soil infiltration rate. The soil infiltration rate is obtained through percolation tests and the wetted wall area of the soak pit. Sandy or granular soils with high permeability are suitable while clayey or black-cotton soils have very low infiltration rates thus leading to quick ponding, back-up of wastewater, and surface overflow.

As the gray water comes in contact with gravel and soil, it gets rid of suspended solids, soap scum, and very fine particles that are all held within the voids of the soil. Such solids together with microbial biofilm undergo the process of forming a clogging layer(biomat) at the interface between the soil and water. This layer gradually decreases the effective infiltration capacity of the soak pit (UNHCR & Eawag, 2024).

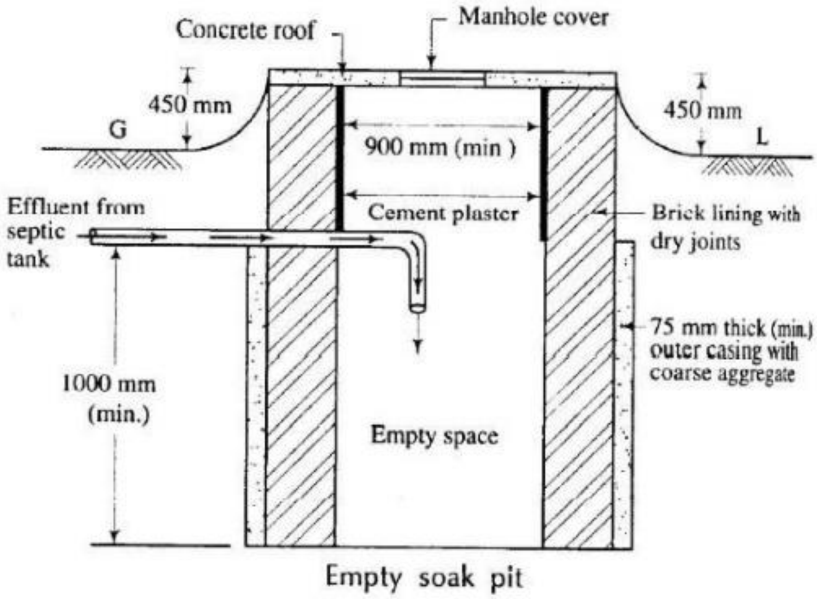

Figure 1: Typical soak pit design (UNHCR & Eawag, 2024).

CHAPTER3: METHODOLOGY

3.1 ASSESSING THE PHYSICO-CHEMICAL CHARACTERISTICS OF GREY WATER.

Grey water samples were collected from St. Francis Borgia, at key discharge points preserved below 4 degrees Celsius in a cooler box and transported to the laboratory.

Samples were collected on different days in morning afternoon and evening to determine how they vary in different times due to different activities

For the physical properties, these tests were carried out: turbidity and total suspended solids (TSS).

For the chemical properties, these tests were carried out: pH, BOD, COD, phosphates and electrical conductivity.

Procedure for determining BOD (APHA 5210B)

Measure the initial dissolved oxygen level in the waste water sample. Pour a portion of the sample into a sealed BOD bottle and a separate bottle for dilution if needed. Incubate the sealed sample in the dark at 20^{o}c for 5days. Measure the final Do level after this incubation period. Calculate the BOD by taking the difference of final DO initial DO

Procedure for determining COD (APHA 520D)

Pick a waste water sample and add a known amount of a strong oxidizing agent such as potassium dichromate in a digestion flask. Heat the flask at a high temperature for a set period to allow chemical reactions to happen. The remaining oxidizing agent is then measured through titration to determine the amount of oxygen required for chemical oxidation

3.2 DETERMINING THE PERCENTAGE REDUCTION OF CONTAMINANTS BY UNTREATED AND TREATED QUARTZ SAND

Sourcing of graded quartz sand from Jomai quary. Sieve quartz sand of particle size(2mm) through a 2mm sieve. Wash, thoroughly the quartz silica sand with distilled water and ensure it gets rid of any dirt. Quartz silica sand is then mixed with a ferric chloride ($FeCl3$) solution to introduce iron oxides in a volume ratio of 1:4 where one unit of silica sand will be added in 4 units of ferric chloride solution. Slowly by slowly, add the NaOH in the mixture until optimum pH 6-8 and soak for 1-2 hours. pH is the most critical to determine the final structure, surface area and the stability of iron oxide coated sand. The FeOH precipitate forms directly on the sand surface and sand is separated from the mixture, washed with clean water and oven dried at 105 degrees Celsius. Wash again to remove free ions that may leach with treated water. Make experimental setups that involve batch and column experiments with different bed heights and determine percentage removal of contaminants using the concentrations before and after treatment. Batch experiments are to determine optimal conditions (pH, contact time, adsorption capacity) and column experiments simulate real-time filtration performance under continuous flow. Measuring of key parameters again to check the percentage removal of contaminants from the samples.

$$\text{Percentage removal} = \frac{\text{Initial Concentration} - \text{Final concentration} \times 100}{\text{Initial concentration}}$$

Figure 2: Ferric chloride and Sodium hydroxide pellets   Figure 3: Plain quartz sand

Figure 4: Coated quartz sand before and after oven drying

3.3 DESIGNING GREY WATER TREATMENT UNIT WITH IRON COATED QUARTZ SAND

By analyzing the quality and quantity of grey water, a suitable treatment unit is chosen using standard procedure. Determining the amount of grey water produced at St. Francis Borgia currently and future population projections, flow rates, velocities, contact time, filter depth and using AutoCAD for the drawings. It was found out that St. Francis Borgia generates 21 cubic metres of grey water per day with a population of 1115 students as of 2025. Pretreatment process was considered to remove large particles or debris from grey water. Filtration methods were incorporated to distribute water evenly over sand bed. Disinfection was to remove any pathogens that could have remained in the filtered water.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

Grey water samples from key discharge points were analyzed at the National Water and Sewerage Corporation (NWSC) Bugolobi Laboratory to determine the physico chemical characteristics. The results obtained were compared to the National Environment Management Authority (NEMA) and NWSC effluent discharge guidelines, which set standards to protect human health, soil quality, and the environment. The parameters analyzed include Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Phosphates, Turbidity, Total Suspended Solids (TSS), pH, and Electrical Conductivity (EC).

Results from grey water tested showed mean values of COD 128.8 mg/L, BOD 62 mg/L, TSS 117.1 mg/L and TP 4.0 mg/L which confirmed that the greywater is high-strength and does not comply with NEMA (2020) discharge limits. The morning and evening peaks correlate with various activities that take place at the school like bathing/laundry activity which accumulate high volumes of grey water and more concentrations (Kulabako, 2009). The neutral pH (7.3) and low EC (248.6 μS/cm) are favorable, indicating no acute salinity or acidity issues for treatment or reuse (WHO, 2006).

