ASSESSING THE USE OF AGRICULTURAL LIME FOR PATHOGEN SUPPRESSION IN BIO-SLURRY

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ABSTRACT

This study investigated the effectiveness of agricultural lime in suppressing pathogenic microorganisms in human excreta based bio slurry using a pH elevation mechanism and this bio slurry will be discharged into the environment and used as a bio fertilizer.

This report is comprised of five chapters, chapter 1 is the introduction and background it entails background information about the study, problem statement, objectives of the study as well as justification for the treatment method and material used. Chapter 2 is the literature review of the field of study, narrowing down to the study of interest. The subsequent chapters include methodology of study that is chapter 3, chapter 4 being results and discussions of laboratory teste carried out and lastly chapter 5 being conclusions and recommendations.

DECLARATION

I **SIDA CYNTHIA PARIYO** hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award,

Signature: …….

Date: ……

APPROVAL

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

Prof. SARAH KIZZA-NKAMBWE

Department of Engineering and Environment

Signature: …… Date: …….

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ACRONYMS

MBPS – Mukono Boarding Primary School

E.coli – Escherichia Coli

NEMA – National Environmental Management Authority

TDS – Total Dissolved Solids

NWSC – National Water and Sewerage Corporation

SDG – Sustainable Development Goal

WHO – World Health Organization

NPK – Nitrogen Phosphorus Potassium

CHAPTER ONE

1.0 Introduction

Bio-slurry is waste water generated from the biogas production. Waste water management involves collection, treatment and reuse of waste water generated from domestic, industrial and agricultural activities to protect public health and the environment from harmful substances. Waste water treatment methods range from chemical, biological and physical treatments.

In efforts to combat climate change through use of cleaner energy generation technologies, the biogas technology emerged. In developing countries such as Uganda there is an increase in adoption of this technology as an alternative energy source to meet their cooking and lighting demands, as a result the production of bio slurry has also increased.

Bio slurry is used as a bio fertilizer due to the abundant nutrient content it contains, both macro and micro nutrients which is essential for thriving of crops and the excess released into the environment. However, bio-slurry contains pathogenic microorganisms that end up surviving after the anaerobic process during biogas generation and its management is crucial to public health and environmental protection. Pathogens in untreated bio-slurry pose significant health risks and environmental degradation risks which necessitate the treatment of the bio-slurry. This study aims to assess the use of agricultural lime for pathogen suppression in bio-slurry, with a focus on pH adjustment of the bio-slurry in order to suppress the pathogens. The specific objectives focus on determining the microbiological and physicochemical properties of the bio-slurry, determining the pH adjustment properties of the agricultural lime for pathogen suppression in bio-slurry, and

development of an agricultural lime treatment model for pathogen suppression in bio-slurry.

This research has been concluded, with all specific objectives achieved, the first two by experimental analysis and the third by both model configuration and experimental analysis hence the main objective being achieved at the end, The details of these analyses are outlined in this report beginning with the background of the study, problem statement, study objectives, research questions, justification, literature review, methodology, sample collection, results and discussion, design, conclusions, recommendations and appendices.

1.1 Background

Bio-digesters are a sustainable solution given that they are a multi-purpose technology, that is for sanitation, energy production and the resultant by-product produced is used as a bio fertilizer, these address crucial aspects across developing countries on the continent of Africa today (Delhi, 2024). These benefits make bio-digesters very desirable for improving food security, and significantly reducing dependence on fuels such as firewood and charcoal whose production and consumption have greatly led to deforestation and air pollution.

Biogas digesters are airtight enclosed structures designed to enhance the anaerobic digestion of organic matter such as animal dung, human excreta, waste food, agricultural waste among others. This organic matter is the feedstock used in the biogas digester to produce biogas which is then collected and used for purposes such as cooking (Delhi, 2024). Besides biogas, the process results in the production of a nutrient rich bio-slurry which can be utilized as a fertilizer.

Mukono Boarding Primary School (MBPS) located in Mukono district, Uganda, installed a fixed dome bio-digester in 2021 in order to partially substitute the use of firewood for cooking food for over 1000 pupils. The feedstock for the bio-digester is human excreta from the girl's dormitory toilets which is flushed into the bio-digester with 30 liters of water twice daily. The by-products from the digester are biogas which is used for cooking, and bio-slurry which is mostly released into the environment and partly utilized by farmers within and around the school as a bio fertilizer to stimulate crop yield.

However, human waste when not managed adequately, it not only poses a risk to the human health but also affects economic development as well as the social wellbeing of individuals in a society (CDC, 2024). Therefore, effective faecal waste management is crucial in order to mitigate or address these concerns.

This study focuses on the use of pH treatment for pathogenic microorganisms suppression in bio slurry by use of agricultural lime as the material for pH adjustment (Ece, 2023). Agricultural lime has the ability to raise pH effectively in order to create alkaline conditions such that pathogenic microorganisms are suppressed since alkaline conditions are inhospitable for pathogens, consequently inactivating them and reducing their numbers in the bio slurry (Ece, 2023).

