VERMIFILTRATION OF SLAUGHTERHOUSE WASTEWATER: A CASE STUDY FOR KAMPALA CITY ABATTOIR

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ABSTRACT

This research focuses on treating the wastewater that is generated from the Kampala city abattoir using the vermifiltration system. It is highly recommended within the Wastewater Management Guide for abattoirs that “small and affordable effluent treatment plants can be assembled using locally available equipment” (Kampala Pollution Task Control Task Force, 2016). The vermifiltration system has been used to treat several other kinds of wastewater, however, through this study, its potential for the treatment of slaughterhouse wastewater was investigated. This would require determining the characteristics of the wastewater, the optimal operational parameters particularly Hydraulic Loading Rate (HLR) and the Hydraulic Retention Time(HRT), which are key parameters for the functionality of a vermifilter. Using a laboratory scale prototype, it was identified that the requisite retention time for a vermifilter to treat slaughterhouse wastewater was 6 hours. With this, it would attain over 85% removal rates of BOD, COD and TSS, which rendered the wastewater safe for discharge into the environment. Though, system and design adjustments are necessary to ably treat large volumes of slaughterhouse wastewater, the vermifiltration system is a viable technological option for the treatment of slaughterhouse wastewater generated from abattoirs.

DECLARATION

I hereby declare that this is my original work, it is not plagiarized and has not been submitted to any other institution for any award.

Signed: ……………………………………………………………………………………………………

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

Name: ………………………………………………………………………………………………………

Registration Number: ………………………………………………………………………………..

APPROVAL

This research has been submitted for examination with my approval as the university supervisor.

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

Prof Sara Kizza Nkambwe.

Academic supervisor

DEDICATION

This project is dedicated to the family, friends and academic support system whose love, guidance and all manner of support were fundamental to the completion of this project. Their continuous encouragement and affirmation were remarkable in fostering my resilience and dedication to ensure that this work gets done to completion.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY OF TERMS AND ACRONYMS

TSS	Total Suspended Solids
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
FOG	Fats, Oils and Greases
EC	Electrical Conductivity
TP	Total Phosphorus
TN	Total Nitrates
HLR	Hydraulic Loading Rate
HRT	Hydraulic Retention Time
SHWW	Slaughter House Wastewater

Chapter 1: INTRODUCTION

1. 1: Background

As a result of urbanization at a fast pace, high population, rising incomes, and dietary preference changes, meat consumption has been rising in Uganda (FAO, 2021). In most regions in Uganda, people have conventionally eaten plant-based foods, but with a better economic status, there has been a rapid shift towards more consumption of goat meat, beef, chicken, and pork (UBOS, 2020).This meat production boom has also created environmental concerns such as high production of wastewater in abattoirs that pose risks to the receiving environment, like surface water bodies.

Slaughterhouse wastewater effluent is an environmental issue with huge organic loading in the form of blood, fats, oil, greases (FOG), total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) (Bustillo-Lecompte & Mehrvar, 2015). When directly discharged without being treated, the pollutants have the potential to contribute to severe water pollution, eutrophication, and water body oxygen consumption (Musa et al., 2018). The conventional techniques such as activated sludge and chemical coagulation are effective but energy intensive and expensive and therefore not suitable in decentralized or low-resource settings (Nasir et al., 2020).

Vermifiltration is an economical, environmentally friendly, and sustainable technology for wastewater treatment that has recently been developed as alternative technology in which earthworms and microbial biofilms are utilized to disintegrate organic material and destroy contaminants (Sinha et al., 2008).

Earthworms, such as Eisenia fetida and Eudrilus eugeniae, play an important role in degrading organic matter, filtration of filter media, and microbial growth stimulation, leading to enhanced BOD, COD, nitrogen, phosphorus, TSS, FOG, and turbidity removal (Li et al., 2021). The system also generates vermicompost as a suitable byproduct that can be applied agriculturally (Zhao et al., 2022).

Experiments have shown that vermifiltration systems give an efficiency of 90% or more for BOD and COD removal at economical operating costs and low energy requirements (Singh et al., 2017). Further, the technology has been utilized efficiently to treat residential, industrial, and abattoir wastewater, showing the potential and efficiency of the technology to suppress organic contaminants (Sharma & Garg, 2018). However, effectiveness is influenced by the species of worm, filter media content, flow rate, and conditions encountered (Li et al., 2021).

Considering the enormous need for a cheap and eco-friendly technology for treatment of slaughterhouse wastewater in Kampala, vermifiltration presents a viable alternative. After running the slaughterhouse wastewater through the vermifiltration system, the expected results are improved removal of the organic load, nutrients, and water quality before discharge into the environment.

1. 2: Problem statement

The Kampala City abattoir is the largest meat producing facility in Uganda. This abattoir is estimated to account for about 40% of the meat that is consumed in Kampala with a capacity of slaughtering about 1000 heads of cattle per day (Nyandebo & Bagla, 2022). Despite having the capacity to separate the solid waste from the liquid waste, and transferring it to another site for treatment, there is no provision for the on-site treatment of the liquid waste water that is produced from the abattoir.

When samples of the released waste water were taken for analysis, it was discovered that all parameters (BOD, COD, Nitrates, Electrical Conductivity, Total Phosphates, TSS, Turbidity) within the slaughter house waste water exceeded the permissible discharge standards according to the National Environmental (Standards for Discharge of Effluent into Water or Land) Regulations, 2020.

Given that this effluent contains large amounts of organic matter, Fats, Oils and Greases, nutrients, its direct disposal into the environment without any prior treatment can have detrimental effects to the receiving environment. The discharge of untreated slaughterhouse wastewater into natural water bodies poses significant environmental and public health challenges. It can lead to eutrophication, altering aquatic ecosystems, microbial contaminates increase in the water, and can also lead to a reduction in the oxygen levels within the surface water (Dalhatou.,et al, 2022).

Conventional waste water treatment methods, though effective, often require significant financial and technical investments that may not be feasible in resource-limited settings (Othman et al., 2022).

To solve such issues, inexpensive and environmentally friendly treatment methods have become more prominent. Vermifiltration is one such – This is a method that employs synergistic interaction of earthworms and microorganisms for waste water treatment (Gasemi., et al, 2020). Vermifiltration has been shown to be a sustainable solution since it can remove organic pollutants simultaneously, filter turbidity, and enhance nutrient recovery (Yadav et al., 2020). However, the potential of vermifiltrationi in treating Slaughterhouse waste water has barely been explored.

This study seeks to assess the efficiency of a vermifiltration system in treating slaughterhouse wastewater from Kampala city abattoir, targeting key parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and phosphorus. By leveraging natural processes, the research aims to contribute to the development of affordable and sustainable wastewater management strategies suitable for urban settings in developing countries.

1. 3: Objectives

Main objective

To Assess the potential of vermifiltration in the treatment of Slaughter House Waste Water.

Specific objective

1. To determine the characteristics of the Slaughterhouse waste water.
2. To determine the optimum Hydraulic retention time for the vermifilter
3. Design the vermifilter

1. 4: Research questions.

1. What are the characteristics of the Slaughterhouse waste water?
2. What is the optimum Hydraulic Loading rate that is required for the treatment of slaughterhouses waste water using a vermifilter?
3. What is the optimum Hydraulic Retention Time that is required
4. What are design dimensions for a vermifilter required in the treatment of Slaughterhouse Waste water?

1. 5: Justification

The effectiveness of vermifiltration systems largely depends on the selection of suitable substrates and earthworm species, which directly influence the degradation of organic contaminants and the overall treatment efficiency. This system mainly relies on the substrate media, the earthworms, and them microorganisms.

Substrate media provides essential structural stability to the filter bed, ensuring proper drainage and preventing clogging, which is critical for maintaining flow through the system. It is comprised of coarse aggregate at the lowest bottom level, followed by sand whose particle size is about 2mm in diameter and lastly the vermibed. It also offers a supportive environment for microbial communities that assist in breaking down organic matter (Bae et al., 2021). This substrate media bed also supports the filtration process through physical straining and adsorption, thereby trapping suspended and dissolved inorganic and organic matter. (Pragyan & Kakolikarar, 2021)

The use of earthworm species, namely Eisenia fetida, is the most important factor in the success of the vermifiltration process. Eisenia fetida can cope with high organic loads, including slaughterhouse wastewater. Eisenia fetida is well known for its consumption of organic matter, promotion of biodegradation of fats, oils, and grease (FOG), and enhancing substrate structure by burrowing activities (Yadav et al., 2021). Through their excretion, useful microbes are released that support the existing microbes that are essential for microbial breakdown of organic matter in the waste water (Saapi., et al, 2024). Microorganisms, however, carry out the role of biochemically breaking down the organic pollutants that are present in the Slaughter house waste water (Sudipti&Sakshi, 2021). Together, their use in a vermifiltration system represents a feasible, low-cost, and eco-friendly solution for the treatment of wastewater. The system enhances the general efficiency of the removal of pollutants, aeration of the system, and the recovery of nutrients, and is particularly well suited to the treatment of high-strength slaughterhouse wastewater in metropolitan areas (Sadeghi et al., 2022; Gao et al., 2023). With these natural materials and mechanisms employed by the system, it offers an environmentally friendly alternative to conventional wastewater treatment technology in a low-cost solution for low-resource settings (Xu et al., 2021).

1. 6: Scope:

Geographical scope

The city abattoir is located at Plot 28/40 Old Port Bell Rd, Kampala, Uganda

Chapter 2: LITERATURE REVIEW

2. 1: Waste water

Description:

This is water whose quality has been greatly affected as a result of contamination by domestic, industrial, commercial, and (or) agricultural activities. It contains pollutants such as organic matter, nutrients (e.g., nitrogen and phosphorus), heavy metals, pathogens, and chemical residues, which, if untreated, can pose environmental and public health risks if not treated. (Khan et al., 2020)

1) Types of water

Waste water can be categorized based on its origin and content. The different types include:

- Domestic waste water.

It is the type of waste water that originates from domestic processes such as bathing, cooking, and sanitation, domestic wastewater mainly contains organic material, nutrients, and pathogens. Treatment is necessary to prevent waterborne diseases and environmental pollution (Ali et al., 2022)

- Industrial Waste water

This type of waste water has its origin from industrial processes and can contain a wide variety of pollutants, e.g., heavy metals, organic chemicals and solvents. It is extremely variable in composition depending on the industry, and thus, needs specialized treatment interventions (Khan et al., 2020)

- Agricultural runoff

This is a type of waste water that originates from agricultural activities. It contributes to waste water in the form of runoff that contains fertilizers, pesticides and sediments. The runoff can lead to nutrient loading of water bodies, eutrophication and associated ecological impacts (Maddela et al., 2022)

- Urban runoff

Urban areas generate runoff that collects pollutants such as microplastics, hydrocarbons, and heavy metals from surfaces including rooftops and roads. The runoff typically enters water bodies without adequate treatment, leading to damage to aquatic ecosystems (Palermo et al., 2023)

- Slaughterhouse water

Meat processing plants are peculiar to this, slaughterhouse wastewater has high concentrations of organic matter, fats, oils, and grease (FOG) and requires specialized treatment processes (Khan et al., 2020)

Sources of water

The main causes of waste water are:

- Household: The residential areas discharge waste water from everyday activities such as bathing, cooking, and sanitation.

- Commercial centers: Some of the business centers that generate wastewater with organic material, chemicals and pathogens include restaurants, hotels, and hospitals.

- Industrial plants: Factories and manufacturing plants discharge wastewater with particular contaminates based on the production type.

- Agricultural activities: Agricultural activities generate runoff with fertilizers, pesticides and animals waste.

- Urban Runoff: Rainwater runoff in urban surfaces collects pollutants from these surfaces, contributing to wastewater streams.

Policies that govern the disposal of wastewater.