Table 3: Results of grey water samples taken from St. Francis Borgia

PARAMETER	MORNING	AFTERNOON	EVENING	MEAN
COD	138	102	146.3	128.8
BOD	62	49.3	74.7	62.0
TP	3.8	3.1	5.1	4.0
Turbidity	29.6	26.6	37.7	31.3
TSS	118.7	80.3	152.3	117.1
EC	244.7	241.7	259.3	248.6
pH	7.3	7.2	7.3	7.3

4.2 Chemical Oxygen Demand (COD)

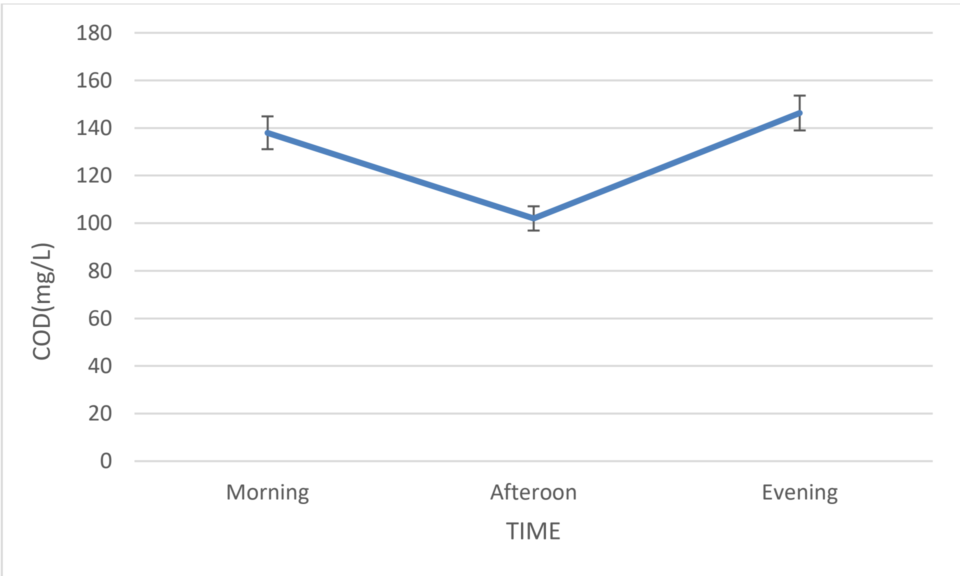

Figure 5:Variation of COD with time

The COD value in the evening was 146.3 mg/L, which was above the NEMA and NWSC discharge limit of 70 mg/L. This trend aligns with greywater patterns in East African institutions, where evening bathing and laundry activities produce concentrated organic-rich greywater (Mbae et al., 2024). COD indicates the amount of oxygen required to oxidize totally both biodegradable and non-biodegradable organic matter in water. Evening high COD levels could be the result of a large amount of grey water that has high concentrations pointing to the presence of organic pollutants such as soap residues, oils, and detergents which are typical in grey water from showers.

These pollutants interact with water and thus they require more oxygen for chemical oxidation since the inorganics cannot be decomposed naturally as shown in **fig 5**

According to the adsorption theory, the presence of large amounts of biodegradable and non-biodegradable organics increases the oxygen demand and determines how much can be removed by adsorption onto modified media. Treated quartz sand with iron oxides offers ligand exchange sites and electrostatic attraction that enhance binding of organic anions, partially explaining the improved removal in Table 4.

4.3 Biological Oxygen Demand (BOD)

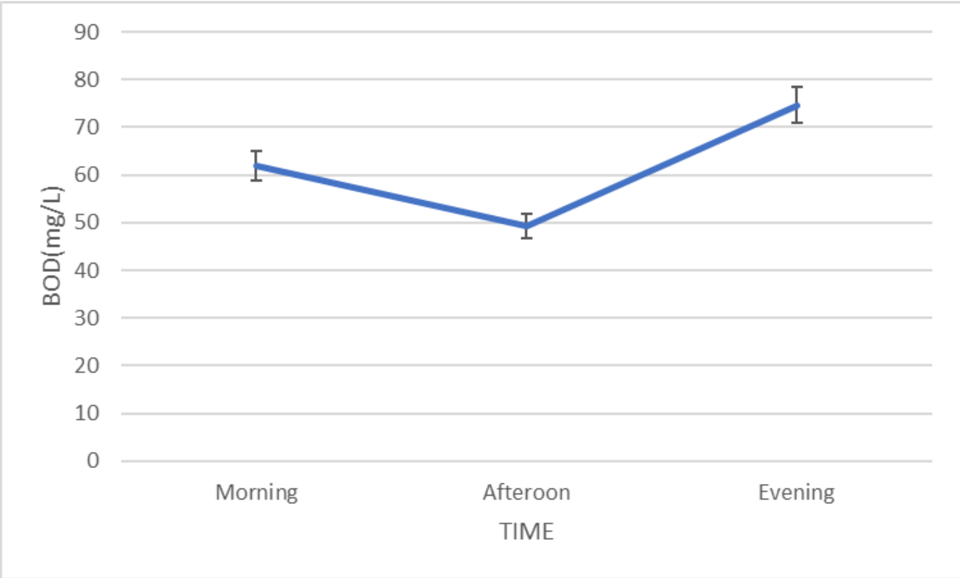

Figure 6: Variation of BOD with time

The BOD value was measured as 74.7 mg/L in the evening, which was above the NEMA recommended limit of 50 mg/L for treated effluent discharge. BOD signifies the quantity of oxygen that living organisms would consume while eating away at organic matter, or rather in an aerobic situation. A high BOD indicates that the gray-water hides a lot of biodegradable organic materials like body fat, soap and skin coming from the shower water. If such water is disposed of or reused without proper treatment, the oxygen that is needed for microbial breakdown will out-compete the one used by aquatic organisms, which will eventually result in oxygen depletion.

4.3.1 VARIATION OF BOD AND COD IN GREY WATER THROUGHOUT THE DAY

Grey water has been mainly produced in schools from kitchen, bathroom, and laundry uses. With the passage of time, the quality of this grey water varies, thus affecting its parameters like Biochemical Oxygen Demand (BOD) and Chemical

Oxygen Demand (COD). These fluctuations are mainly caused by humans' different activities and the differing amounts of water being produced at different times.

Morning

The generation of grey water in the morning is at its highest point when most of the students and staff take their baths, brush their teeth, and do laundry. Soaps, detergents, body oils, and a little bit of organic matter make up the grey water at this time. Consequently, BOD and COD levels range moderately high because of both fresh organic input and higher concentrations.

On the other hand, the highwater volume leads to slight dilution thus lowering the concentration of the pollutants a bit**. (fig6)**

Afternoon

In the afternoon, the production of grey water is less because most daily activities have already taken place. The water might become a bit stagnant, which would allow some microbial degradation to happen. The BOD and COD values are moderate or slightly lower than in the morning due to the less addition of fresh organic matter to the system.

Evening

Grey water production in the evening goes up again because of increased bathing and cooking activities. This water usually contains food particles, grease, soaps, and other organic pollutants in higher proportions. Hence the BOD and COD levels are highest at night due to a higher concentration of pollutants and less dilution compared to the morning period.