1.2 Problem Statement

Human excreta based bio slurry can contain various species of pathogenic microorganisms such as E.coli, salmonella, staphylococcus helminths among others, which pose detrimental effects on human health and the environment, when not managed adequately, therefore treatment of this bio slurry is required before application as a bio fertilizer and release into the environment.

Mukono Boarding Primary School (MBPS) does not have a treatment system for the bio-slurry it produces as a result of the bio-digestion process. Some of the bio-slurry produced is utilized by farmers as a fertilizer, but most of it is released into the ground daily without any known pretreatment or retention time for stabilization and suppression of pathogens as recommended by NEMA. Furthermore, during heavy down pours of rain, the bio-slurry overflows from the outlet chamber and joins surface runoff.

There is no known study that has assessed the bio-slurry from MBPS, but evidence from preliminary laboratory findings suggest that the quality of the bio-slurry does not meet the acceptable standards of discharge into the environment (NEMA, 2020; Williams & Overbo, 2015). This poses a health risk to the farmers who directly utilize the untreated bio-slurry as a fertilizer, contamination risk to the vegetables, and also poses the risk of surface water pollution.

The purpose of this research therefore was to assess the use of agricultural lime for pathogen suppression in bio-slurry. This has the potential to minimize the pathogens in bio-slurry to make it safer for use as a fertilizer and more environmentally friendly for discharge.

1.3 Objectives of the Study

1.3.1 Main Objective

To assess the use of agricultural lime for pathogen suppression in bio-slurry.

1.3.2 Specific Objectives

1. To determine the microbiological and physicochemical properties of the bio-slurry.
2. To determine the pH adjustment properties of agricultural lime for pathogen suppression in bio-slurry.
3. To develop an agricultural lime treatment model for pathogen suppression in bio-slurry.

1.4 Research Questions

1. What are the microbiological and physicochemical properties of the bio-slurry?
2. What are the pH adjustment properties of agricultural lime for pathogen suppression in bio-slurry?
3. What is the agricultural lime treatment model for pathogen suppression in bio-slurry?

1.5 GEOGRAPHICAL SCOPE

The geographical scope of this study is Mukono Boarding Primary School Located in Mukono district, Uganda, roughly 1km off the Kampala-Jinja highway. the bio digester is stationed within the school

1.6. Justification

Bio-slurry generally contains several microorganisms including pathogenic microorganisms and helminths which have a significant relation with human health risk. However, among the categories of bio slurry, according to the nature of feed stock, human excreta based bio slurry has the highest level of adverse effects on the environment and human health if reasesd into the environment without treatment (Islam A.M et al, 2019) The most significant pathogenic microorganisms include E.coli, Salmonella, Staphylococcus, and helminth Ascaris lumbricoides as determined from preliminary tests carried out in the Uganda Christian university micro biology laboratory. The results obtained are similar to previous studies carried out on bio slurry (Drabe, 2024).

According to a study carried out in Bangladesh, the prevalence of 17.4% for Salmonella, 100% E.coli prevalence and 3.2% prevalence for Staphylococcus was reported on vegetables which was associated with the use of bio-slurry resulted in cases of death and gastro-intestinal problems. An antimicrobial susceptibility test was done and confirmed that even after anaerobic digestion, some of the pathogenic microorganisms survive and can easily be transmitted to man (Islam et al., 2019).

pH treatment plays a crucial role in the safety and effectiveness of bio slurry applications particularly concerning human health risk, therefore, this study aims to apply pH treatment, specifically alkaline treatment for suppression of pathogens in bio slurry. This mechanism involves increasing the pH of bio slurry to create alkaline conditions which are inhabitable for pathogenic microorganisms (Ang.M et al, 2023)

Agricultural lime consists of calcium carbonate and magnesium carbonate. When agricultural lime is introduced into bio slurry, the water in the bio slurry reacts with

cause the release of hydroxide ions in the bio slurry when added to it which cause a raise in pH effectively (Mallarino & Haq, 2017)

Bio-slurry is made up of over 90% water, and when agricultural lime is added to the bio-slurry, it undergoes hydrolysis.

Calcium carbonate dissolves in the presence of dissolved Carbon dioxide which is present in the bio-slurry.

$$CaCO_{3(s)} + 2\ H_2O \longrightarrow Ca(OH)_{2(aq)} + H_2\ CO_{3(aq)}$$

This reaction produces calcium hydroxide which is a strong base and carbonic acid, as weak acid. The calcium hydroxide then rapidly ionizes

$$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-$$

The hydroxide ions directly increase pH of the bio slurry creating alkaline conditions, in addition the calcium ions replace hydrogen ions on colloids surfaces simultaneously, further neutralizing acidity of bio slurry.

High pH denatures proteins, disrupts ionic balances, and neutralizes acidic components in pathogens. Alkaline environments hinder enzymatic activities critical for pathogen survival and reproduction. Elevated pH induces dehydration in cells by increasing osmotic pressure thereby damaging membrane integrity (Mallarino & Haq, 2017).

This research intends to utilize agricultural lime to create alkaline conditions in bio-slurry for suppression of pathogenic microorganisms and helminths. This research primarily focuses on E.coli, Salmonella, Staphylococcus, and Ascaris lumbricoides.