Effective wastewater management is regulated by policies at the international, regional and national levels to safeguard environmental and public health.

a) International Policies.

- Sustainable Development Goal 6 (SDG6): Established by the United Nations, SDG 6 aims to ensure availability and sustainable management of water and sanitation for all, emphasizing the importance of wastewater treatment and water quality (United Nations, 2015).
- European Union Water Framework Directive (2000/60/EC): This directive commits EU member states to achieve good qualitative and quantitative status of all water bodies, including comprehensive wastewater management strategies (European Commission, 2000).

b) National Policies (Uganda).

- The National Environmental Act, 2019: Uganda's framework for environmental management includes provisions for pollution control and mandates proper treatment of wastewater before discharge (NEMA, 2019)
- The Water Act, Cap 152: This act regulates water resources management, including the issuance of wastewater discharge permits and enforcement of standards (Government of Uganda, 1997).

2. 2: Waste water treatment mechanisms

Waste water treatment encompasses various processes to remove contaminants and ensure safe discharge or reuse.

a) Primary treatment

   This involves screening and sedimentation: Physical processes that remove large solids and settleable particles from wastewater.

b) Secondary treatment

   Biological Treatment: This utilizes microorganisms to degrade organic matter. Technologies include activated sludge processes, biofilm reactors and membrane bioreactors (Ali et al., 2022)

c) Tertiary Treatment

   This is advanced treatment: This involves the processes like filtration, disinfection, and nutrient removal to achieve higher effluent quality.

d) Nature- Bases solutions.

   This could include Constructed Wetlands and Biofilm-based systems: Employ natural processes involving plants microbial communities to treat wastewater sustainably (Palermo et al., 2023)

Slaughter house waste water.

Slaughterhouse wastewater, also known as abattoir wastewater, is a complex effluent generated from various processes within meat processing facilities. These processes include animal washing, bleeding, carcass dressing, equipment cleaning, and rendering. The resulting wastewater is characterized by high concentrations of organic matter, nutrients, and pathogenic microorganisms, making it a significant environmental concern.

Characteristics

- High organic load: Wastewater from the slaughterhouse contains high levels of blood, fat, protein, and carbohydrate and thus high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). High organic load makes it a strong pollutant (Adeleye et al., 2023)
- Nutrient Rich: Wastewater contains high nitrogen and phosphorus levels because of blood content and tissue residues. The nutrients can lead to eutrophication in receiving waters
- High Suspended solids: Wastewater contains high amount of suspended solids like hair, tissue fragments, fecal matter, which cause turbidity and sedimentation.
- Fats, Oils, and Greases (FOG): Slaughterhouse wastewater has high FOG content, which has a tendency to clog sewerage systems and float as scum on water surfaces.
- Pathogenic Microorganisms: The wastewater may contain a variety of pathogenic bacteria (e.g., E.coli, Salmonella), viruses, and parasites from animal feces and tissues that are deleterious to human and animal health (Olukanni et al., 2022)
- High color and Turbidity: Blood and tissue residues impart dark color and high turbidity to the wastewater that leads to aesthetic degradation of water bodies.
- pH variations: depending on operations, the pH can vary, and often needs to be neutralized before discharge.

Potential detrimental Effects of untreated slaughterhouse wastewater:

If discharged into the environment without prior treatment, Slaughterhouse waste water can have the following consequences:

- Surface Water pollution: The high organic load, which consequently leads to an increases in BOD and COD levels, thereby depleting the dissolved oxygen in the water can lead to mortality of the aquatic life. The excess nutrients, as earlier mentioned can lead to eutrophication, which results into algal blooms.
- Soil Contamination: Untreated wastewater may contaminate soil with pathogens, heavy metals, and surplus nutrients. This is harmful to soil fertility and puts crops and groundwater at risk.
- Groundwater contamination: Nitrates and pathogens from raw wastewater can infiltrate groundwater. This adversely impacts ground water quality.
- Public health risks: If humans get exposed to the pathogens in the wastewater, it can lead to waterborne disease transmission.
- Odor nuisance: Organic waste decay in the wastewater can be offensive-smelling, and it could affect adjacent communities.
- Negative effects to aquatic ecosystems: The high organic load and turbidity can disrupt aquatic ecosystems. This can affect fish populations and other aquatic organisms. (Eze et al., 2024).

Generally, the Slaughterhouse waste water, if untreated, can pose detrimental environmental challenges. However, appropriate treatment technologies can effectively mitigate its impact. Implementing a combination of preliminary, primary, secondary and tertiary treatment methods, including advanced oxidation processes, is crucial for ensuring the safe disposal or reuse of this waste water.

2. 3: Vermifiltration: An Eco-friendly Approach

Description:

Vermifiltration is a biological wastewater treatment system that leverages the combination of earthworms, microorganisms, and the filter media to treat the wastewater. It is an eco-friendly and cost-effective approach, particularly suitable for treating organic-rich wastewaters like slaughterhouse effluent, municipal effluent, and sometimes grey water.

Working mechanism.

The vermifiltration system typically consists of a bed of filter media (e.g., sand, gravel, saw dust, vermicompost). The layers are usually arranged in such a way that the vermibed (in our case we used vermicompost) on top, sand in the middle and finally gravel at the bottom. When waste water is applied to the surface of the filter bed, it percolates through the media, the earthworms and associated microbial communities work synergistically to remove pollutants.

- Earthworm activity: Earthworms consume organic matter and microorganisms present in the wastewater. Their digestive systems breakdown complex organic compounds into simpler, more stable forms. Hey also enhance the porosity and aeration of the filter media through their burrowing and casting activities (Ansari & Raj, 2020).
- Microbial action: The filter media provides a habitat for diverse microbial communities, including bacteria, fungi, and protozoa. These microorganisms are important in the biodegradation of organic pollutants. Earthworm activity stimulates microbial growth and activity, creating a highly efficient treatment system (Gajendran et al., 2021).

- Filtration: Physical filter medium holds back particulate matter and suspended solids from wastewater. Earthworm castings also contribute to natural filtration along with enhanced removal of pollutants.
- Nutrient removal: Vermifiltration removes effectively nutrients such as nitrogen and phosphorus from wastewater. The microorganisms and earthworms incorporate these nutrients, and nitrogen is eliminated through denitrification.
- Pathogen Reduction: Synergistic action between earthworms and microbes significantly reduces the level of pathogenic microorganisms in wastewater. Earthworms consume and destroy pathogens, whereas microbial competition and antagonism also remove pathogens (Sinha et al., 2020)

Advantages of Vermifiltration:

- Low energy consumption: The vermifiltration system does not require a lot of energy since it mostly relies on gravitational flow and biological processes.
- Simple operation and maintenance: The vermifiltration system requires minimal technical expertise. Thus, with a simple ease-to-follow instructions guide, anyone can operate the system.
- Cost-effectiveness: This systems relies on locally available material which makes it cost-effective.
- Effectiveness: It has quite effective in the removal of organic matter, nutrients, and pathogens from wastewater.
- Production of valuable vermicompost: Earthworm castings can be used as fertilizers in other soils.

- It is environmentally friendly: The use of vermifiltration if environmentally friendly and sustainable.

The vermifiltration system or technology can be applied to treat different kinds of wastewater, that is to say:

- Domestic waste water
- Slaughterhouse wastewater
- Dairy wastewater
- Industrial wastewater
- Landfill leachate

Types of Vermifilters

Vermifiltration systems can be divided according to their design and operational characteristics. Some of the different types are described below:

1. The Downflow Vermifilters:

These are most commonly used form of vermifilters. Here, the wastewater is sprayed onto the surface at the top of the filter bed and percolates downwards through the media. These systems are simple to design and operate. Flow through these systems is due to gravity. They are more effective in removing suspended solids and organic matter from wastewater. However, they can get blocked if the waste water has high suspended solids (Gajedran et al., 2021)

2. Up flow vermifilters

In this type of vermifilter, the waste water is introduced at the base of the filter bed and flows upwards. The system can provide better contact between earthworms and microorganisms and waste water. The up-flow systems could be more effective in removing nutrients and pathogens. They could also be effective in reducing clogging by allowing solids to settle at the bottom of the filter (Ansari&Raj, 2020).

3. Horizontal Flow Vermifilters:

Here, the wastewater flows horizontally through the filter bed. This design can be efficient for the treatment of large quantities of wastewater. Horizontal flow systems may provide a longer contact time between earthworms and microorganisms and wastewater. They may be less prone to clogging than downflow systems (Kumar et al., 2022).

4. Continuous flow vermifilters:

Wastewater is continually applied to the filter bed. This design is suitable for treating a uniform flow of wastewater. Continuous flow systems need careful control of hydraulic loading rate so that it does not get overloaded. They also offer a high level of treatment efficiency.

5. Batch Flow Vermifilters:

Batch wastewater is applied in the form of wastewater on the filter bed. Such a type proves to be excellent for handling irregular or variable flow of wastewater. Batch flow systems allow control of the treatment process. They tend to handle the removal of targeted pollutants more effectively.

6. Combined vermifilters.

These systems combine all types of vermifilters in an effort to maximize the treatment effectiveness. For example, it can be a combination of up flow and down flow vermifilters which are suitable in an effort to achieve high removal levels of the pollutants. These systems can be configured to have treat or specialize in specific wastewater characteristics.

7. On-site vermifilters.

These are compact vermifilters intended for domestic households or small communities. They treat domestic wastewater at the point of generation. They are extremely useful in rural or decentralized communities. (Singha et al., 2020)

The choice of a vermifilter will be based on several factors such as: flow rate, target treatment efficiency, and available resources. Each type has distinct pros and cons.

2. 4: Substrates

One of the key components of the vermifilter is the substrates to be used. This comprises of several substrates. The substrates are typically arranged in layers with coarse gravel and the bottom, relatively fine grave next, fine gravel follows and finally the most biologically active layer, which is the vermibed. This part of the vermifilter is extremely sensitive given that it serves as the host environment for the earthworms and most of the microorganism that are responsible for the organic biodegradation of the wastewater. Various substrates have been researched and utilized effectively in vermifiltration systems based on the treatment target, local availability of substrates, and the nature of the wastewater to be treated.

Typically Used Vermifilter Substrates

<u>Gravel and Sand Layers</u>

Sand and gravel constitute the lower layers in the majority of vermifilters, and their main functions are to provide support for upper substrates and physical filtration.

Gravel facilitates good drainage and aeration, and sand promotes mechanical entrapment of suspended solids (Yadav et al., 2013).

Coconut Husk and Coir

Coir and husk of coconut are common tropical bedding materials. They have high surface area for microbial colonization and also have moisture content, which is necessary to support worm activity. Coir also has lignocellulosic content in high proportion, so it is durable and not prone to rapid decomposition (Arora et al., 2020).

Wood Chips and Sawdust

They are sometimes added as bulking agents to the vermifilter to increase porosity. They do degrade, though slowly, and will immobilize nitrogen during the breakdown process, which can affect the treatment efficiency if not well managed (Zhao et al., 2010).

Activated Carbon and Biochar

They are utilized due to their high adsorption capability. Activated carbon or biochar, when mixed into vermifilter media, can improve the elimination of organic pollutants and heavy metals (Singh et al., 2017). Their extensive application might be restricted by cost and availability, though.

Natural Fibrous Materials (e.g., Rice Straw, Jute Fibers) Agricultural wastes like jute fibers and rice straw are gaining increasing popularity as vermifilters since they are cheap and biodegradable. They provide habitat for microorganisms and act as supplementary organic content for filter bed composting (Sinha et al., 2008).