Influence of grey water volume on BOD

The volume of water generated has an impact on the Biochemical Oxygen Demand (BOD) of grey water. **From fig6,** when the volume is high, such as during the morning, pollutants are more diluted thereby leading to a lower BOD concentration (dilution effect). In the case of the evening when the water volumes are low, there is less dilution of pollutants which results in the high BOD values. Hence, the concentration of BOD is inversely related to the volume of grey water produced. table

4.4 Total Phosphates

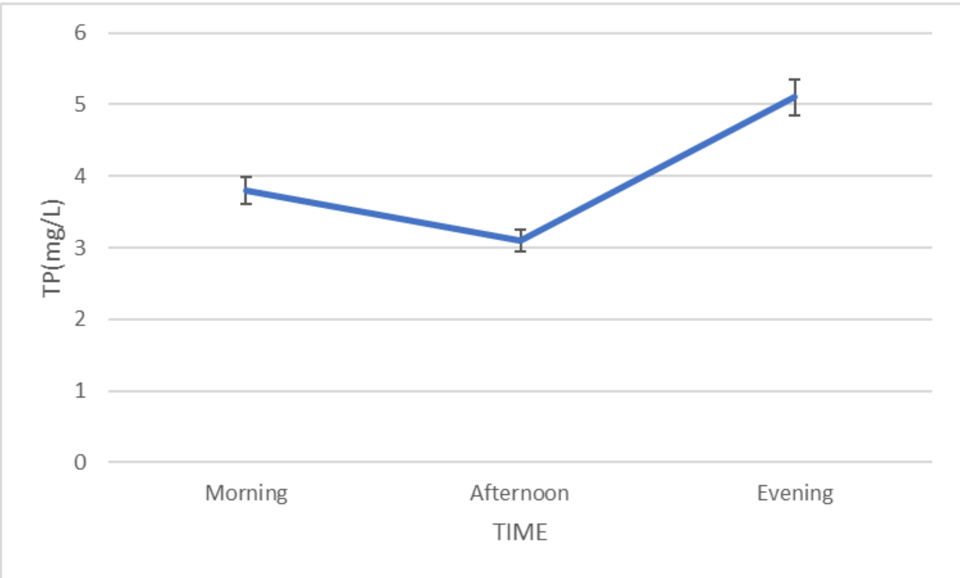

Figure 7: Variation of TP with time

The total phosphate concentration was found to be 5.1 mg/L, in the evening time which is slightly above the NEMA standards for effluent discharge of 5 mg/L. These results reflect detergent-based phosphate inputs a problem widely documented in African and Asian greywater streams (Eriksson et al., 2002). These values are nearly same as those found in Ethiopian and Kenyan institutional greywater (4-8 mg/L) where detergent regulations are weak similar to Uganda

Excessive phosphate levels can lead to eutrophication of surface water if runoff occurs. However, the moderate concentration observed in this study is not harmful. For irrigation purposes, such phosphate levels are beneficial, as phosphorus is a key nutrient that supports plant growth and root development.

But also applying phosphates grey water for irrigation might result in the soil's high phosphorus content which could change the chemical composition of the soil causing nutrient imbalance.

4.5 Total Suspended Solids (TSS)

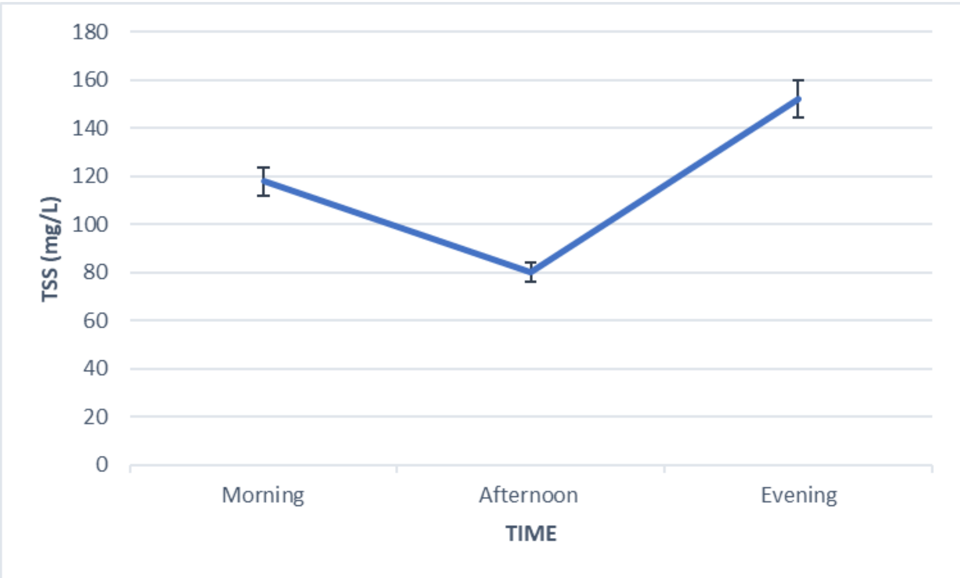

Figure 8: Variation of TSS with time

The evening value of Total suspended solids concentration was 152 mg/L which is more than the NEMA discharge limit of 50 mg/L. These values are the main factor in the rapid clogging of soak pits. In Uganda, it has been reported that soak pits with TSS >100 mg/L will lose their infiltration capacity within 6–12 months due to the formation of a bio mat (Semiyaga et al., 2015). The TSS levels are over this limit in **fig 8** thus demonstrating that the failure of the system was anticipated.

TSS is made up of very tiny particles like silt, hair, soap residues, and other organic waste usually found in grey water. The presence of high TSS can slow down the water movement in soil and that can eventually lead to sealing up the surface and clogging the soak pits. The high TSS value implies that effective sedimentation or filtration is required before the grey water is approved for watering plants.

4.6 Ph

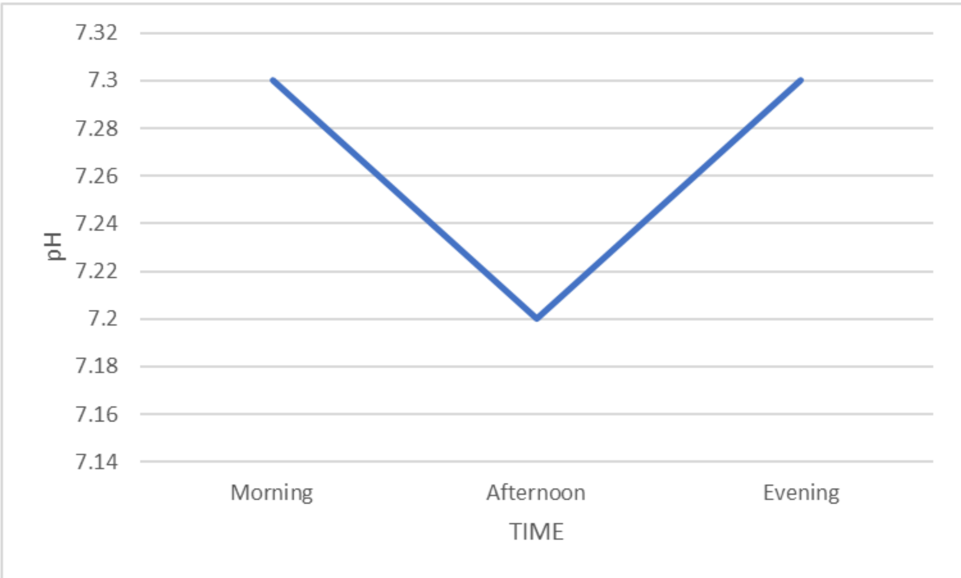

Figure 9: Variation of pH with time

The pH of the grey water was 7.3 in the evening and morning time which falls within the NEMA and WHO acceptable range of 5.0 to 8.5 for effluent discharge reuse. This means that the grey water is not acidic or strongly alkaline hence it is safe for all types of soils and plants. A pH of 7 neutral helps nutrients and microorganisms in the soil.