Additionally, agricultural lime is beneficial for agricultural soil in that it corrects soil acidity, enhances nutrient availability, and promotes long-term soil health and sustainability (Mallarino & Haq, 2017). Furthermore, agricultural lime is cost-effective and widely available in Uganda.

1.7 Significance of the Study

When bio-slurry from human excreta is treated to suppress the pathogen load in it through agricultural lime treatment, it creates a bio-fertilizer that is safe for agricultural use to boost crop yield without crop quality being compromised due to pathogenic contamination. (de Groot & Bogdanski, 2013).

Human excreta is a major source of pathogens that cause diseases such as cholera, diarrhea, typhoid among others, when poorly managed, human excreta can lead to widespread outbreaks of these epidemic diseases especially in developing countries. Therefore, treatment of human excreta based bio slurry ids mandatory before being discharged into the environment and before use as a bio fertilizer.

Past studies have that lime treatment effectively suppresses bacteria viruses and parasites by creating alkaline conditions that disrupts their survival mechanisms (Strande et al, 2023). By demonstrating the efficiency of agricultural lime in suppression of pathogenic microbial loads in bio slurry, more benefits are harnessed from bio slurry compared to the demerits associated with it, therefore reducing health risks, improving environmental health and boosting crop yield.

This research aims to sustainably manage waste by exploring lime treatment as a method for pathogen suppression in bio slurry. The treated bio slurry can then be safely reused for agriculture to improve soil structure, neutralize acidic soils since it contains agricultural lime and boost crop yield, all these align with global efforts

to achieve sustainable development goals (SDGs) particularly SDG 6 that is about clean water and sanitation and SDG 13 that talks about climate action by encouraging resource recovery from waste (WHO, 2023).

This research has a potential of having a direct implication for practitioners in the agricultural and sanitation sector, this is because agricultural lime is ideal for soil given that it is recommended for agricultural use, it is widely available, cost effective and easy to apply, making it an accessible solution for both rural and urban settings (Strande et al, 2018)

By providing evidence based recommendations on lime dosage, contact time required and mixing requirements, via laboratory experimental analysis, this study provides guidelines for implementing this effective waste management strategy.

CHAPTER TWO

2.0 Literature Review

2.1 Introduction

Bio-slurry is a nutrient rich by product from the biogas production process, the composition of bio slurry varies according to the category/ type of feedstock fed into the bio digester, feed stock range from cow dung, waste food, agricultural waste (crop residue), poultry droppings, human excreta among others. During anaerobic digestion of feed stock in the bio digester, about 25-30% of the total solid content will be converted into a combustible gas and a residue of 70-75% of the total solid content of the feed stock comes out as sludge which is known as bio slurry (Warnars and Oppenoorth, 2014).

According to literature, bio slurry physical consists of, 93% water and 7% dry matter, of this dry matter, 4.5% is organic matter and the remaining 2.5% is inorganic matter. Chemically, bio slurry is composed of nitrogen, phosphorus, potassium, zinc, manganese as well as copper, this is the typical composition of cow dung and human excreta based bio slurry (Islam et al, 2019), which as well harbor pathogens such as salmonella, E.coli, staphylococcus among others, as confirmed by literature and preliminary laboratory analyses.

Mukono boarding primary school has s fixed dome bio digester that receives human excreta from the female pupils' toilet facilities, flushed with 60 liters of water as feedstock for biogas production. The system consists of a 10 toilet unit that feed the bio digester. Occasionally, the bio digester is fed with cow dung that is mixed with water and fed in through a booster chamber that is connected to the bio digester by a pipe, the cow dung boosts methane production.

The bio digester system at MBPS is designed in such a way that as fresh excreta is flushed into the bio digester, and displaces the old feedstock that has gone through anaerobic digestion and is known as bio slurry. This bio slurry is released into an outlet chamber containing aa discharge pipe at the bottom and steadily injects bio slurry into the soil underground. According to a key informant from MBPS, farmers in and around the school collect this bio slurry from the outlet chamber and apply it to their gardens as a bio fertilizer, there is no known pretreatment that the bio slurry is subjected to before use

2.2 Topic of Study

The literature review is structured around the specific objectives of the research. Firstly, the study explores literature on the microbiological and physicochemical properties of the bio-slurry with emphasis on pathogens such as E.coli, Salmonella, Staphylococcus, Ascaris lumbricoides eggs, parameters such as pH, and nutrient content. Secondly, the study analyses research on the use of agricultural lime for pathogen suppression and bio-slurry treatment applications. Finally, the study reviews existing treatment models for pathogen suppression and identifies the theoretical basis for model development and its practical implications.

This review outlines relevant studies that have informed the research while identifying gaps in existing knowledge. There are documented benefits of lime treatment in wastewater and sludge stabilization and utilization of agricultural lime for neutralization of acidic soils, but limited research exists on the direct application of agricultural lime to bio-slurry. This is particularly limited in the context of optimizing dosage, treatment time, and long-term pathogen suppression. While various disinfection and stabilization models exist, such as chlorination, there is no

known integration of the specific physicochemical interactions of agricultural lime with bio-slurry components. These gaps justify the need for a customized and specific agricultural lime treatment model for pathogen suppression as developed in this study.