Compost

Compost blended with cow dung is one of the most efficient and common substrates used for vermifiltration systems. As a bedding material and source of food for earthworms, the blend permits microbial and vermi-bioremediation processes. Cow manure is rich in organic matter, nitrogen, and microbial communities that trigger degradation of contaminants. When pre-composted and mixed with organic residues, e.g., market or kitchen waste, it is a nutrient source that supports dense microbial growth and earthworm activity (Arora et al., 2014). The synergy increases the degradation of organic matter and encourages the removal of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids from wastewater. The compost-cow dung mixture also enhances the buffer capacity of the filter to maintain the pH level favorable for microbes, and earthworms (Gupta et al., 2012). The substrate also favors stable aggregates that improve porosity and water-holding capacity. Besides, studies have shown that cow dung compost favors the survival and multiplication of key vermifiltration species such as Eisenia fetida, making it suitable for long-term system stability and performance (Yadav et al., 2013).

Chapter 3: METHODOLOGY

3. 1: Characterization of the SHWW.

To ably determine the composition of the slaughterhouse waste water, several tests were carried out in accordance to the Standard Operating Procedures for the National Water and Sewerage Corporation.

Table 1: Summary of tests

Parameter	**Standard test**
pH	Use of the pH meter.
BOD	Winkler or oxygen electrode method)
COD	Open reflux method
Total Phosphorus	Total phosphate method
Electrical conductivity	Electrical conductivity test
Turbidity	Use of the turbidimeter
Total suspended solids	Photometric method
Fats, Oils and Greases	Partition Gravimetric method

3. 2: Sampling

- The bottles to be used were cleaned with distilled water.
- The bottles were all marked with masking tape and markers to distinguish them from each other.
- Each bottle was used to collect the samples and later placed in an ice box as seen in the figure below

Figure 1: Sampling apparatus

- The entire box was covered with ice and tightly sealed to be transported to the laboratory at 4^0C
- At the laboratory, the samples were placed in the refrigerators awaiting the various tests that needed to be done.

Electrical Conductivity

Materials and reagents used

Table 2: EC analysis materials and reagents

Materials	Reagents
- 50ml beaker - Soft tissue - Conductivity meter	- Standard Potassium Chloride solution (0.10N): 0.7456g of anhydrous potassium chloride (dried at 105^0C) was dissolved in distilled water to make up to 1000ml at 25^0C. This became the standard reference solution with a conductivity of 1413µS/cm. - This solution was stored in a glass stoppered Pyrex bottle ready for use.

Procedure.

- The conductivity cell was rinsed with at least 3 portions of 0.01N KCL solution. The temperature at the 4^{th} portion was adjusted to 25.0
- The cell was rinsed with distilled water then followed by a portion of the sample to be tested.
- The conductivity meter was prepared in accordance with the instrument instructions manual.
- The probe was immersed in a beaker containing the sample solution. The probe was agitated to free up the bubbles from the electrode area.
- The reading on the conductivity of the sample was made.
- The readings were made in µS/cm at a temperature of 25^0C

pH

This stands for the logarithm of the hydrogen-ion concentration in moles per liter.

Materials used.

- pH meter: This was used in a battery-operated mode with temperature adjustment, reading to an accuracy of 0.1pH units
- Glass electrode: This had to be compatible with the pH meter used and should cover the entire pH range with minimum sodium ion error.

The reagents used were standard pH buffers (pH =4, pH = 7, Ph=9). These were prepared using the buffer tables.

Procedure

- The electrode was rinsed with distilled water and dried by gentle wiping with a soft tissue paper. This was done each time before applying the electrode to a new buffer solution sample.
- The instrument was calibrated according to the manufacturer's specifications
- The rinsed electrode (s) was put in a buffer solution 7.00 by adjusting the symmetry control.
- The rinsed electrode was put in a buffer of pH = 4.0 and also in pH 9.0. The reading of the appropriate number was adjusted by the Slope control
- The previous steps were repeated
- The buffer solution was discarded after use.

Total Phosphorus

The method used was the persulphate method. This was based on the principle that organically combined phosphorus and all phosphates should first be converted to orthophosphate. Then the wet technique is applied to ensure that the phosphorus is released as ortho-phosphate from organic matter.

Equipment and Apparatus

- Heating equipment
- Hot plate (30*50cm heating surface)
- Autoclave
- Spectrophotometer DR 3900, reading at 880nm
- Acid – washed glassware

Reagents

- Sulphuric acid, H2S04, 4M, 0.04M and 5N
- Potassium persulphate; $K_2S_2O_8$.50g/l: this was obtained by dissolving 5g of potassium persulphate in distilled water and diluted to 100ml.
- Potassium antimony tartrate solution: This was obtained by dissolving 1.37g of potassium antimony tartrate, K(Sbo)C4H40 in 400ml of distilled water.
- Ammonium Molybdate solution: This was obtained by dissolving 20g $(NH_4)_6Mo_7O_{24}.4H_20$ in 500ml of distilled water
- Ascorbic acid: obtained by dissolving 1.76g of ascorbic acid powder in 100ml distilled water
- Stock phosphate solution: Obtained by dissolving distilled water 0.2197g of potassium hydrogen phosphate, KH_2PO_4.This was after it had been dried in an oven at 105^0C. The solution was diluted to 1000ml
- The standard phosphate solution: This solution was obtained by diluting 10.0ml of stock phosphate solution to 1000ml with distilled 1.0ml = 0.5µg/P

Procedure

- 25.0ml of whole sample. This was acidified with 1ml H_2SO_4, 0.04M, then 5ml of digestion reagent was added and the mixture was mixed well.
- Blank (25ml of blank distilled water) was prepared. Phosphate standard was also prepared by taking 25ml of known standard concentration. Both blank and phosphate standard were treated in the same way as the sample.
- This was heated for 30 minutes in an autoclave at 120^0C and cooled at room temperature.

- The color reaction was made in the destruction bottles. 3m of combined reagent were added which comprised of 50ml of 5N H_2SO_4 +5ml potassium antimony tartrate +15ml ammonium molybdate and mixed well.
- Finally, 1ml of ascorbic acid was added to each sample and then swirled to mix.
- This was later allowed to stand for 20 minutes for blue color development.
- The concentration was then measured in mg/L at 880nm wavelength using the spectrophotometer DR3900 and multiplied the reading by the dilution factor.

It was important to note that the missed reagent had to be freshly prepared as was required.

Calculations.

The concentration of the Total Phosphorus in mg/L in the sample was obtained from

Sample TP conc. Mg/L = $\frac{mg/TP \times 1000}{sample\ volume\ (ml)}$

Total Suspended Solids (TSS)

The working principle is that a well-mixed sample is evaporated in a weighed dish and dried to constant weight in an oven at 103 to 105^{0}C

Apparatus and Equipment

- Evaporation dishes
- Glass micro-fiber papers
- Beakers

- Forceps
- Dissector
- Drying oven
- Analytical balance
- Marker pen

Reagents: Distilled water

Procedure

- Micro-fibre of 47mm was dried in an oven at 105^0C for 1 hour
- This was cooled in desiccators and weighed. The reading was noted.
- Each of the weighed paper was wrapped in aluminium foil to avoid moisture.
- A suitable volume of the sample was taken and filtered under suction using a glass microfiber paper, which had been previously dried at 105^0C and weighed.
- The residue was washed thoroughly with distilled water
- The wet glass micro-fiber was carefully folded into half using forceps
- The sample was placed back into aluminum foil
- This was then dried in the oven at 105^0C
- This was cooled in desiccators and then the glass micro-fiber was weighed with the residue to constant weight
- The difference in weight between the weight of the dry glass micro-fiber and the glass micro-fiber + residue gave the weight of the total suspended solids.
- The results were entered in the workbook and the later expressed in mg/L

Calculations

The difference in weight between the two papers was calculated and the total suspended solids in mg/l was obtained as:

TSS (mg/L) = $\frac{Weight\ of\ paper+weight\ of\ sample)\ (g)-weight\ of\ dry\ paper\ alone\ (g)\times10^{6}}{Simple\ volume\ taken\ in\ (ml)}$

Turbidity:

This was determined using the turbidimeter.

Procedure:

1. Calibration: Here a suspension of known turbidity was inserted in a standard tube.
2. The sample was thoroughly shaken until air bubbles disappeared and the sample was poured into the turbidimeter tube.
3. The standard was removed and the water sample was inserted.
4. The turbidimeter reading was taken. This was done three times and the average value was taken as the turbidity.

Total Nitrates

<u>Principle</u>

This test is based on the principle that the alkaline persulphate digestion converts all forms of nitrogen to nitrate. Sodium metabisulfite is added after the digestion to eliminate halogen oxide interferences. Nitrate then reacts with chronotropic acid under strongly acidic conditions to form a yellow complex with an absorbance maximum at 410nm.

Procedure

- The reactor was turned on to heat at 105^0C.
- Using the funnel, contents of Total Nitrogen Persulphate reagent powder were added to each of the two vials.
- 2ml of the sample were added to one vial. Then 2ml of the deionized water was added to the second vial.
- Both vials were caped tightly.
- They were shaken vigorously for at least 30 seconds to mix.
- The vials were inserted in the reactor and the lid was closed. This was then heated for 30 minutes.
- Then hot vials were then removed from the reactor and called to room temperature.
- The caps were removed from the digested vials and the contents of one Total Nitrogen (TN) reagent A powder pillow was added to each vial.
- The tubes were capped again and shaken for 15 seconds.
- The instrument timer was started. A three-minute reaction began.
- When the timer expired, the caps were removed from the vials and one TN reagent B powder pillow was added to each vial.
- The vials were capped again and shaken for 15 seconds.
- The instrument timer was gain started. A 2 minutes reaction period began. There after the caps were removed.
- The vials were capped and inverted 10 times and mixed.
- The instrument timer was started. A five-minutes reaction period was started. The yellow color intensified.
- The reagent was wiped blank and inserted into the 16-mm round cell holder.

- The instrument was zeroed so that it read 0.0mg/L N.
- The reagent vial was wipped and inserted into the 16-mm round cell holder.
- Then lastly the results in mg/l of TN were measured.

BOD

To determine the amount of organic matter present in the slaughterhouse waste water the BOD_5 test was carried out.

Apparatus

- Incubator
- BOD bottles, 400ml air tight glass bottle
- pH buffer solution
- Diluting phosphate
- BOD bottles, each of about 300ml
- Measuring cylinders and pipettes.
- Personal Protective Equipment

Procedure

Three bottles of 500l, washed with distilled water were used to collect the samples. The samples were transferred to the lab using in an icebox.

At the lab the samples were diluted using a nutrient solution which allowed for the microbes to be able to grow and perform well.

Given that the pH of the preliminary samples had already been between 6-8, there was no need for using a buffer solution.

The measuring of DO got started and the value obtained was recorded.

The diluted samples were then incubated for 5 days while maintained at a temperature of 20^0C.

After the 5 days, the amount of DO present was again measured using the DO meter.

Thus, the BOD was computed using the expression

BOD $=(DO_{Initial} - DO_{final}) \times The\ dilution\ factor.$

COD

Apparatus:

- Heating block, cast aluminum 45 to 50 mm deep.
- Oven
- Digestion vessels
- Ampule sealer
- Spectrophotometer , DR/2000, DR/20 10 or Cecil 1010
- Spectrophotometer cells

Procedure:

- The digestion tube was washed with 4M H_2SO_4 to prevent contamination.
- 2ml of sample was transferred to digestion tube and 2.0mls and 2mls of digestion solution was added.

- 2.0ml of H_2SO_4 was run down inside the tube so that an acid layer would formed under the sample. The tubes were tightly capped and swirled several times to mix completely.
- The tubes were placed in a preheated oven at about 150^0C during the 2 hours.
- The content was allowed to mix and the content were allowed to settle.
- The content was gently transferred to the next day without mixing to a 1 cm tube and the concentration was measured at 620nm against blank.
- The concentration of the samples was read and recorded

Calculation

COD (mg/l) = $\frac{mgO_2 \; in \; final \times 100ml}{mL \; Sample}$

Results expressed in mg/l.