4.7 Electrical Conductivity (EC)

The Electrical Conductivity (EC) was found to be 265 µS/cm, which is significantly lower than the NEMA recommended maximum limit of 1000 µS/cm. The measurement of EC indicates the amount of dissolved ions including sodium, chloride, and sulfate that are present in the water. Low EC values indicate low salinity, which is ideal for irrigation because it minimizes the risk of salt accumulation in soil and prevents osmotic stress in plants.

High EC values, by contrast, suggest high salt levels that can damage soil structure and inhibit plant water uptake. Therefore, the recorded EC value (tab shows that the grey water poses minimal risk of soil salinization and is appropriate for reuse after basic treatment.

4.8 PERCENTAGE REDUCTION OF CONTAMINANTS WITH PLAIN AND TREATED QUATRZ SAND

4.8.1 COLUMN EXPERIMENTS

Column experiments were carried out for adsorption and filtration with different bed heights, surface areas and with plain quartz sand and treated quartz sand at different contact times.

Results showed that there is a higher percentage removal of contaminants by increase in contact time from 30minutes to 60minutes and bed height of treated quartz sand from 20cm was 40cm because adsorption is time dependent. The plain quartz sand showed a smaller percentage of contaminant reduction indicating that treatment(modifying) was necessary. This was indicated by different percentages by the parameters measured before and after treatment of grey water. The treated quartz sand showed better results possibly because higher adsorption capacity of iron oxides for contaminants. These findings are similar to studies in Kenya and South Africa where ICQS increased phosphate removal by 40–80% and enhanced organic matter capture (Oteng-Peprah et al., 2018)

Table 4: Percentage reduction of contaminants by untreated quartz sand and treated quartz sand after column experiments

	Untreated quartz sand		Treated quartz sand	
Media depth(cm)	20	40	20	40
Parameter	**Percentage reduction (%)**			
COD	11.8	22.1	44.1	47.1
BOD	21.6	29.7	40.5	51.4
Total phosphates	34.5	37.5	41.2	50.4
Turbidity	10	11.6	20.8	49.6
TSS	35.2	39.8	62.9	70.3