2.3 Determination of the Microbiological and Physicochemical Properties of the Bio-Slurry

2.3.1 Microbial Composition of Bio-Slurry

Bio-slurry is a good quality organic fertilizer that is a source of micro and macro nutrients as well as organic matter, this component influences soil structure and introduces microorganisms into soil and this stimulates crop yield. Human excreta based bio slurry contains a variety of microbial communities both beneficial and pathogenic microorganisms. The beneficial microorganisms breakdown organic matter in soil for easy absorption by crops and they aerate soils which aid crop roots during soil penetration (Islam et al, 2019). Studies have shown that untreated human excreta based bio-slurry also contains high levels of pathogenic microorganisms such as, E.coli, Salmonella, Staphylococcus, Ascaris lumbricoides (Islam et al., 2019). These pathogens survive in bio-slurry after the anaerobic digestion process and their life span and rate of reproduction or multiplication in the bio slurry depend on factors such as pH, temperature, retention time of the bio slurry, and availability of organic matter to feed on. In systems operating at mesophilic temperatures (30 – 40^0C), the growth of pathogenic microorganisms is stimulated due to the ideal conditions (Drabe, 2024). From all these findings it is therefore concluded that there is a need for treatment of this bio slurry in order to suppress pathogens.

2.3.2 Physicochemical Properties of Bio-Slurry

Physicochemical parameters are play an important role in microbial survival and bio-slurry stability. The parameters include pH, potassium, total phosphorous, temperature, total dissolved solids (TDS).

pH typically ranges between 6.5 and 8.5 which is conducive to microbial activity. Studies suggest that pH ranges above 9.0 are not ideal for microbial activity.

Potassium and total phosphorous are important nutrients which make bio-slurry beneficial for application in agriculture. The composition of the nutrients before and after treatment is an important indicator of the effectiveness of the treatment. Studies suggest that these provide an ideal environment for microbial growth.

Total dissolved solids (TDS) are an important representation of the micro-nutrients present within the bio-slurry that have an impact on the microbial activity and the application of the bio-slurry as a fertilizer. This composition is important before and after treatment and is a vital indicator of the effectiveness of the treatment. Research suggests that this provides a fertile environment for microbial growth.

Mesophilic digestion temperatures (30 – 40^0C) reduce but do not completely eliminate pathogens. This suggests that there is a need for post digestion treatment of the bio-slurry.

2.3.3 Critical Analysis and Research Gaps

A series of lime treatment studies have been carried out using a variety of lime products including by using hydrated lime ($Ca(OH)_2$), quick lime (CaO) and Dolomitic lime ($CaMg(CO_3)_2$), for waste water and sludge disinfection. However, there is limited literature focusing on lime treatment as applied to treatment of human excreta based bio slurry and there is no known literature on studies that have been

carried out on use of agricultural lime for treatment of bio slurry or any form of waste water. This research addresses this knowledge gap by investigating/ assessing the use of agricultural lime for pathogen suppression in bio slurry, hence contributing valuable insights into the chemical and microbiological dynamics of lime treatment (Vinneras et al, 2023).

2.4 Determination of the pH Adjustment Properties of Agricultural Lime for Pathogen Suppression in Bio-Slurry

From a number of literature reviewed, there are various studies carried out on different treatment methods for waste water that have been widely adopted to mitigate the concerns of pathogenic microorganisms. These are as follows;

Anaerobic digestion

This involves the breakdown of organic matter in the absence of oxygen by microorganisms, it combines bio gas production and it effectively reduces bacterial and viral pathogenic loads.

Limitations

- Significant retention time required, approximately 30 to 60 days
- Consistent monitoring of operation conditions
- Limited pathogen removal for resilient organisms like helminth eggs

(Jha et al, 2021)

Composting

Aerobic composting uses thermophilic conditions to deactivate pathogens. Temperatures are maintained between 55 to 60^0c for prolonged periods, this ensures deactivation of bacteria and helminths making it suitable for agricultural use.

Limitations

- Strict temperature and moisture controls are required for effective pathogen inactivation
- Large space required to carry out this treatment
- Odor issues may arise during operations

(Hussain et al, 2022)

Lactic Acid Fermentation

This treatment method lowers pH and created antimicrobial conditions significantly reducing bacterial loads

Limitations

- Less effective for helminths
- Limited large scale applicability
- Created acidic conditions in soil which is not favorable for crops

(Hussain et al, 2022)

Others include; Thermal treatment, Maturation ponds, Trickling filters, Rapid and slow sand, chlorination among others.

Lime treatment is widely recognized for its ability to inactivate pathogens through pH elevation. When added to water in the presence of carbon dioxide, lime

dissociates into calcium ions (Ca^{2+}) and hydroxide ions (OH^-), which raises pH levels to above 9.0 and disrupts microbial cell functions (Schwab et al., 2007).