Fats, Oils and Greases (Partition Gravimetric method)

Apparatus

- Separating funnel: 1L, with TFE stop clock
- Flasks (125ml)
- Water bath
- Filter paper or cotton balls
- Tripod stands
- Fume chamber.

Procedure:

- The collected samples were acidified to a pH of 2 by addition of 5ml of HCL 1+1

- The acidified sample was then transferred to a separating funnel.
- The bottle samples were carefully rinsed with 600ml of organic solvent. The was done in a fuming chamber.
- The bottles were then shaken vigorously for about two minutes
- The layers were let to separate.
- The aqueous layer was drawn off carefully.
- The solvent was drained through a funnel containing moistened solvent cotton balls in a pre-weighed flask.
- The solvent was then evaporated using a water bath at about 70^0C until all the solvent was driven off.
- The was cooled in a desiccator for about 30 minutes and the dry flask was weighed.

Calculation

The gain in weight of the flask was found to be equivalent to the Oil and Grease present.

Chapter 1: Oil and Grease (mg/l) = $\frac{(A-B)\times 10^6}{ml\ of\ sample\ taken}$

3. 3: Optimization of operational conditions.

Determination of the Theoretical Hydraulic Retention time

This involved the determination of the Rate of flow of the Slaughterhouse wastewater:

<u>Materials used:</u>

- A water bottle top.

- A timer
- A measuring tape.
- And all the PPE, including gloves, and protective shoes.

Procedure:

- The dimensions of the trench were taken including the with and the height and they were recorded.
- A distance of 5 meters was measured along the trench through which the wastewater was flowing.
- One person two people stood, each at one end of the measured distance.
- One held the water bottle top, with the timer.
- The water bottle top was released by the other partner. As soon as it was released, the timer was started.
- As soon as it reached the other partner, the bottle top was picked from the flowing waste in the trench and the consequently the timer was stopped.
- The time taken for it to reach was measured and recorded.
- The process was repeated three times.
- The results were tabulated.

Determination of the Actual retention time

Materials

- A 60l bucket and 3 approximately 15-liter buckets
- 2 mm fine sand
- 14 mm Coarse Aggregate of approximately

- Flexible 1.5ft flexible pipes.
- 2 Kg Eisenia Fetida Earth worms
- Compost to serve as the vermibed.

<u>Procedure:</u>

- The buckets were arranged as shown in the figure below
- The bigger bucket was placed above to allow for the flow of waste water by gravitational force.
- Layers of coarse gravel, fine sand and finally were place the lower buckets (vermifilters) at their respective buckets as indicated in the design in the appendix.
- The top most layer (vermibed) is where the earthworms were placed.

Figure 2: Prototype setup1

- They were given three days to acclimatize to the new environment.
- Plain water was the allowed to flow through the vermifilters just to clear up any debris, or turbidity that would otherwise compromise the results.
- The valve on the upper bucket was adjusted to ensure that the HLR is the maintained at the one obtained before.
- Then, the wastewater was introduced into the upper bucket.
- It was allowed to flow into all the buckets accordingly.

- Each of the three buckets was maintained at different HRT conditions. The two buckets which contained earthworms were at 4 hours and the other was at 6 hours. The control which had no earthworms was maintained at 5 hours.
- After the stipulated time, samples were collected and taken to the laboratory for analysis.
- Basing on the results, the vermifilter whose samples indicated best removal rates was considered and the respective retention time was finally considered as the optimal Hydraulic Retention time for a vermifilter in the treatment of slaughter house wastewater.

Performance Evaluation

The effectiveness of the pilot-scale system was evaluated by comparing the influent and effluent concentrations of pollutants such as BOD, COD, TSS, FOG, and phosphorus.

Operation and maintenance.

Vermin Activity and System Health: The earthworm population was monitored throughout the study to assess health, activity, and reproduction rates. Good enough, the earthworms remained health through the experiment and even several months after the experimentation period. Implying that the conditions (temperature, pH, salinity) were ideal for their thrival.

Chapter 4: DISCUSSION OF RESULTS

4. 1: Introduction

Here, the findings of this project are analyzed and interpreted in the context of the aims of the project. The data from the experiment are utilized in order to decipher the effectiveness of the vermifiltration as an effective method of wastewater treatment. The various parameters, such as the filtration efficiency, the role of earthworms in nutrient cycling, and the treated water quality, are examined. In comparing these results with the literature and theoretical expectations, this discussion will address the practical implications of the vermifiltration and its feasibility as a sustainable wastewater management solution. Additionally, any shortcomings and possibilities for future research will be identified, giving an integrated interpretation of the results and their utility in fostering environmental sustainability.

4. 2: Determination of the characteristics of the SHWW

The summary of the peak values obtained for each of the parameters are as indicated in the table below:

Table 3: parameter peak values

Parameter	Peak value	Standard
Fat, Oils and Greases (mg/l)	87.67	10
Nitrates (mg/l)	48.8	10
Total Phosphorus (mg/l)	24.7	5

Turbidity (NTU)	956.32	25
BOD (mg/l)	256	50
COD(mg/l)	488	70
TSS (mg/l)	426	50
Electrical conductivity (μs/cm)	922	1000

The standards indicated in the table above are in accordance to the The National Environment (Standards for Discharge of Effluent into Water or Land) Regulations, 2020.

The general overview for each parameter is as shown below:

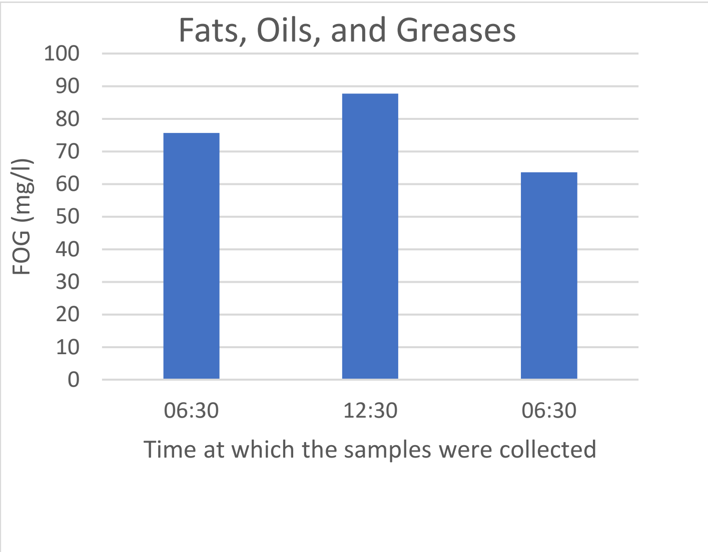

Figure 3: FOG Graph 1

According the graphs, the peak value of FOG was 87.67mg/l. This value is way above the disposal standards but since it is below 100mg/l, it is within the functional limits of a vermifilter. Thus, there is no need for grease traps in our design. It should be noted that Earth worms, which are key to the operation of the vermifilter are highly sensitive to high concentrations of FOG. If their concentrations exceed the minimum limits, they can potentially suffocate them by clogging their digestive systems, disrupt microbial activity since they can impair their biological processes which are essential to the organic waste breakdown.

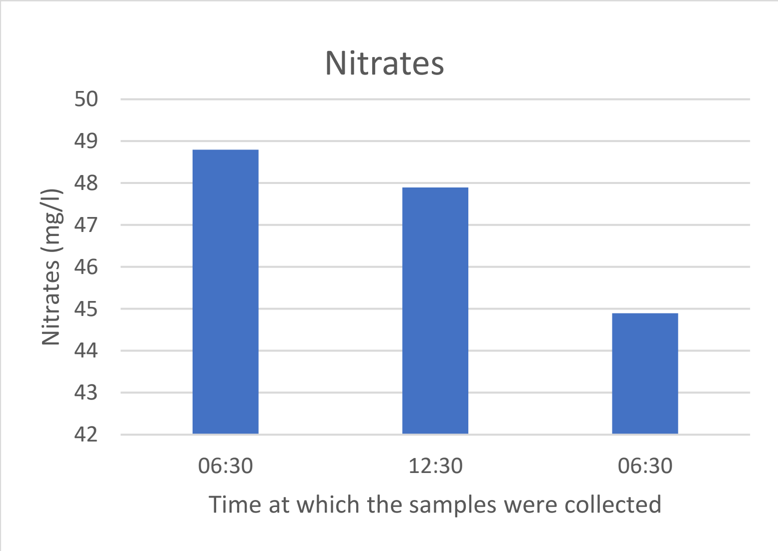

Figure 4: Nitrates Graph 1

These were equally high at a peak of 48.8mg/l, way above the disposal standard of 10mg/l. This implies the treatment is required. The presence of nitrates in this slaughterhouse waste water is mostly attributed to the presence of animal blood, which is high in proteins and nitrogenous compounds (Tiwari et al., 2020). Also, chemical treatments, and disinfectants used during mean processing, such as nitrogen-based compounds, may also contribute to elevated nitrate levels (Dey et al., 2018).

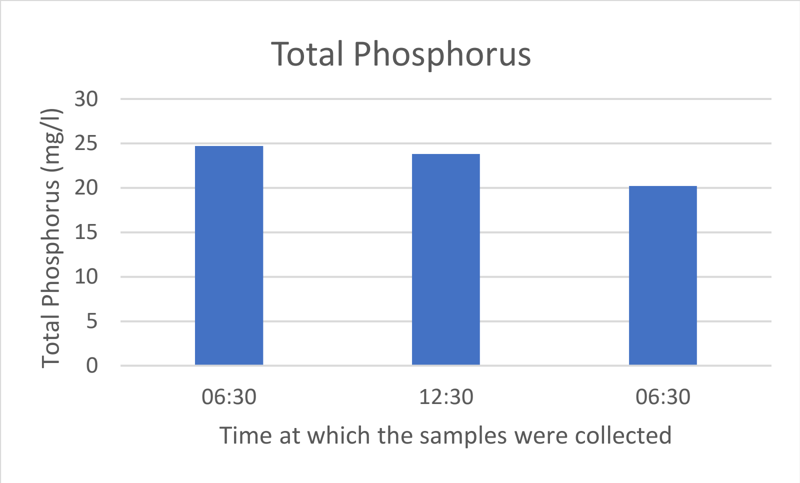

Figure 5: TP Graph 1

Phosphorus levels were above the disposal standards of 5mg/l. This is attributed to the fact that phosphorus is a naturally occurring element found in animal tissues particularly bones and blood. Some of the phosphorus is from feed, particularly in the digestive system, this enters the waste water stream during cleaning processes (Sanchez et al., 2019). This phosphorus is one of the major contributors to eutrophication if released into surface water bodies when it exceeds the standards for discharge.

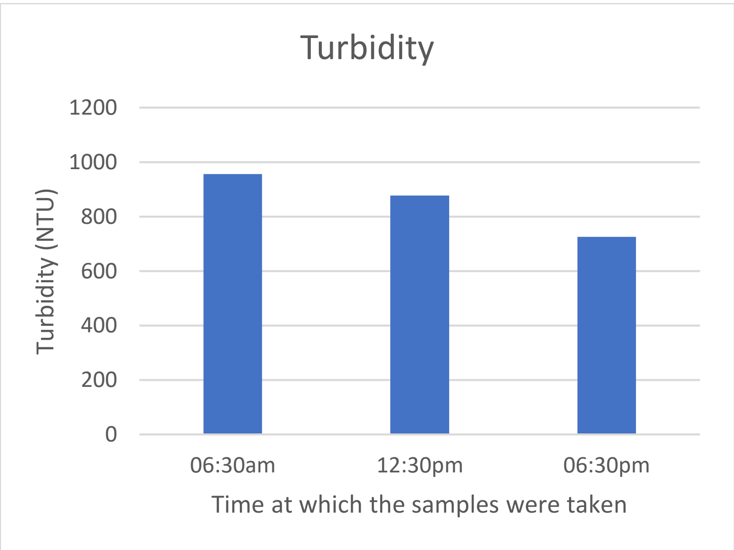

Figure 6: Turbidity Graph 1

The turbidity levels were high, also exceeding minimum discharge standards. This can be attributed to the presence of tissue debris, fats, intestinal content, and several others. One other cause is that blood, which contains cells, proteins, and other organic material that, when mixed with water, form a colloidal suspension (Tiwari et al., 2020). This suspension, along with solids from blood contribute to both the visible and non-visible turbidity in slaughterhouse wastewater.