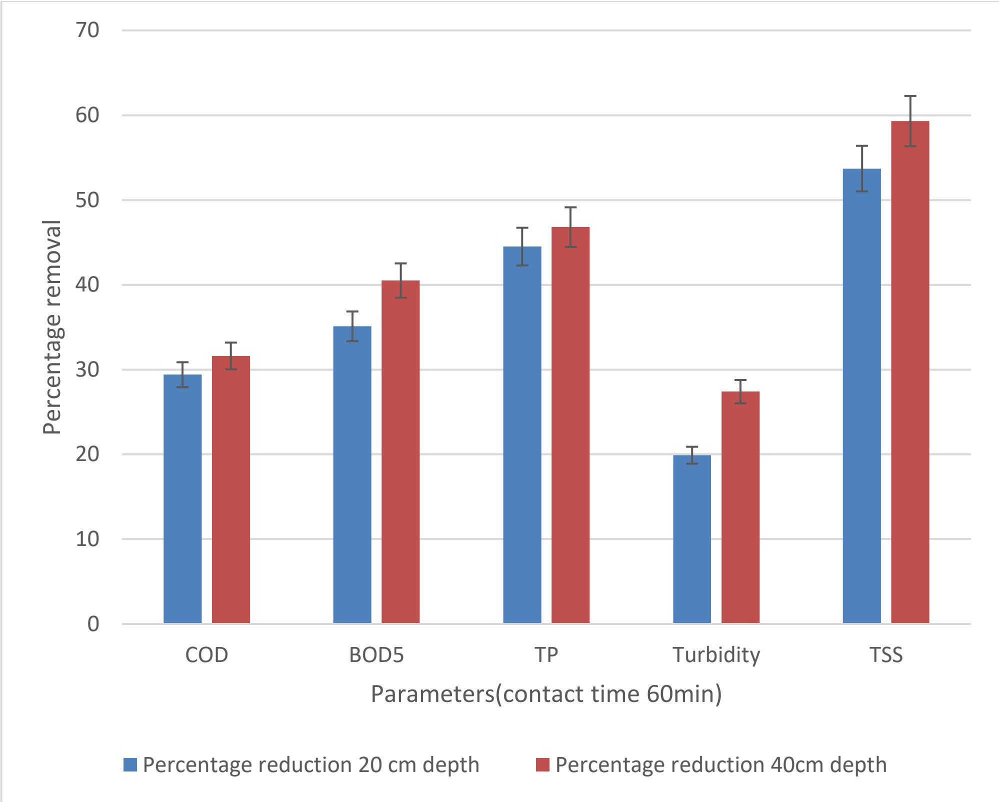

Figure 10: Percentage reduction of contaminant with contact time 60 minutes

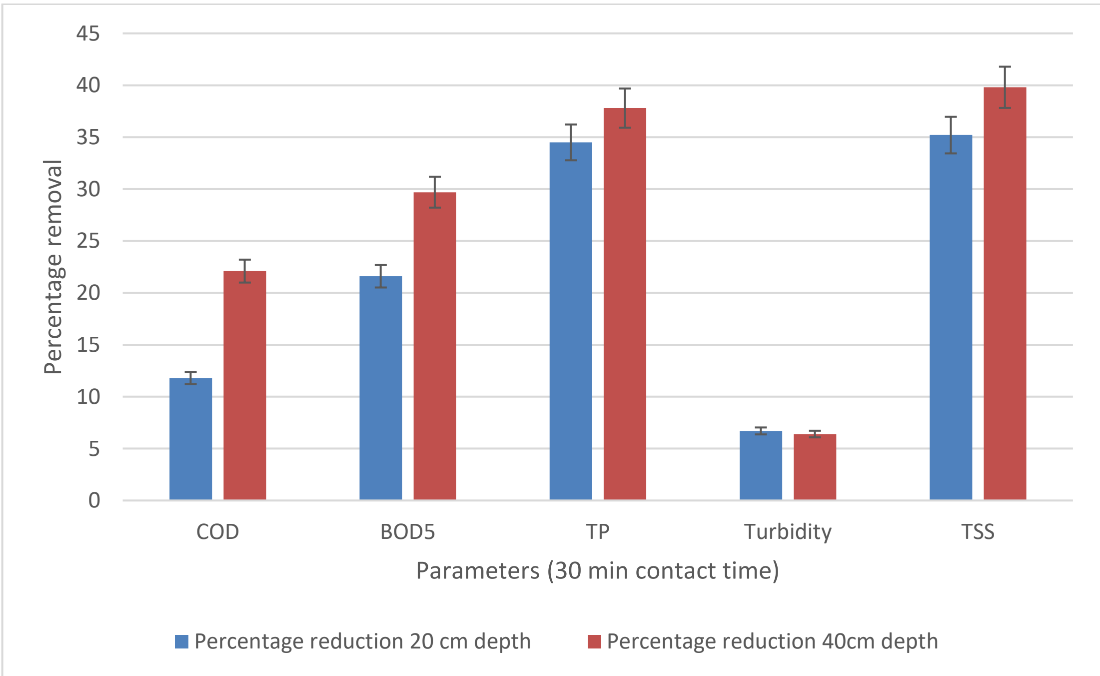

Figure 11: Percentage removal with contact time 30 minutes

The percentage of contaminant reduction was between 20% and 58% with contact time 60minutes and between 10% and 48% with contact time 30minutes for all the parameters. A higher percentage removal was noted with more contact time in the media

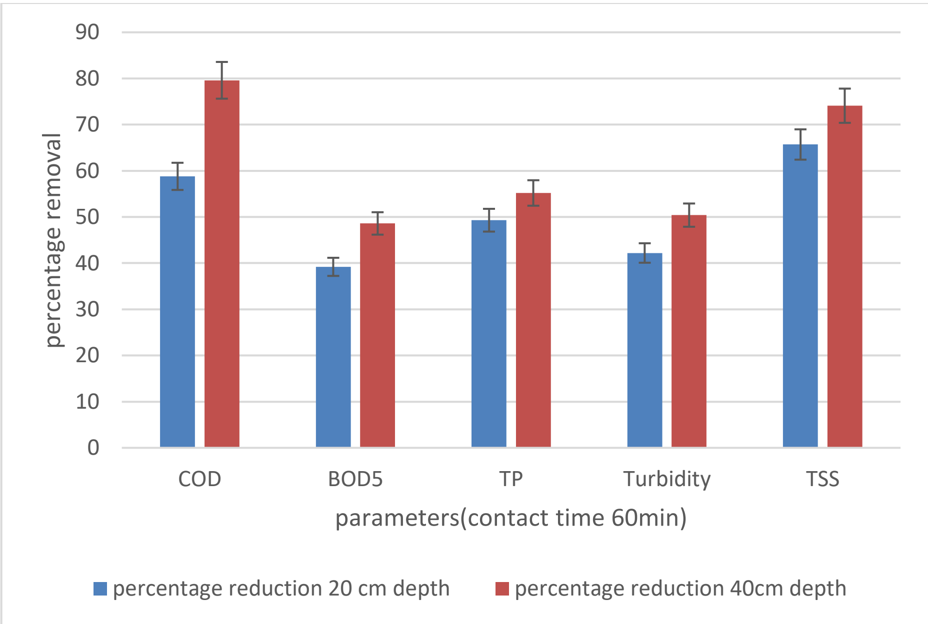

Figure 12: Percentage reduction of with treated quartz sand

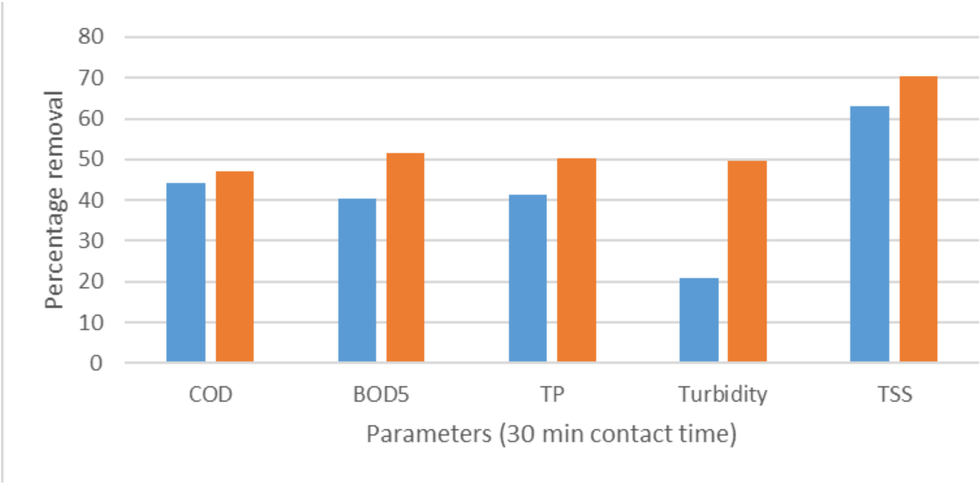

Figure 13: A graph of percentage reduction with treated quartz sand

Percentage removal of contaminants with iron coated quartz sand was between 20% and 70% with contact time 30minutes and 40% and 80% with contact time 60 minutes

This indicated that the performance of treated sand outweighed the plain quartz sand. The 40cm depth column reduced 47% COD, 51% BOD, 50% TP, and 70% TSS removal, thus outperforming plain sand (22%, 30%, 38%, and 40% respectively).

Laboratory scale experiments with bed height 40cm showed higher percentage removal compared to 20cm height because the higher the depth, the more the time the water stays thus increased reduction of contaminants. More contact time improved the performance of the filter media.

Through the column experiments, it was determined that ICQS was able to achieve a TSS removal rate of 70.3% (with a bed depth of 40 cm), which is consistent with (Xu et al.2020) findings that iron-coated surfaces facilitate depth filtration(**fig13**)