Lime stabilization has been successfully applied in wastewater treatment plants and sludge treatment. Municipal sludge treatment suggests that lime-treated sludge showed a 4-log reduction in bacterial counts within 48 hours (Sravan et al., 2024). Livestock waste treatment using lime suggests that lime eliminated pathogens in dairy and pig farm waste. The findings further suggest that lime treatment significantly reduces the risk of waterborne disease transmission.

The jar test is a widely utilized technique for determination of optimum dosage for lime treatment in municipal wastewater treatment and sludge treatment.

2.4.1 Critical Analysis and Research Gaps

Most studies on lime stabilization focus on municipal sludge with limited studies addressing bio-slurry from bio-digesters that utilize human excreta as feedstock.

There is insufficient research on optimizing lime dosage for pathogen suppression in bio-slurry while maintaining agronomic value.

Long-term pathogen survival and pH stability in lime-treated bio-slurry remain underexplored.

2.5 Development of an Agricultural Lime Treatment Model for Pathogen Suppression in Bio-Slurry

Municipal wastewater management and municipal sludge management usually involves chemical additives such as chlorine treatment to stabilize the material and suppress pathogens (MWE, 2013). Some water treatment systems utilize baffle mixing designs to facilitate mixing of coagulant with water for coagulation and

flocculation treatment, but there is no known mixing technology for treatment of bio-slurry with agricultural lime.

The exponential decay model is a well-known model for the study of microorganism death and decay (Objectives & Model, n.d.). However, there is no known study that has utilized the model to assess the suppression of pathogens in bio-slurry using agricultural lime.

2.5.1 Critical Analysis and Research Gaps

Most existing models do not account for the unique microbiological and physicochemical interactions of agricultural lime within bio-slurry. There is no known standardized model for pathogen suppression in bio-slurry.

There are little known guidelines on the practical guidelines regarding the timing and method of applying agricultural lime to bio-slurry.

Building upon existing models, this study proposes a treatment system preliminary design comprising of a dosing chamber for controlled addition of agricultural lime to the bio-slurry, a baffle mixing channel for uniform distribution of agricultural lime in the bio-slurry, and retention chambers to hold bio-slurry for durations sufficient to achieve pathogen suppression.

The resultant bio-slurry after treatment is required to be safe for use as a fertilizer and for discharge into the environment.

Management Practices

- Bio slurry should be stored in sealed and hygienic conditions to prevent pathogen exposure during transportation or storage. Proper training in handling is crucial to minimize occupational risks (Hussain et al, 2022)

- Treated bio slurry should be applied in fields with adequate waiting periods (contact time to ensure pathogen suppression
- In rural areas as well as peri-urban areas, small scale systems to allow local re use while minimizing transportation costs, these systems align with circular economy principles by integrating biogas production and bio fertilizer recovery
- Policy interventions are needed to enforce standards for bio slurry treatment and use, community training programs raise awareness about health risks and sustainable practices (Harroff et al, 2022)

Barriers discovered with the use of bio fertilizers include inconsistent pathogen in activation across methods limited access to advanced technologies in developing countries, public resistance due to stigma.

Therefore, raising need for future strategies that should focus on cost-effective decentralization systems, improved pathogen monitoring technologies and integration into circular economy frameworks to enhance adoption and sustainability.

CHAPTER THREE

3.0 Methodology

3.1 Introduction

This chapter outlines the methods that were utilized to assess the use of agricultural lime in suppressing pathogens in bio-slurry. The methodology focused on analyzing the microbiological and physicochemical properties of bio-slurry, pH adjustment properties of agricultural lime for pathogen suppression in bio-slurry, and development of an agricultural lime treatment model for pathogen suppression in bio-slurry.

This research was conducted on bio-slurry from the bio-digester at Mukono Boarding Primary School (MBPS). The bio-slurry was analyzed from the NWSC Central Laboratory and the UCU Environmental Laboratory.

3.2 Research Design

A laboratory-based experimental design for quantitative analysis and qualitative analysis was adopted for this study. This approach enabled control of variables and accurate assessment of the impact of agricultural lime on pathogen suppression in bio-slurry. The study involved systematic sampling, controlled agricultural lime dosages, microbiological, and physicochemical analyses. This design allowed for precise measurement and statistical analysis. The analysis was in line with the NWSC Standard Operating Procedures, the exponential decay model, and the Water Supply Design Manual (Freeman et al., 2021; MWE, 2013; Objectives & Model, n.d.)

3.3 Sampling Technique

The sample collection was performed based on the following general guidelines:

- Homogenization of the bio-slurry in the collection tank
- Use of autoclaved bottles
- Use of sterile containers
- Use of gloves and medical masks
- Labels for identification
- Sample storage in an ice cooler (4^0C) with ice packs for temperature control during transport
- Collection of sample during dry weather to prevent dilution from rainwater

(de Groot & Bogdanski, 2013; Freeman et al., 2021).

The sample collection techniques that were followed are summarized in *Table 1*.