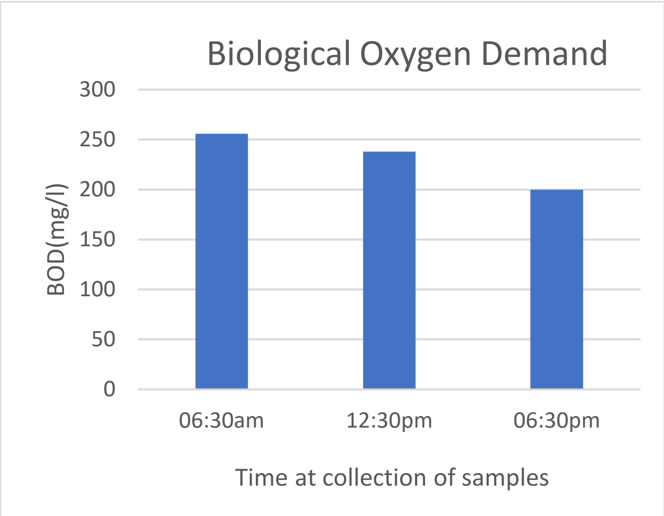

Figure 7: BOD Graph 1

Given the type of waste water we are dealing with, the organic load is high which leads to increase of BOD levels above the disposal standards of 50mg/l.

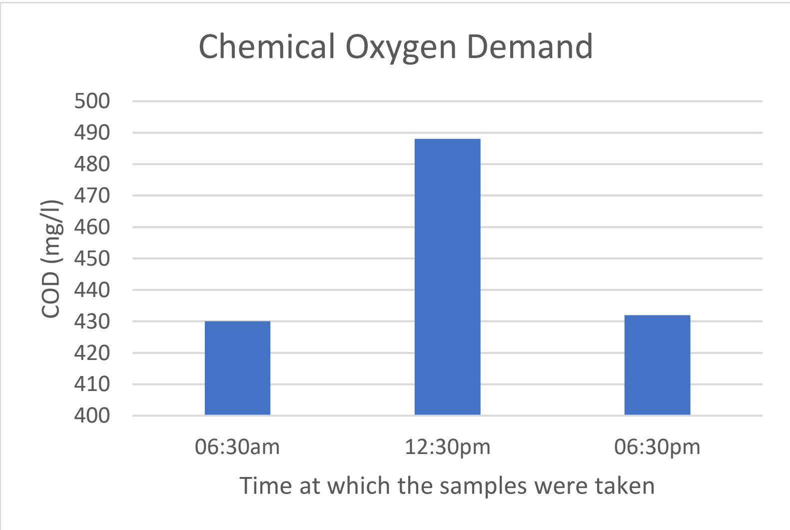

Figure 8: COD Graph 1

This, too, was above the minimum disposal standard of 70mg/l. This is because of the high organic matter in the waste water. This high organic matter is due to the presence of animal blood and organic tissues, FOG, animal feed residues (Sanchez et al., 2019).

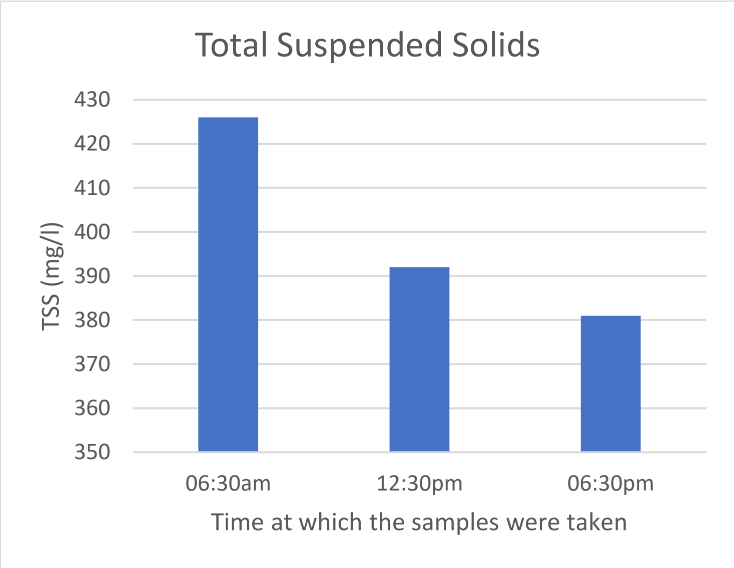

Figure 9: TSS Graph 1

This was above the standard of 50mg/l. This high value is due, among other to the debris of tissues, bones, that are released during the slaughtering process. Also, particulate matter contained in blood increases the TSS levels significantly (Tiwari et al., 2020).This will however, offer food particularly for the earth worms.

4. 3: Determination of hydraulic Retention Time

The values obtained were as shown in the table below:

Table 4: Flow velocity determination values

	6:00am			12:00pm			6:00pm		
Height(cm)	21			15			4 cm		
Attempts	1	2	3	1	2	3	1	2	3

Duration (Seconds)	14	15	16	17	18	21	27	30	26
Average Duration (seconds)	15			19			28		

It should be noted that the Width of the trench and the distance travelled by the bottle top were constant through as 33cm and 500cm respectively.

From the table, it was observed that the least average time taken for the bottle top to travel was 15 seconds. This this was considered to determine the peak velocity of the effluent using V = $\frac{Distance}{Time}$ = $\frac{5}{15} = 0.33m/s$

The cross-sectional areas of the channel at this time was also determined from

A = $\frac{1}{2}(a + b) \times H$

The channel was trapezoidal with dimensions as indicated below:

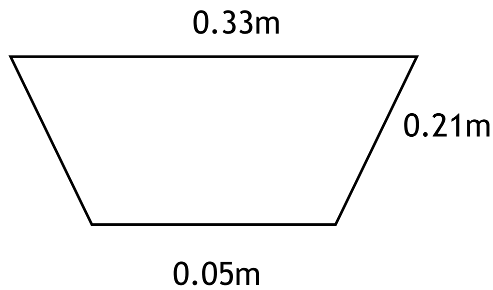

Figure 10: Schematic of the discharge trench

Thus, the Area, A = $\frac{1}{2}$(0.33+0.05)$\times$ 0.21= 0.0399m^2

Using the area and the velocity obtained above, the flow rate was obtained from

Q = AV

Q= 0.0399 $\times 0.33 = 0.013 m^3/s$

But HLR = Q/A = 0.013/1 = 0.013$m^3/m^2/s$ (Considering the area of the surface area of the vermifilter to be 1m^2.

Table 5: Quantities slaughtered

Month	Peak number of Slaughtered animals/days		Waste water produced
April	Cows	400	16000
	Goats	300	6000
	Sheep	70	1400
	Total		23400
June	Cows	770	30800
	Goats	700	14000
	Sheep	85	1700
	Total		46500
December	Cows	800	32000
	Goats	750	15000
	Sheep	100	2000
	Total		49000

From the table, it can be observed that the peak month is December with an average production volume of close to 50,000l of wastewater produced. This is attributed to the festive season, a season in which traditionally several people in Uganda celebrate with relatively higher meat consumption.

Analysis of laboratory results for the effluent.

For this to be determined, we required to run waste water through the prototype vermifiltration system shown below:

The results obtained were summarized in the table below

Table 6: Summary of lab results for objective 2

Parameter	**Units**	**Results**						
		Peak value Before treatment	Average value After treatment			Percentage removal		
				With earthworms				
			Control	**4 hours**	**6 hours**	**Control**	**4 hours**	**6 hours**
Fats, Oils and Greases (FOG)	mg/l	87.67	34.0	17.2	11.3	61.18	80.42	87.07
Nitrates	mg/l	48.8	33.9	10.2	8.3	30.53	79.10	82.99
Total Phosphorus	mg/l	24.7	11.6	5.4	4.9	52.90	78.14	80.16
Turbidity	NTU	956.32	282.0	383.3	268.3	70.51	59.92	71.94
Biological Oxygen Demand	mg/l	256	71.6	41.2	33.4	72.02	83.91	86.97

Chemical Oxygen Demand	mg/l	488	113.8	69.8	62.4	76.67	85.70	87.22
Total Suspended Solids	mg/l	426	64.0	33.7	22.0	84.98	92.10	94.84
pH		8.9	7.5	6.8	6.9	15.58	23.82	22.85
Electrical conductivity	µs/cm	922	776.7	718.0	620.0	15.76	22.13	32.75

According to the values indicated in the table above, after the introduction of earthworms into the vermifilters, there was a significant change in all the parameters. For most of the parameters, the percentage removals were above 80% as indicated. This was a positive remark.

Discussion:

Fats, Oils and Greases.

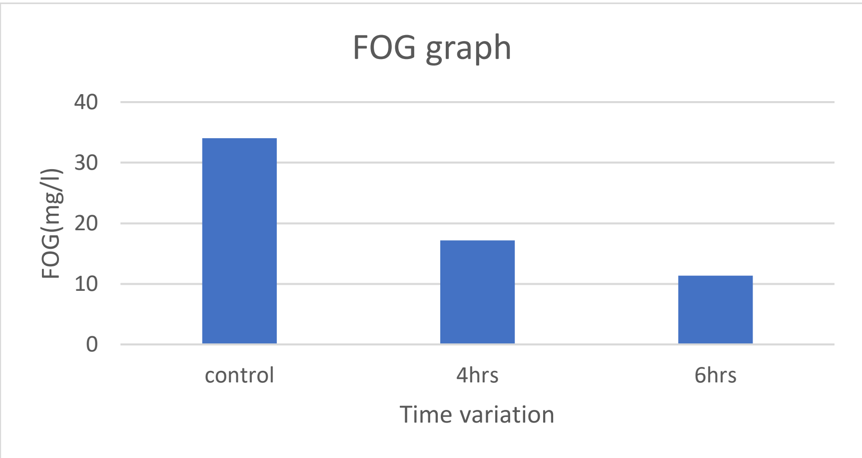

Figure 11: FOG Graph 2

For example, for FOG, the percentage removal after 6 hours was about 87.07% compared to the removal after 4 hours of about 80.42%. The variation can be illustrated in the graph above. According to other studies, this removal rate is similar and is mostly attributed to ability of earthworms to consume organic matter, including emulsified fats, and their gut enzymes assist in breaking down organic lipids (Yadav &Garg, 2021). Also, their movement within the filter media helps to distribute microbial populations effectively. Another factor is the fact that the filter media provides a large surface area upon which the FOG adhere, thereby reducing their mobility in the wastewater (Bhat et al., 2020). Over time the adsorbed fats are gradually degraded by microbial action. This implies that the vermifiltration system can actually reduce the Fats, Oils and Greases even without a grease trap provided preliminary analysis is done to ascertain that indeed the FOG in the influent is less than 100mg/l.