4.9 COMPARISON OF PLAIN QUARTZ SAND AND TREATED QUARTZ SAND IN CONTAMINANT REDUCTION

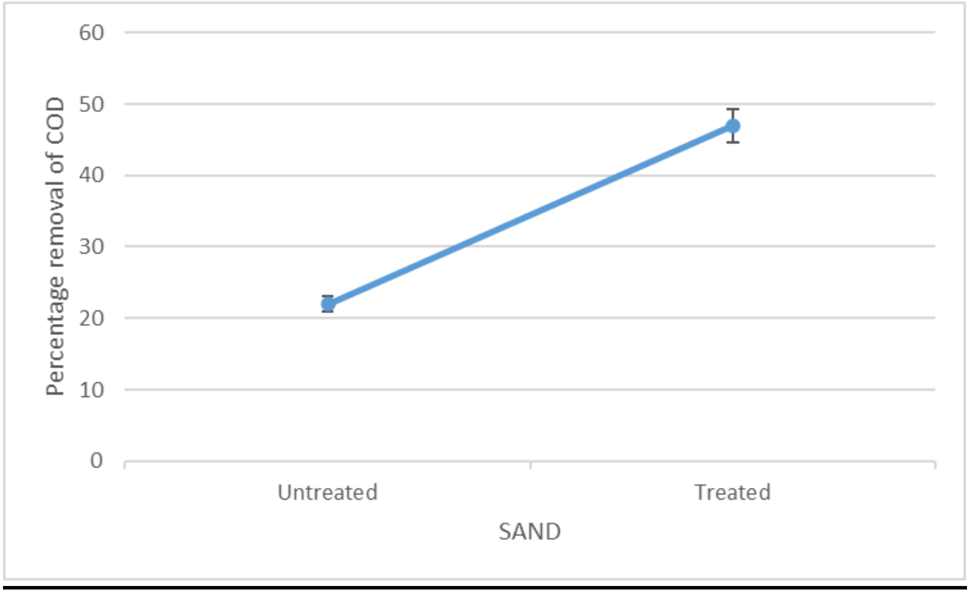

Figure 14: Percentage removal of treated and untreated sand for COD

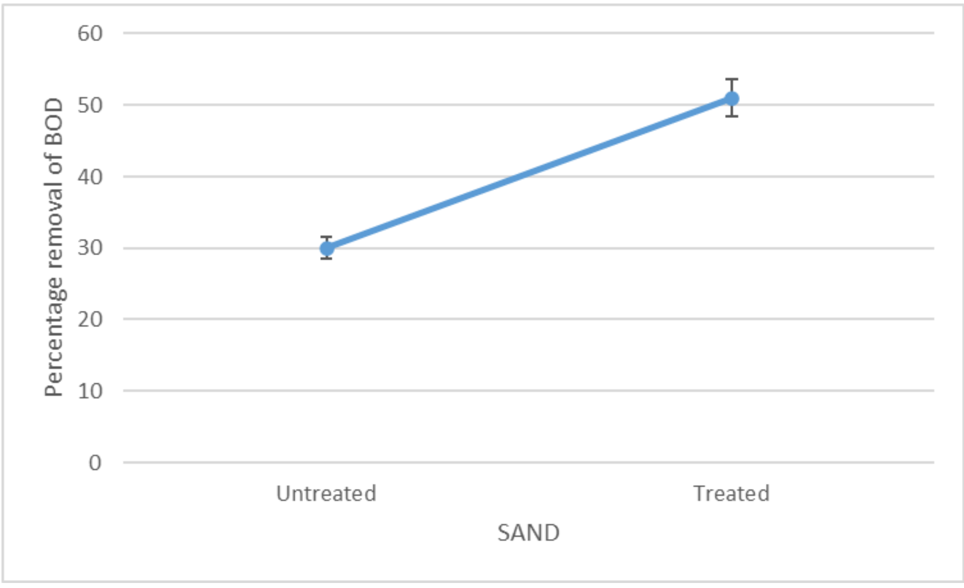

Figure 15: Percentage reduction between untreated and treated quartz sand for BOD

Percentage removal of COD increased from 22% to 47% with treated sand and from 30% to 51% for BOD. This is possibly due to higher adsorption capacity of iron oxides on the coated sand for contaminants in grey water as supported by Liu et al. (2018)

Also, the increased surface area and electrostatic interactions provided by the rough iron coating which also improves depth filtration by trapping finer particles (Xu et al., 2020). Treated quartz sand has a positive surface charge at neutral pH whereas uncoated sand is negatively charged under similar conditions.

4.10 DESIGN CALCULATION (Metcalf and eddy)

Sedimentation tank

Retention time (1-3 hours)

Design flow capacity 21m3/day   21/24= 0.875m3/hr

Over flow rate 12m3/day 12/24=0.5m3/hr

Tank depth 2.5m

Tank volume= 0.875x3= 2.625m3

Surface area=0.875/0.5 =1.75m2

For a rectangular tank, L=3W

W=0.76m

L=2.3m

Adsorption and filtration chamber

Filter type: vertical

Design flow capacity=21m3/day

Time to filter 1 liter= 2minutes

Flow rate=1/2=0.5litres per minute

Depth= 1m

Cross section area=0.07m2

Storage tank volume= 22.5m3

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study assessed the use of iron-coated quartz sand (ICQS) for greywater treatment in institutions of Uganda. The greywater from St. Francis Borgia was characterized and found to have high levels of organics (BOD, COD) and suspended solids (TSS) that exceed NEMA discharge standards, confirming that it is necessary to be treated before reuse or disposal. Iron coated quartz sand proved more effective than plain quartz sand in removing contaminants. At a 40 cm bed depth, it achieved removal percentages of approximately 51% for BOD, 47% for COD, 50% for Total Phosphates, and 70% for TSS. The enhancement is attributed to the adsorption capacity of the iron oxide coating, particularly for phosphate removal via ligand exchange.

Based on the experimental results, a treatment unit comprising screening, sedimentation, and Iron coated quartz sand filtration was designed for the school which has a daily flow of 21 m^3 of grey water. The design incorporates the optimal parameters that is bed depth and contact time

Finally, Iron coated quartz sand presents a viable, low-cost, and technically effective filtration medium for the primary treatment of institutional greywater. If incorporated in institutions for grey water treatment for reuse will help conserve freshwater, reducing environmental pollution, promoting public health and sustainable water management in schools.

5.2 RECOMMENDATIONS

Adopt the use iron-coated quartz sand treatment unit to enhance safe reuse of greywater for irrigation and landscaping.

Monitor the treated grey water and the long-term use of treated quartz sand to ensure there is no leaching of iron into treated grey water

Conduct routine monitoring of treated greywater quality to ensure compliance with irrigation water standards.

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APPENDICES

APPENDIX A1: OVEN DRYING, SAMPLE PREPARATION

APPENDIX A2: MEASURING MASS OF FERRIC CHLORIDE, DIRECT READING MACHINE, BOD REACTOR

APPENDIX B: LABORATORY RESULTS

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

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

Student: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 04[th] October , 2025.

Analysis Laboratory results for waste water sampled on 04th October 2025

Parameter Description	Morning 7:30am	Afternoon 01:30pm	Evening 06:30pm	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	140	135	156	70
Biological Oxygen Demand (BOD)	64	60	84	50
Total Phosphates (TP)	4.31	3.72	5.66	5
Turbidity	35.62	34.19	46.14	25
Total Suspended Solids (TSS)	128	132	155	50
pH	7.34	7.20	7.28	5.0 - 8.5
Electrical Conductivity	231	242	248	1000

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 10/10/2025
M22B32/039 Nimusiima Editor

NATIONAL WATER AND SEWERAGE CORPORATION
10 OCT 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: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 30th September , 2025.

Analysis Laboratory results for waste water sampled on 30th September 2025

Parameter Description	Morning 7:30am	Afternoon 01:30pm	Evening 06:30pm	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	128	76	135	70
Biological Oxygen Demand (BOD)	57	38	70	50
Total Phosphates (TP)	3.80	2.77	5.60	5
Turbidity	22.70	18.42	28.41	25
Total Suspended Solids (TSS)	108	37	118	50
pH	7.21	7.28	7.30	5.0 - 8.5
Electrical Conductivity	231	224	251	1000

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 06/10/2025
M22B32/039 Nimusiima Editor

NATIONAL WATER AND SEWERAGE CORPORATION
06 OCT 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: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 19th September , 2025.