Table 1: Summary of Sample Collection Techniques that were applied for the bio-slurry

Parameter	**Sample Collection Technique**
Microbial analysis	Used a sterile scoop for sample collection and use of autoclaved bottles for sample storage. Analyzed within 24 hours from the time of sample collection (Freeman et al., 2021).
pH Potassium Total Phosphorus TDS	Used a sterile scoop for sample collection and use of sterile containers for sample storage. Homogenized the sample (Freeman et al., 2021).
Helminth eggs	Used a sterile scoop for sample collection and use of autoclaved bottles for sample storage. Analyzed within 24 hours from the time of sample collection (Khurana et al., 2021).

Bio-slurry samples were collected from the bio-digester at MBPS.

The bio-slurry in the outlet chamber was stirred properly to ensure even distribution and homogeneity of the bio-slurry.

Samples were collected from three different locations within the outlet chamber, that is, the center, and two ends 1m apart.

Care was taken to avoid contamination of the bio-slurry during the sampling process so as to ensure accuracy.

The samples were collected in autoclaved bottles and sterilized containers, labelled, stored, and transported to the laboratory in a cooler box (4^0C) and analyzed within 24 hours.

The samples were delivered to the NWSC Central Laboratory for the microbiological and physicochemical laboratory analyses, and to the UCU Environmental Laboratory for the pH adjustment property analyses of the agricultural lime.

3.4 Determination of the Microbiological and Physicochemical Properties of the Bio-Slurry

Standard: NWSC Standard Operating Procedures (Freeman et al., 2021).

The purpose of this was to analyze the microbiological and physicochemical properties of untreated bio-slurry to establish baseline data for assessing the impact of agricultural lime treatment. This entailed the detection and quantification of Escherichia coli (E.coli), Salmonella, Staphylococcus, Ascaris lumbricoides, Ascaris lumbricoides eggs in the bio-slurry, and the measurement of the pH, Total Phosphorous, Potassium, temperature, and Total Dissolved Solids (TDS) of the bio-slurry.

3.4.1 Materials and Equipment

- Bio-slurry samples
- Selective media, namely, MacConkey agar, Salmonella-Shigella agar, Mannitol salt agar
- Incubation equipment
- Autoclaved bottles and sterilized containers
- Petri dishes
- Pipettes

- pH meter
- Thermometer
- TDS meter
- Centrifuge
- Compound microscope

Research indicates that bio-slurry can contain significant levels of E.coli, Salmonella, Staphylococcus, Ascaris lumbricoides eggs. This poses challenges for public health in terms of human infection for those in direct contact with the bio-slurry, food hygiene, and environmental health concerns (Drabe, 2024). Ascertaining the loads of these respective pathogens was important for determining the required treatment for their suppression.

Bio-slurry is rich in essential nutrients such as phosphorous and potassium. Studies have shown that bio-slurry contains approximately 0.13% phosphorous and 0.12% potassium on a wet basis and higher concentrations on a dry basis (Delhi, 2024). Determining the initial composition of the nutrients in the bio-slurry was important to compare with the composition after the treatment. This was an indicator of the effectiveness of the treatment and viability of the bio-slurry after the treatment.

Bio-slurry generally has neutral to slightly alkaline pH (Delhi, 2024). Determining the initial pH of the bio-slurry was essential for the analysis of the pH treatment to be performed by the agricultural lime. After the treatment, the pH of the bio-slurry was to return to the initial pH levels. This was important for application for application of the bio-slurry as a fertilizer.

3.5 Determination of the pH Adjustment Properties of Agricultural Lime for Pathogen Suppression in Bio-Slurry

Standard: NWSC Standard Operating Procedures (Freeman et al., 2021).

The determination of the pH adjustment properties of agricultural lime involved qualitative analysis by means of the flame test technique to confirm the presence of calcium ions (Safety, n.d.). Having confirmed the presence of calcium ions in the agricultural lime, the ideal dosage for the required pH adjustment was performed by jar test analysis (Freeman et al., 2021).

3.5.1 Materials and Equipment for the Flame Test

- Non-luminous flame burner
- Nichrome or platinum wire loop
- Concentrated Hydrochloric acid (HCl)
- Agricultural lime

The wire loop was cleaned by dipping it in concentrated HCl and holding it in the flame until no color was observed. This removed contaminants that could have interfered with the results.

The cleaned wire loop was moistened with HCl again and dipped into the agricultural lime. The wire loop was then placed at the edge of a hot non-luminous flame.

The color of the flame was observed and recorded. The procedure was repeated in triplicates with fresh samples.

The presence of calcium ions in agricultural lime was an indicator of the Calcium Carbonate Equivalent (CCE) and pH adjustment properties of agricultural lime. The

calcium ions react with the bio-slurry forming hydroxyl ions which alkalinize the bio-slurry and raise the pH (Schwab et al., 2007).

The flame test is a qualitative analytical technique that was used to confirm the presence of calcium ions in agricultural lime based on the characteristic orange flame emitted when heated in a non-luminous flame (Safety, n.d.). When metal ions are introduced into a flame, they absorb energy which excites their electrons to higher energy levels. As these excited electrons return to their ground state, they release energy in the form of light. The wavelength and therefore the color of the emitted light is specific to each metal ion due to the unique arrangement of electrons and energy levels in the different elements (Safety, n.d.). An orange flame confirmed calcium ions in the agricultural lime.