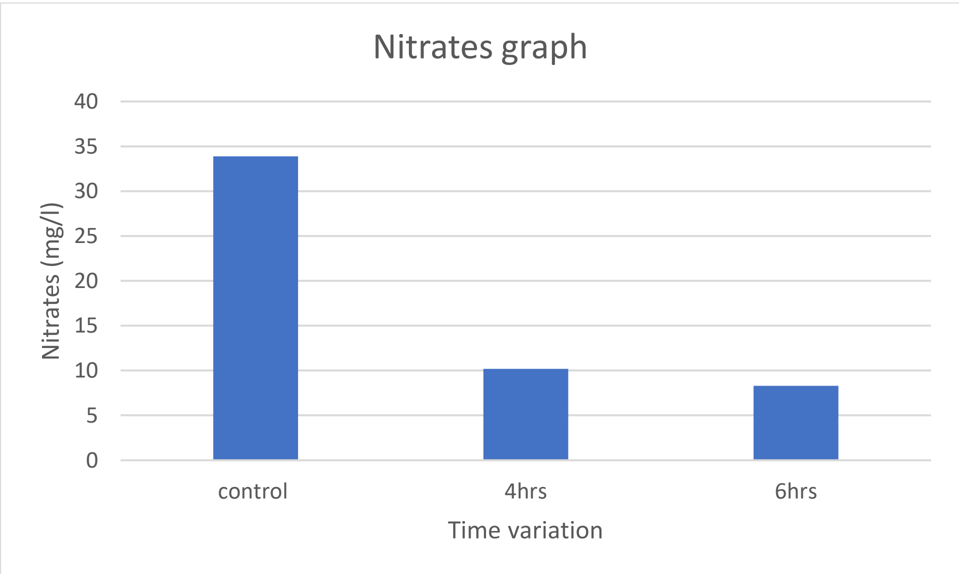

Figure 12: Nitrates Graph 2

The percentage reduction of nitrates after 6 hours was also above 80%, which is quite significant. According to other studies, this reduction is due to the microbial denitrification. Heterotopic bacteria, such as Pseudomonas, Bacillus, paraccoccus, thrive in the anoxic microenvironments within the filter media and convert nitrates into nitrogen gas (N_2), which is released into the atmosphere (Singh et al., 2017). This process follows the sequence:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Through this, the NO_3^- is reduced step by step into the molecular nitrogen. Another key factor is while breaking down organic matter, the earthworms create conditions for nitrification and denitrification (Yadav & Garg, 2021). Through their gut, the microbiota plays a role in nitrogen transformation, contributing to the nitrate reduction.

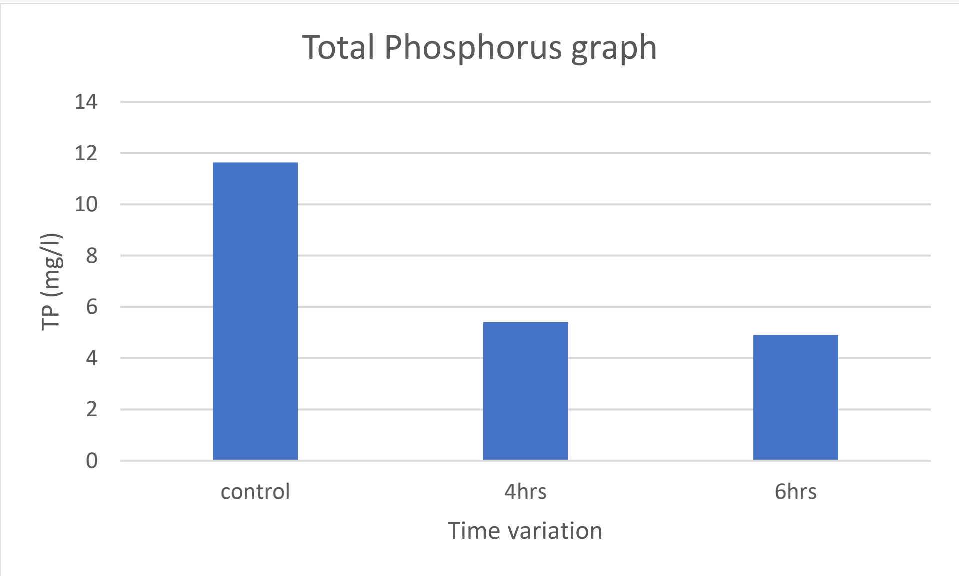

Figure 13: TP Graph 3

According to similar studies, the 80.1% removal of phosphorus can equally be attributed to similar mechanisms just like the removal of nitrates from the slaughterhouse waste water. However, one other contributor to this reduction rate is the adsorption by the filter media. The filter media materials provide binding sites for phosphate ions, reducing their mobility in wastewater (Bhat et al., 2020). The efficiency of adsorption depends on the media's composition; for instance, calcium-rich media facilitate phosphate precipitation as calcium phosphate.

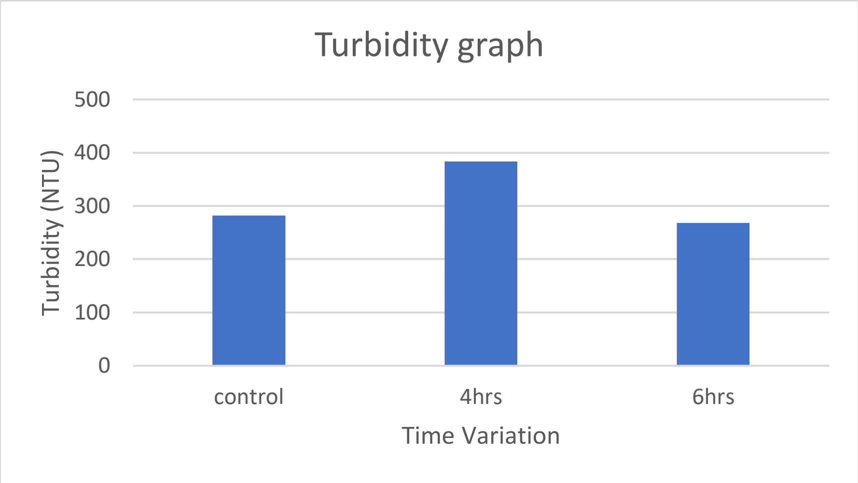

Figure 14: Turbidity Graph2

Unlike other parameters, the turbidity levels didn't reduce as much. This was largely due to the material we chose to use in the vermibed. We used vermicompost. This material was comprised of several components, including cow dung, which, if mixed with water, would naturally lead to increased turbidity. The mild reduction rates are mostly due to the filtration mechanism of the media (Bhat et al., 2020). As waste water percolates through the filter layers, particulate matter is retained, leading to a significant reduction in turbidity. There is also biofiltration due to the earthworm activity (Yadav & Garg, 2021). One fundamental limitation here was the fact that the compost used in the vermibed contained highly turbiditious materials, particularly from cow dung. That's why the results obtained were not so similar to what other studies have.

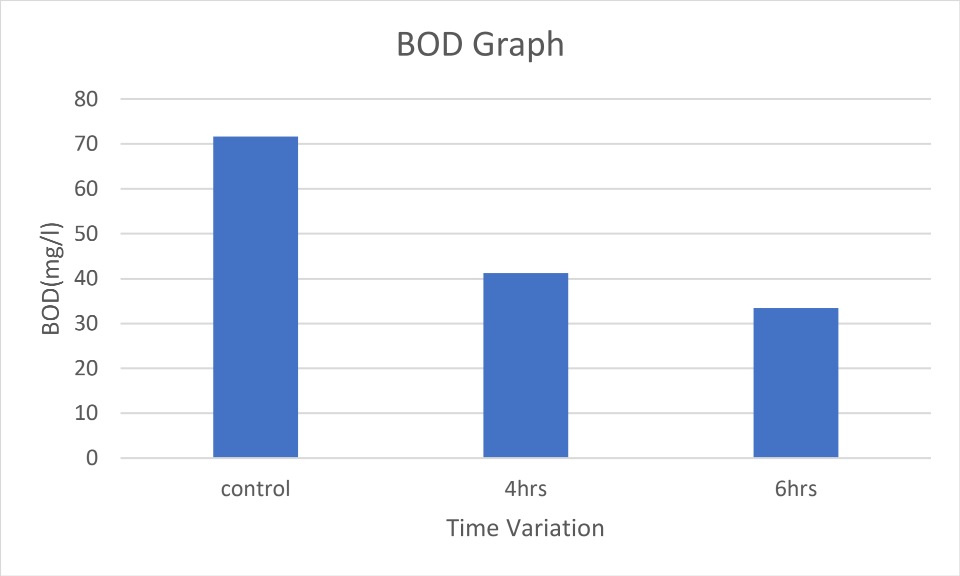

Figure 15: BOD Graph 2

The BOD reduction levels were approximately 87%. In comparison to other studies, these reduction levels are primarily due to microbial degradation. The filter media supports the growth of aerobic and facultative bacteria. This bacteria plays a crucial role of metabolizing organic pollutants and converting them into simpler, less harmful compounds such as carbon dioxide and water (Singh et al., 2017). While the earthworm's barrow through the filter media, they enhance aerobic conditions which lead to an increase in oxygen levels. This microbial respiration, accelerates the breakdown of biodegradable organics, which significantly reduces BOD.

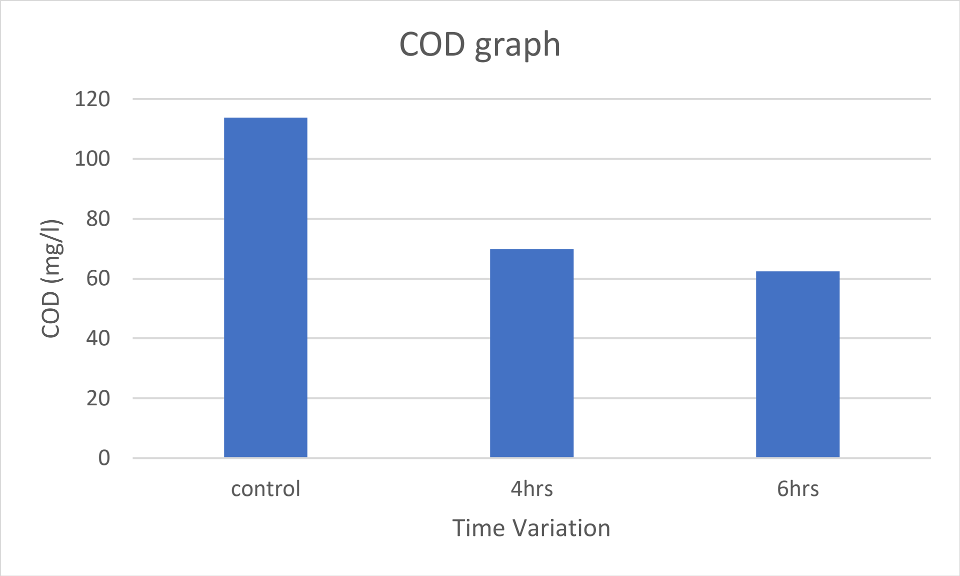

Figure 16: COD Graph 2

As observed on the basis of percentage BOD removal from the table above, the COD, which is also partially an indicator of organic loading in the wastewater was also removed at a percentage of 86.97%. This is attributed to the aerobic break of complex organic compounds into simpler molecules by aerobic and facultative bacteria, leading the reduction of COD (Singh et al., 2017). These compounds are converted into carbon dioxide and water through enzymatic hydrolysis and oxidation of proteins, fats, and carbohydrates. As result the demand for oxygen is reduced.