Analysis Laboratory results for waste water sampled on 19th September 2025

Parameter Description	Morning 7:30am	Afternoon 01:30pm	Evening 06:30pm	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	146	95	148	70
Biological Oxygen Demand (BOD)	65	50	70	50
Total Phosphates (TP)	3.21	2.82	4.06	5
Turbidity	30.60	27.30	38.40	25
Total Suspended Solids (TSS)	120	72	184	50
pH	7.40	7.26	7.38	5.0 - 8.5
Electrical Conductivity	272	259	279	1000

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

Analysed by: Wanyera Julius (QCO) & 27/09/2025

M22B32/039 Nimusiima Editor

NATIONAL WATER AND SEWERAGE CORPORATION

25 SEP 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

NATIONAL WATER AND SEWERAGE CORPORATION
23 OCT 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

Student: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 17 th October , 2025.

Analysis Laboratory results for waste water (Composite) received on 17th October 2025.

Before treatment.

Parameter Description	Units	Results	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	128	70
Biological Oxygen Demand (BOD)	mg/L	66	50
Total Phosphates (TP)	mg/L	3.184	5
Turbidity	NTU	29.4	25
Total Suspended Solids (TSS)	mg/L	126	50
pH	-	7.24	5.0 - 8.5
Electrical Conductivity	µS/cm	246	1000
Iron: Total	mg/L	0.01	0.3

After treatment with sand filter media contact time (30 mins).

		Plain sand		Treated sand		
		Media depth (cm)				
Parameter Description	Units	20	40	20	40	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	125	117	96	80	70
Biological Oxygen Demand (BOD)	mg/L	60	57	48	40	50
Total Phosphates (TP)	mg/L	3.092	3.080	2.991	2.651	5
Turbidity	NTU	28.4	25.2	20.3	15.2	25
Total Suspended Solids (TSS)	mg/L	124	122	119	89	50
pH	-	7.16	7.08	7.14	7.12	5.0 - 8.5
Electrical Conductivity	µS/cm	236	240	230	226	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

After treatment with sand filter media contact time (60 mins).

Parameter Description	Units	Plain sand		Treated sand		Effluent Discharges Standard
		Media depth (cm)				
		20	40	20	40	
Chemical Oxygen Demand (COD)	mg/L	110	94	82	73	70
Biological Oxygen Demand (BOD)	mg/L	54	52	45	38	50
Total Phosphates (TP)	mg/L	2.173	2.083	1.983	1.752	5
Turbidity	NTU	20.6	19.7	14.8	12.7	25
Total Suspended Solids (TSS)	mg/L	118	108	87	54	50
pH	-	7.15	7.13	7.14	7.12	5.0 - 8.5
Electrical Conductivity	µS/cm	235	239	230	223	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 23/10/202
M22B32/039 Nimusiima Editor

NATIONAL WATER AND SEWERAGE CORPORATION
23 OCT 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION
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NATIONAL WATER AND SEWERAGE CORPORATION
03 NOV 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

Student: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 27th October , 2025.

Analysis Laboratory results for waste water (Composite) received on 27th October 2025.

Before treatment.

Parameter Description	Units	Results	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	156	70
Biological Oxygen Demand (BOD)	mg/L	65	50
Total Phosphates (TP)	mg/L	5.662	5
Turbidity	NTU	56	25
Total Suspended Solids (TSS)	mg/L	134	50
pH	-	7.20	5.0 - 8.5
Electrical Conductivity	µS/cm	243	1000
Iron: Total	mg/L	0.01	0.3

After treatment with sand filter media contact time (30 mins).

		Plain sand		Treated sand		
		Media depth (cm)				
Parameter Description	**Units**	**20**	**40**	**20**	**40**	**Effluent Discharges Standard**
Chemical Oxygen Demand (COD)	mg/L	146	132	125	86	70
Biological Oxygen Demand (BOD)	mg/L	74	62	61	59	50
Total Phosphates (TP)	mg/L	5.321	5.016	4.329	4.260	5
Turbidity	NTU	52	50	42	28	25
Total Suspended Solids (TSS)	mg/L	137	128	95	82	50
pH	-	7.18	7.16	7.16	7.12	5.0 - 8.5
Electrical Conductivity	µS/cm	240	239	236	235	1000
Iron: Total	mg/L	0.01	0.00	0.00	0.00	0.3

NATIONAL WATER AND SEWERAGE CORPORATION

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

Student: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 05 th November , 2025.

Analysis Laboratory results for waste water (Composite) received on 05th November 2025.

Before treatment.

Parameter Description	Units	Results	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	124	70
Biological Oxygen Demand (BOD)	mg/L	46	50
Total Phosphates (TP)	mg/L	3.723	5
Turbidity	NTU	28.416	25
Total Suspended Solids (TSS)	mg/L	87	50
pH	-	7.09	5.0 - 8.5
Electrical Conductivity	µS/cm	254	1000
Iron: Total	mg/L	0.01	0.3

After treatment with sand filter media contact time (30 mins).

		Plain sand		Treated sand		
		Media depth (cm)				
Parameter Description	Units	20	40	20	40	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	120	108	74	72	70
Biological Oxygen Demand (BOD)	mg/L	55	52	46	40	50
Total Phosphates (TP)	mg/L	2.960	2.830	2.531	1.902	5
Turbidity	NTU	26.4	24.6	25.6	22.1	25
Total Suspended Solids (TSS)	mg/L	70	68	66	42	50
pH	-	7.14	7.14	7.12	7.13	5.0 - 8.5
Electrical Conductivity	µS/cm	250	248	246	245	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

After treatment with sand filter media contact time (60 mins).

Parameter Description	Units	Plain sand		Treated sand		Effluent Discharges Standard
		Media depth (cm)				
		20	40	20	40	
Chemical Oxygen Demand (COD)	mg/L	84	68	75	38	70
Biological Oxygen Demand (BOD)	mg/L	40	37	32	17	50
Total Phosphates (TP)	mg/L	2.436	2.372	1.848	1.312	5
Turbidity	NTU	22.38	18.93	19.44	16.36	25
Total Suspended Solids (TSS)	mg/L	63	52	39	23	50
pH	-	7.12	7.11	7.11	7.11	5.0 - 8.5
Electrical Conductivity	µS/cm	240	238	236	236	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 11/11/2025
M22B32/039 Nimusiima Editor

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

NATIONAL WATER AND SEWERAGE CORPORATION

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

Student: M22B32/039 Nimusiima Editor

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 11 th November, 2025.

Analysis Laboratory results for waste water (Composite) received on 11th November 2025.

Before treatment.