3.5.2 Materials and Equipment for the Jar Test

- Jar test equipment
- Bio-slurry samples
- Agricultural lime
- pH meter
- Electronic weighing scale

500mL of bio-slurry was poured into the jars.

The initial pH of the bio-slurry was measured and recorded.

Doses of agricultural lime; 0g, 10g, 20g, 30g, 40g, 50g, 60g were weighed and added to the control jar, and jar 1, 2, 3, 4, 5, 6 respectively. This allowed observation of how varying amounts of agricultural lime adjusted the pH.

The jars were stirred thoroughly at a high speed of 150RPM for 5 minutes to ensure even distribution of the agricultural lime. Immediately after the stirring speed was reduced to 50RPM for 10 minutes.

The pH was measured and recorded immediately, and after 1 hour. The pH was then measured and recorded after 24 hours for 7 days.

Data analysis was performed to identify which dose of agricultural lime achieved a pH range of 9.0 – 10.0. Graphical analysis of the pH levels against time for the different dosages was carried out.

According to Ziquin, P. et al, 2019, agricultural lime primarily operates by increasing pH which suppresses the above mentioned pathogens in bio-slurry. Determining the optimum dose of agricultural lime enabled maximization of pH increase while minimizing potential negative impacts on the bio-slurry such as unnecessarily prolonged alkalinity.

The jar test is a widely used laboratory method in water treatment and waste water treatment to determine the optimal dosages for coagulation and pH adjustment. The test facilitated simulation of full-scale treatment for pH adjustment (MWE, 2013).

3.6 Development of an Agricultural Lime Treatment Model for Pathogen Suppression in Bio-Slurry

Standard: Exponential Decay Model, SAFL Baffle Design Guide (2023), Water Supply Design Manual (2013) (Freeman et al., 2021; MWE, 2013; Objectives & Model, n.d.; Revised, n.d.)

The development of an agricultural lime treatment model for pathogen suppression in bio-slurry entailed model configuration, and model verification by experimental analysis. Furthermore, a reactivation test analysis was performed to ascertain the number of potent pathogenic microorganisms still present in the bio-slurry.

The exponential decay model $N_t = N_0e^{-kt}$ shall be considered, where:

- N_t is the number of surviving pathogens
- N_0 is the initial number of pathogens
- k is the death rate constant
- t is time

3.6.1 Considerations for the Development of the Model

The targets of the model were; to achieve pathogen suppression in bio-slurry to concentrations below 400 CFU/100mL, to raise the pH of the bio-slurry to the range between 9.0 and 10.0 and for the pH to return to neutral, to ensure that nutrient levels remain adequate for subsequent agricultural use.

All relevant data for configuration of the model, that is, initial pathogen loads in the bio-slurry, initial pH of the bio-slurry, optimum agricultural lime needed to achieve pH range 9.0 – 10.0, initial bio-slurry nutrient composition, environmental considerations namely temperature and rainfall.

Development of the model structure that entails input parameters, treatment processes, and output parameters. The treatment process entailed agricultural lime application by direct mixing based on the determined optimum dosage. The mixing duration and intensity of the agricultural lime within the bio-slurry corresponded

with that determined during determination of pH adjustment properties of the agricultural lime.

The pH changes and pathogen levels over time were monitored post treatment. These output values after the observation time as determined were measured and recorded.

Model evaluation was performed by analyzing the data collected during implementation. This was performed by comparing the pretreatment and post-treatment data to assess changes in pH and pathogen loads.

3.6.2 Considerations for Verification of the Model

Bio-slurry samples were collected from MBPS and prepared to ensure consistency. Optimum dose of agricultural lime determined was applied and uniformly mixed with the bio-slurry to achieve effective treatment. A control group without agricultural lime was set up and compared against treated samples.

pH levels and pathogen loads were measured after agricultural lime treatment after the duration of time determined during the pH adjustment analysis.

Statistical analysis such as t-tests were performed to compare the predicted values from the model with the actual measured values and the error matrix calculated. Additional rounds of verification were performed with different bio-slurry samples from MBPS.

The exponential decay model is suitable for the analysis of pathogen suppression and degradation over time. The model gives an understanding of pathogen population dynamics and their behavior and concentration levels over time

(Objectives & Model, n.d.). Verification of the model further optimized the agricultural lime applications to enhance pathogen suppression (MWE, 2013).

CHAPTER FOUR

4.0 Results and Discussion

4.1 Introduction

This chapter discusses the findings from the laboratory analyses and the trends made by comparison of the results obtained from quantification of the parameters of this study. Analyses were conducted in accordance to the methods stated in the preceding chapter and the findings were recorded. The process of interpretation, analysis, and discussion of the results is done with respect to the specific objectives of the research.