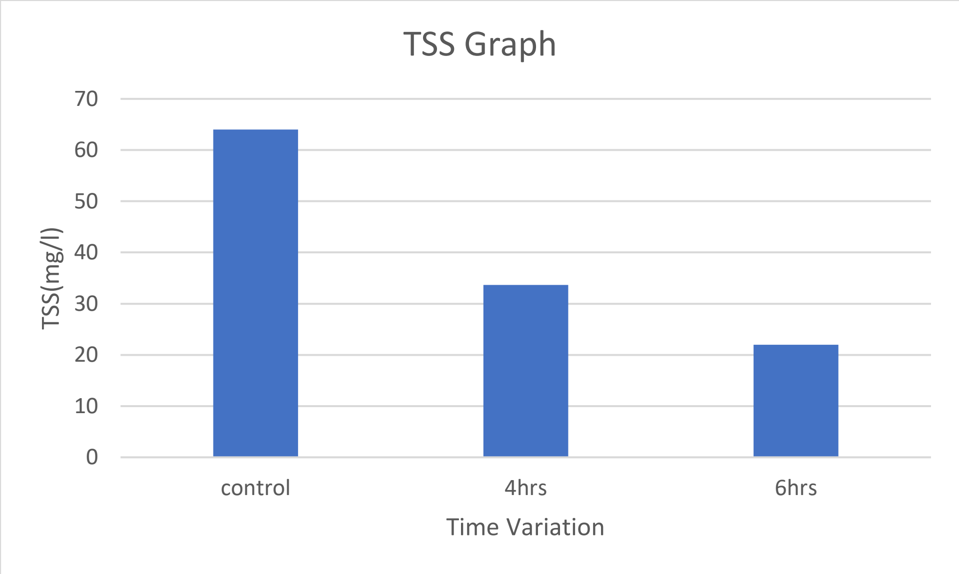

Figure 17: TSS Graph 2

The percentage removal of Total Suspended Solids (TSS) of about 95% aligns with other studies, particularly (Saapi et al., 2024). The efficiency of the vermifilter in the removal of TSS is as a result of physical filtration by the media, sedimentation where heavier particles will naturally settle down at the bottom of the vermifilter, also the earthworms ingest suspended organic matter, breaking it down through their gut enzymes and microbial symbionts (Yadav & Garg, 2021). Their barrowing activity improves percolation and prevents clogging, allowing suspended solids to be efficiently retained and decomposed.

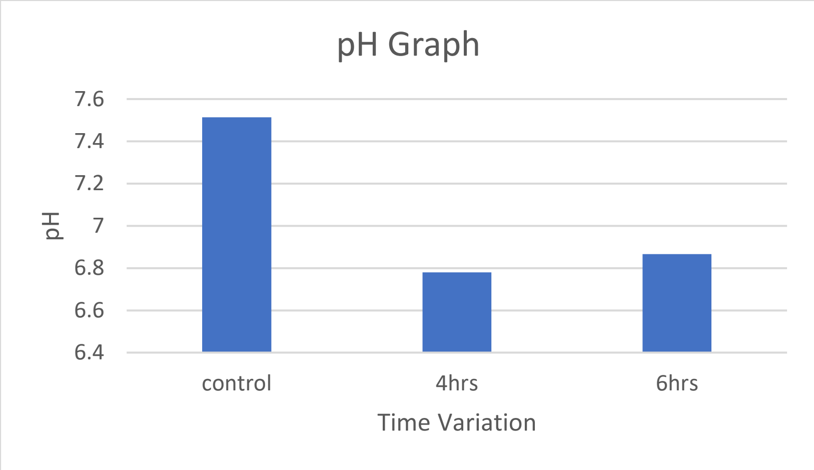

Figure 18: pH Graph 2

The pH was slightly lowered from the peak of about 8.9 to about 6.5. This is due to the microbial respiration in the vermifilter releases CO_2, which, when dissolved in water, forms carbonic acid (H_2CO_3). This slightly lowers the pH in highly alkaline wastewater (Gupta & Suther, 2020). In contrast, the breakdown of nitrogenous compounds can produce ammonium (NH_4^+), which increases pH. But generally, the pH remained the range (6.5-8.5) in which it cannot have any detrimental effects to the earthworms in the vermifilter. The earthworms remained healthy throughout the experimentation period.

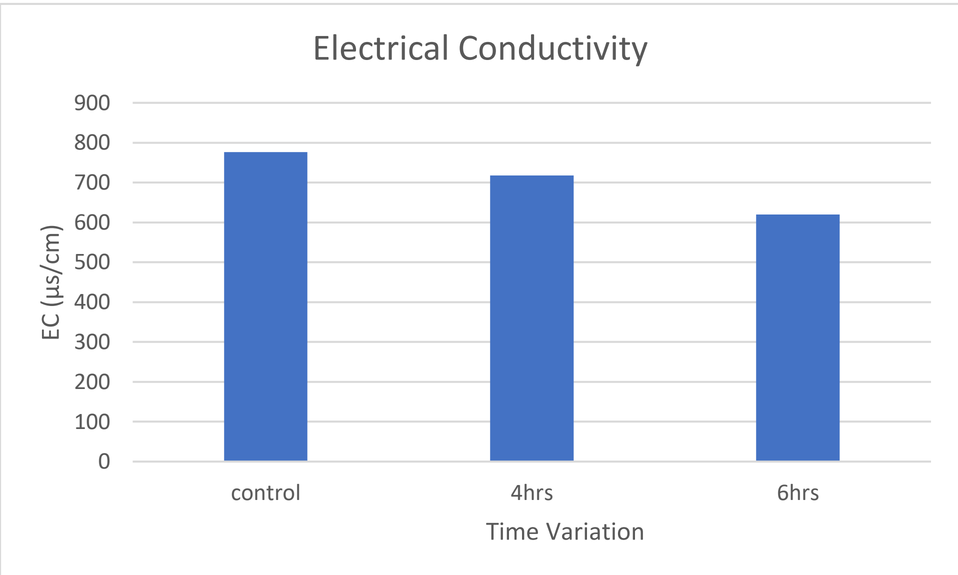

Figure 19: EC Graph 2

The electrical conductivity was slightly affected, though reduced. This could have been due to the presence of inorganic ions, which hinder the adsorption capacity of the filter media, preventing the efficient removal of ions (Singh et al., 2017). Due to the presence of Organic matter in the wastewater, some levels of oxygen stress are parts of the vermifilter might have led to anaerobic conditions in those areas, which could have affected the of removal of ions, and thus leading to a reduced EC reduction rate.

4. 4: Design

The Hydraulic Retention time = 6hours (as observed from the laboratory results)

Design volume = 50000*2 = 100000l, accounting for the peak factor and seasonal variations

Vermifilter size = 1m^3, with layers of gravel, sand, and vermibed (at thicknesses: 0.3m, 0.3m, and 0.2 meters from the bottom)

Length of pvc pipe = 30.8m with a diameter of 10cm (distance was determined from the site)

Earthworm type = Eisenia Fetida (as explained in the justification)

Size of the screening chamber = 1 m*1m*1m (1m^3)

Distance between screening chamber and settling tank = 1m.

The on-scale design is indicated in figure 20 found in the appendix.

Chapter 5: CONCLUSION AND RECOMMENDATIONS

5. 1: Conclusion

As a consequence of the research, it was discovered that:

- The vermifiltration process is absolutely free of bad odor: It is a system that can be stationed anywhere without becoming a nuisance to the surrounding communities.
- The vermifiltration system particularly excels in the removal of organic matter from the wastewater. This is due to the crucial role played both the earthworms and the microbes that help to break it down.
- This system is cost effective and does not require highly skilled labor to operate. Earthworms, which are a key component in the functionality of the system will only be purchased once; they will be reproducing to replenish just in case of any need.

5. 2: Recommendation

Though, the vermifiltration system was largely effective, it could be better if:

- Before such a system can be rolled out in the field, there is need for a pilot to test it outside the laboratory setting to determine how effectively it can deal with large volumes of wastewater.
- Further research should be done to investigate the potential of alternatives to cow-dung compost in its ability to serve as the main constituent of the vermibed since it proved to be highly turbiditious.
- Further research should also be done to assess its removal efficiency of pathogens. This might be useful to determine if this wastewater can potentially be reused.

- A combination of both the Vertical Flow with the Horizontal Flow Vermifilters should also be researched about.

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APPENDIX

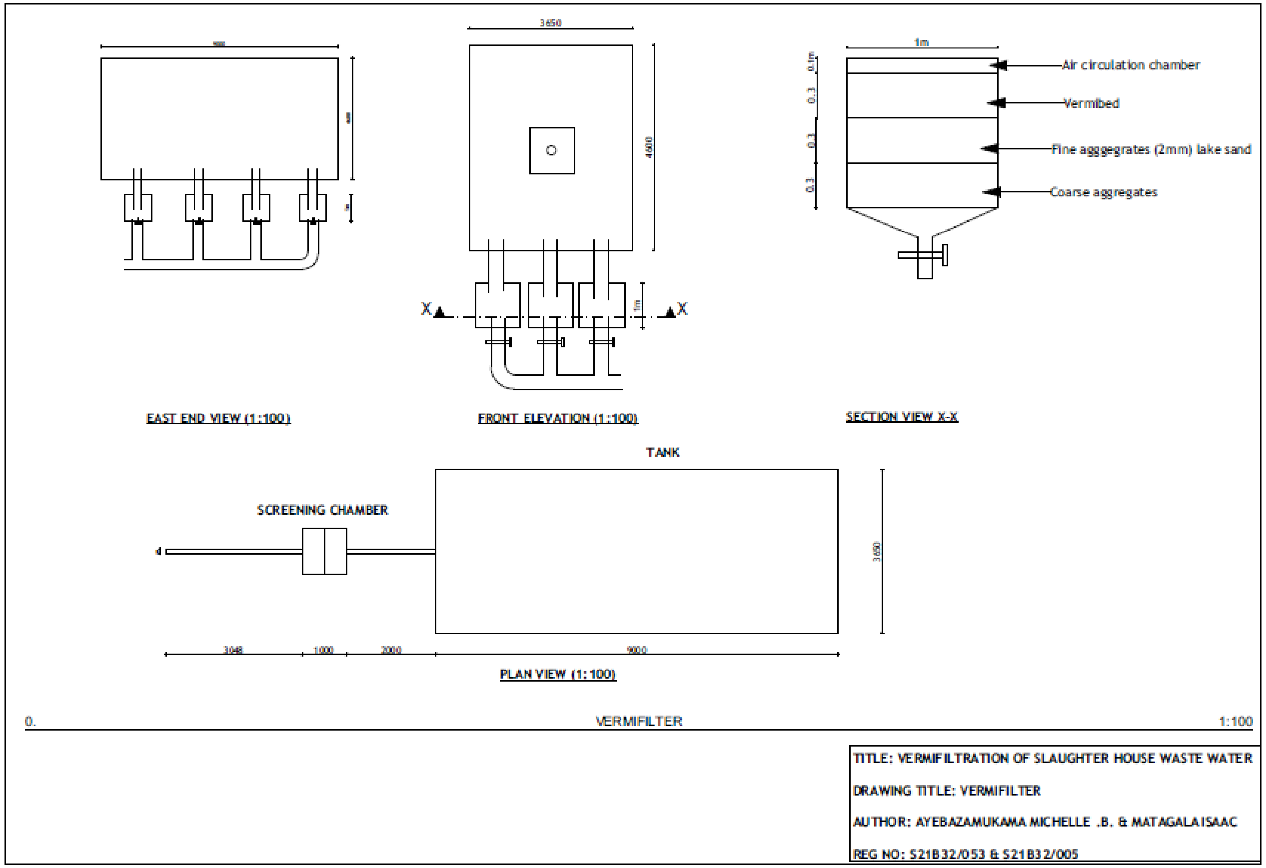
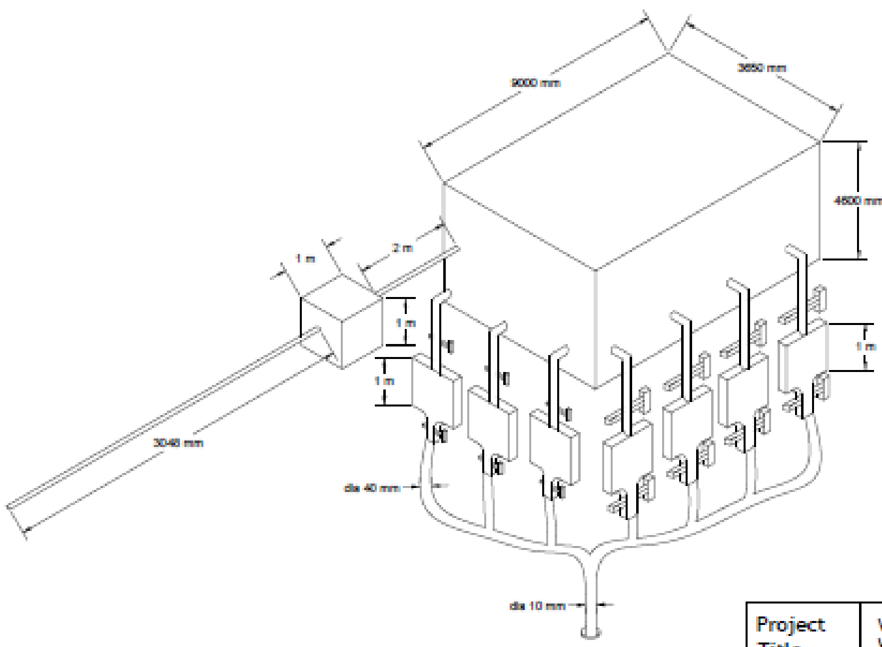