Parameter Description	Units	Results	Effluent Discharges Standard
Chemical Oxygen Demand (COD)	mg/L	136	70
Biological Oxygen Demand (BOD)	mg/L	74	50
Total Phosphates (TP)	mg/L	3.912	5
Turbidity	NTU	25.62	25
Total Suspended Solids (TSS)	mg/L	108	50
pH	-	7.25	5.0 - 8.5
Electrical Conductivity	µS/cm	248	1000
Iron: Total	µS/cm	0.02	0.3

After treatment with sand filter media contact time (30 mins).

		Plain sand		Treated sand		
		Media depth (cm)				
Parameter Description	**Units**	**20**	**40**	**20**	**40**	**Effluent Discharges Standard**
Chemical Oxygen Demand (COD)	mg/L	120	106	76	72	70
Biological Oxygen Demand (BOD)	mg/L	58	52	44	36	50
Total Phosphates (TP)	mg/L	2.563	2.432	2.300	1.940	5
Turbidity	NTU	23.9	21.4	20.3	12.9	25
Total Suspended Solids (TSS)	mg/L	70	65	40	32	50
pH	-	7.18	7.16	7.14	7.16	5.0 - 8.5
Electrical Conductivity	µS/cm	243	240	242	242	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

After treatment with sand filter media contact time (60 mins).

		Plain sand		Treated sand		
		Media depth (cm)				
Parameter Description	**Units**	**20**	**40**	**20**	**40**	**Effluent Discharges Standard**
Chemical Oxygen Demand (COD)	mg/L	96	93	56	50	70
Biological Oxygen Demand (BOD)	mg/L	48	44	32	21	50
Total Phosphates (TP)	mg/L	2.083	1.982	1.832	1.362	5
Turbidity	NTU	20.5	18.6	16.3	13.2	25
Total Suspended Solids (TSS)	mg/L	50	44	37	28	50
pH	-	7.16	7.16	7.16	7.16	5.0 - 8.5
Electrical Conductivity	µS/cm	242	242	242	242	1000
Iron: Total	mg/L	0.00	0.00	0.00	0.00	0.3

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 17/11/2025
M22B32/039 Nimusiima Editor

NATIONAL WATER AND SEWERAGE CORPORATION
17 NOV 2025
WATER QUALITY MANAGEMENT DEPT
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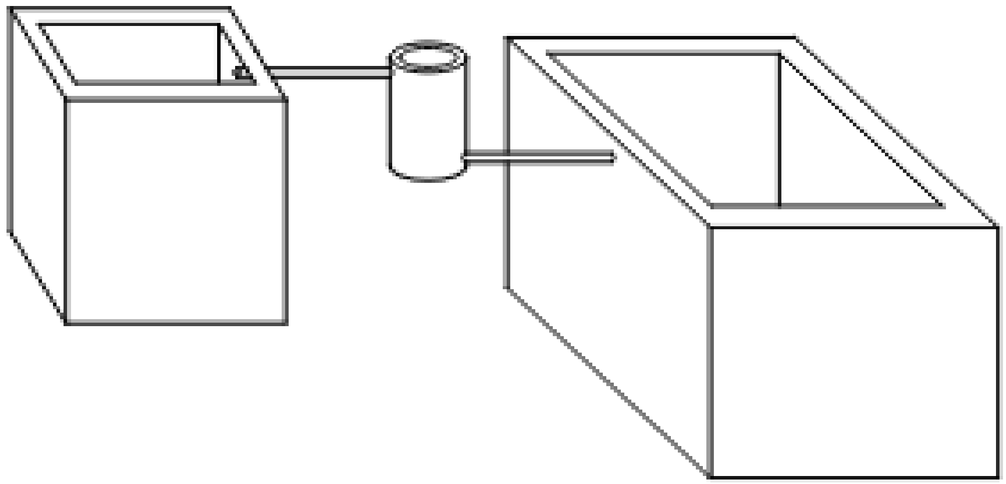
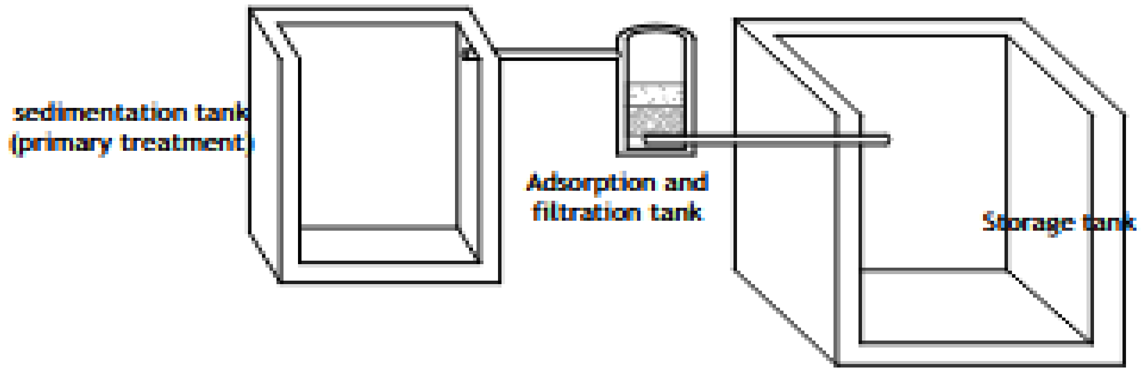
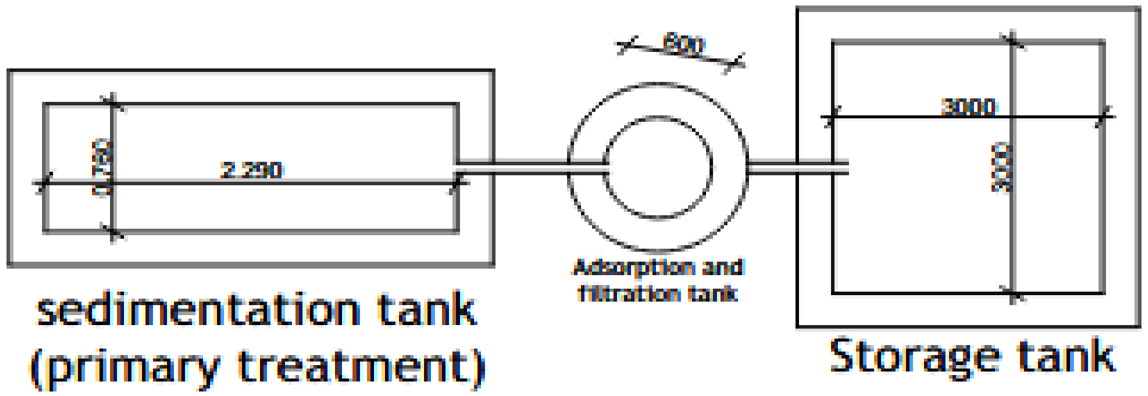


3D Diagram 1:75



3D Cross section 1:75



Plan View 1:40

PROJECT;-

ASSESSING THE USE OF COATED QUARTZ SAND IN GREY WATER TREATMENT FOR REUSE

DROWING NAME;- **PLAN VIEW, 3D VIEW AND 3D VIEW CROSS SECTION**

DRAFTED BY;- **NIMUSIMA EDITOR M22B32/039**

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