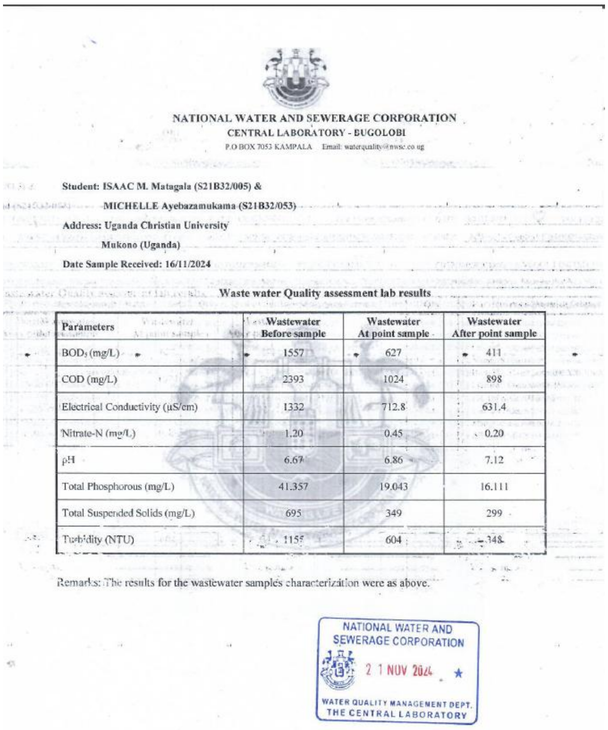
Figure 20: On-scale design of the vermifiltration system

VERMIFILTER SYSTEM DESIGN



Project Title	VERMIFILTRATION OF SLAUGHTERHOUSE WASTEWATER
Drawing	VERMIFILTER SYSTEM DESIGN
Name	Ayebazamukama Michelle.B. & Isaac Matagala
Reg No.	S21B32/053 & S21B32/005

APPENDIX



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Student: ISAAC M. Matagala (S21B32/005) &
MICHELLE Ayebazamukama (S21B32/053)
Address: Uganda Christian University
Mukono (Uganda)
Date Sample Received: 16/11/2024

Waste water Quality assessment lab results

Parameters	Wastewater Before sample	Wastewater At point sample	Wastewater After point sample
BOD_5 (mg/L)	1557	627	411
COD (mg/L)	2393	1024	898
Electrical Conductivity (µS/cm)	1332	712.8	631.4
Nitrate-N (mg/L)	1.20	0.45	0.20
pH	6.67	6.86	7.12
Total Phosphorous (mg/L)	41.357	19.043	16.111
Total Suspended Solids (mg/L)	695	349	299
Turbidity (NTU)	1155	604	348

Remarks: The results for the wastewater samples characterizition were as above.

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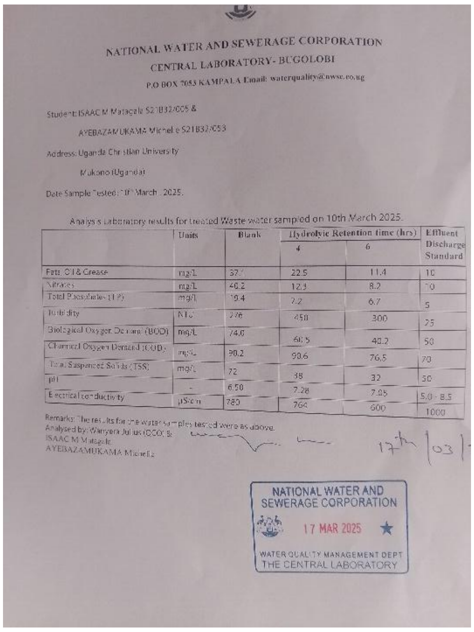

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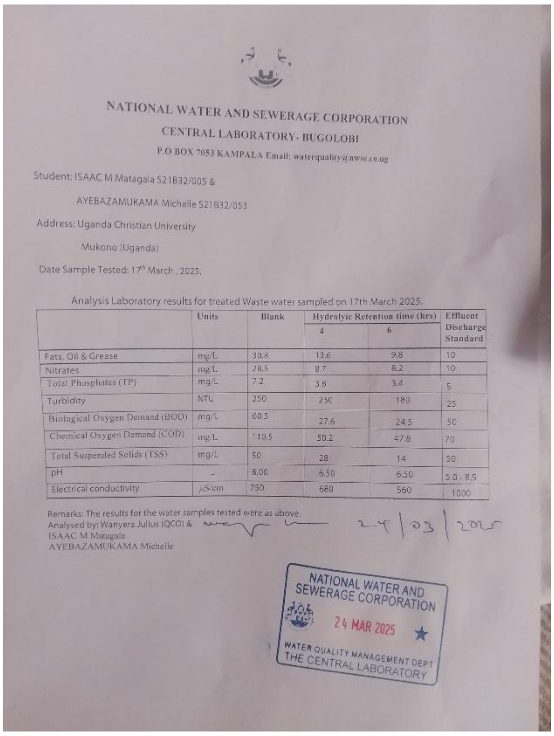
Student: ISAAC M Matagala S21B32/005 &
AYEBAZAMUKAMA Michelle S21B32/053
Address: Uganda Christian University
Mukono (Uganda)
Date Sample Tested: 10th March , 2025.

Analysis Laboratory results for treated Waste water sampled on 10th March 2025.

	Units	Blank	Hydrolyic Retention time (hrs)		Effluent Discharge Standard
			4	6	
Fats, Oil & Grease	mg/L	37.[illegible]	22.5	11.4	10
Nitrates	mg/L	40.2	12.3	8.2	10
Total Phosphates (TP)	mg/L	10.4	7.2	6.7	5
Turbidity	NTU	276	450	300	25
Biological Oxygen Demand (BOD)	mg/L	74.0	60.5	40.2	50
Chemical Oxygen Demand (COD)	mg/L	90.2	90.6	76.5	70
Total Suspended Solids (TSS)	mg/L	72	38	32	50
pH	-	6.50	7.28	7.05	5.0 - 8.5
Electrical conductivity	µS/cm	780	764	600	1000

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
ISAAC M Matagala
AYEBAZAMUKAMA Michelle

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



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Student: ISAAC M Matagala S21B32/005 &
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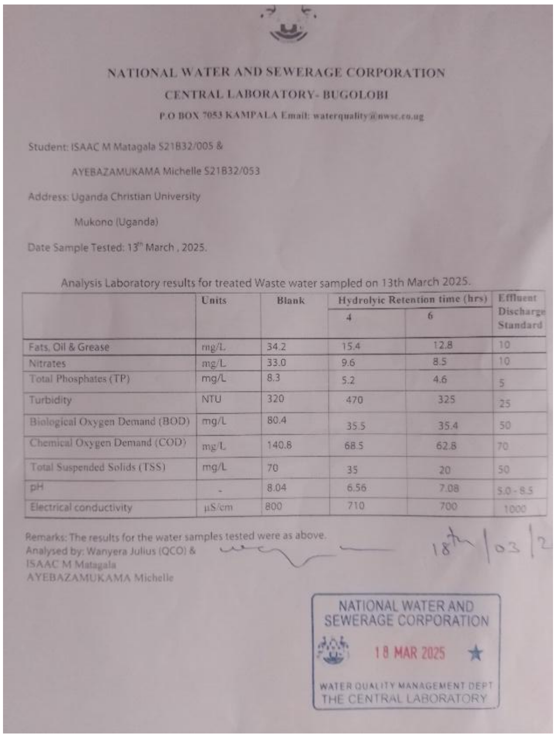
Address: Uganda Christian University
Mukono (Uganda)
Date Sample Tested: 17th March , 2025.

Analysis Laboratory results for treated Waste water sampled on 17th March 2025.

	Units	Blank	Hydrolyic Retention time (hrs)		Effluent Discharge Standard
			4	6	
Fats, Oil & Grease	mg/L	30.8	13.6	9.8	10
Nitrates	mg/L	28.5	8.7	8.2	10
Total Phosphates (TP)	mg/L	7.2	3.8	3.4	5
Turbidity	NTU	250	230	180	25
Biological Oxygen Demand (BOD)	mg/L	60.5	27.6	24.5	50
Chemical Oxygen Demand (COD)	mg/L	110.5	50.2	47.8	70
Total Suspended Solids (TSS)	mg/L	50	28	14	50
pH	-	8.00	6.50	6.50	5.0 - 8.5
Electrical conductivity	µS/cm	750	680	560	1000

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
ISAAC M Matagala
AYEBAZAMUKAMA Michelle

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



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Student: ISAAC M Matagala S21B32/005 &
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Address: Uganda Christian University
Mukono (Uganda)
Date Sample Tested: 13th March , 2025.

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

	Units	Blank	Hydrolyic Retention time (hrs)		Effluent Discharge Standard
			4	6	
Fats, Oil & Grease	mg/L	34.2	15.4	12.8	10
Nitrates	mg/L	33.0	9.6	8.5	10
Total Phosphates (TP)	mg/L	8.3	5.2	4.6	5
Turbidity	NTU	320	470	325	25
Biological Oxygen Demand (BOD)	mg/L	80.4	35.5	35.4	50
Chemical Oxygen Demand (COD)	mg/L	140.8	68.5	62.8	70
Total Suspended Solids (TSS)	mg/L	70	35	20	50
pH	-	8.04	6.56	7.08	5.0 - 8.5
Electrical conductivity	µS/cm	800	710	700	1000

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
ISAAC M Matagala
AYEBAZAMUKAMA Michelle

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

Figure 21: Laboratory results

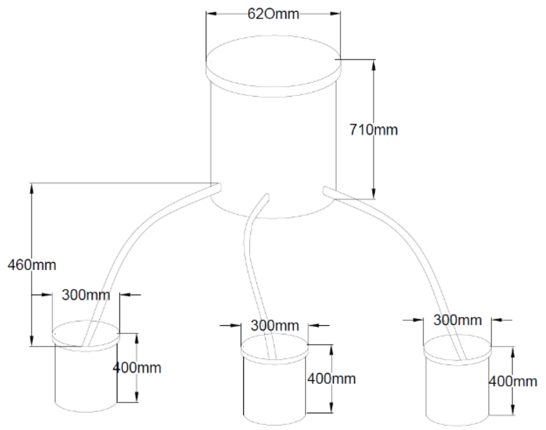

Figure 23: Prototype design

Figure 22: Aeration display on vermifilters

Figure 24: Earth worms