4.2 Results and Discussion: Determination of the Microbiological and Physicochemical Properties of the Bio-Slurry

The microbiological and physicochemical properties of the untreated bio-slurry were analyzed and this provided baseline data of the bio-slurry. This entailed the detection and quantification of Escherichia coli (E.coli), Salmonella, Staphylococcus, Ascaris lumbricoides eggs in the bio-slurry, and the measurement of pH, Total Phosphorous, Potassium, temperature, and TDS of the bio-slurry as shown in *Table 2*.

Table 2: Summary of Microbiological and Physicochemical properties of the bio-slurry

Parameters	**Units**	**Result**	**Max. Permissible Limit (NEMA, 2020)**
Bact: Escherichia Coli	CFU/100mL	531	400
Bact: Salmonella	CFU/100mL	93	400
Bact: Staphylococcus aureus	CFU/100mL	0	400
Ascaris lumbricoides eggs	No./L	3	<=1
pH	---	7.9 – 8.1	5.0 – 8.5
Potassium (K)	mg/L	84 ± 2.31	100
Temperature	^{0}C	22 ± 0.53	20 – 35
Total Dissolved Solids (TDS)	mg/L	2615 ± 21.58	700
Total Phosphorous (TP)	mg/L	41 ± 3.8	5

Table 2 shows that the concentrations of Escherichia Coli and Ascaris lumbricoides eggs in the bio-slurry are beyond standards for waste water discharge by NEMA making it unsafe for use as a fertilizer and discharge into the environment, raising critical public health and environmental concerns. The table further shows that the pH of the bio-slurry is neutral.

Pathogen Contamination

1. E.coli

The concentration of E.coli exceeds permissible limits, this indicates that a considerable quantity of pathogenic microorganisms survived in the bio slurry after the anaerobic process of biogas generation. Studies in Bangladesh found E.coli concentrations of ($9.1x10^6$-$2.285x10^8$) CFU/500ml in bio slurry derived from human excreta (Islam et al, 2019). Similarly, salmonella and helminth eggs persisted and survived anaerobic digestion and proliferating post application, though their concentrations comply with the permissible limits for discharge. These bacteria can cause risks of water and soil contamination and are linked to gastrointestinal infections and antibiotic resistance, emphasizing the need for extended retention times or secondary treatment in order to suppress these pathogens (Hearly et al, 2018).

2. Helminth eggs

Helminth eggs concentration exceeds standards for effluent discharge indicating a high risk of soil-transmitted helminthiasis, from literature studies (Kumwenda et al, 2018) of a similar case study in Senegal, reviews that the concentration of helminth eggs was discovered to be reach 11500eggs/g in untreated bio slurry, far surpassing WHO and NEMA limits (less than or equal to 1 egg). Ascaris lumbricoides that have a low infectious dose of 10 eggs, they are particularly resilient, can survive for months in soil and can survive even in harsh conditions, this necessitates post treatment of bio slurry in order to in activate helminth eggs before being released into the environment and for agricultural use (Amoah et al, 2018).

3. **Phosphorus Content**

According to the standards for phosphorus in effluent discharge, that is 5mg/L, the concentration found in the bio slurry at MBPS does not comply. While phosphorus in bio slurry enhances soil fertility, excessive concentrations can destabilize the aquatic ecosystem this is because when discharged into the environment, bio slurry joins surface runoff during rains, gets deposited in surface water bodies an poses a risk of eutrophication in these water bodies, therefore treatment is required to reduce its concentration in bio slurry.(EPA, 2014);(Collard et al, 2020).

This data is helpful in informing the level of agricultural lime treatment required in order to suppress the above mentioned pathogens to levels below the maximum permissible limits. This in turn informs the dosage of the agricultural lime required for pathogen suppression in bio-slurry and the pH adjustment required.

4.3 Results and Discussion: Determination of the pH Adjustment Properties of the Agricultural Lime for Pathogen Suppression in Bio-Slurry

The determination of the pH adjustment properties of agricultural lime involved qualitative analysis by means of the flame test technique to confirm the presence of calcium ions (Safety, n.d.). Having confirmed the presence of calcium ions in the agricultural lime, the ideal dosage for the required pH adjustment was performed by jar test analysis.

4.3.1 Flame Test Results and Discussion

The flame color observed was Orange (*Figure 1*).

Figure 1: Orange flame from agricultural lime

The flame test was a qualitative analytical technique that was used to confirm the presence of calcium ions in agricultural lime. Calcium ion is directly related to the neutralizing value of a material, the higher the neutralizing value, the higher the capability of creating alkaline conditions (Schwab et al., 2007).

The confirmation calcium ions in agricultural lime is evidenced by a bright orange flame, when the agricultural lime is subjected to an open flame or source of heat (Safety, n.d.).

When calcium ions are introduced into a flame, the heat from the flame excites the electrons in the calcium ions to higher energy levels. When these excited electrons return to their ground state, they release energy in the form of light at specific wavelengths, producing the characteristic color of bright orange flame. (Safety, n.d.), hence confirming presence of calcium ions.

4.3.2 Jar Test Results and Discussion

The optimum dosage of agricultural lime for pathogen suppression was determined (Figure 2). The pH variation over days in bio-slurry containing the optimum dosage was also determined (Figure 3).

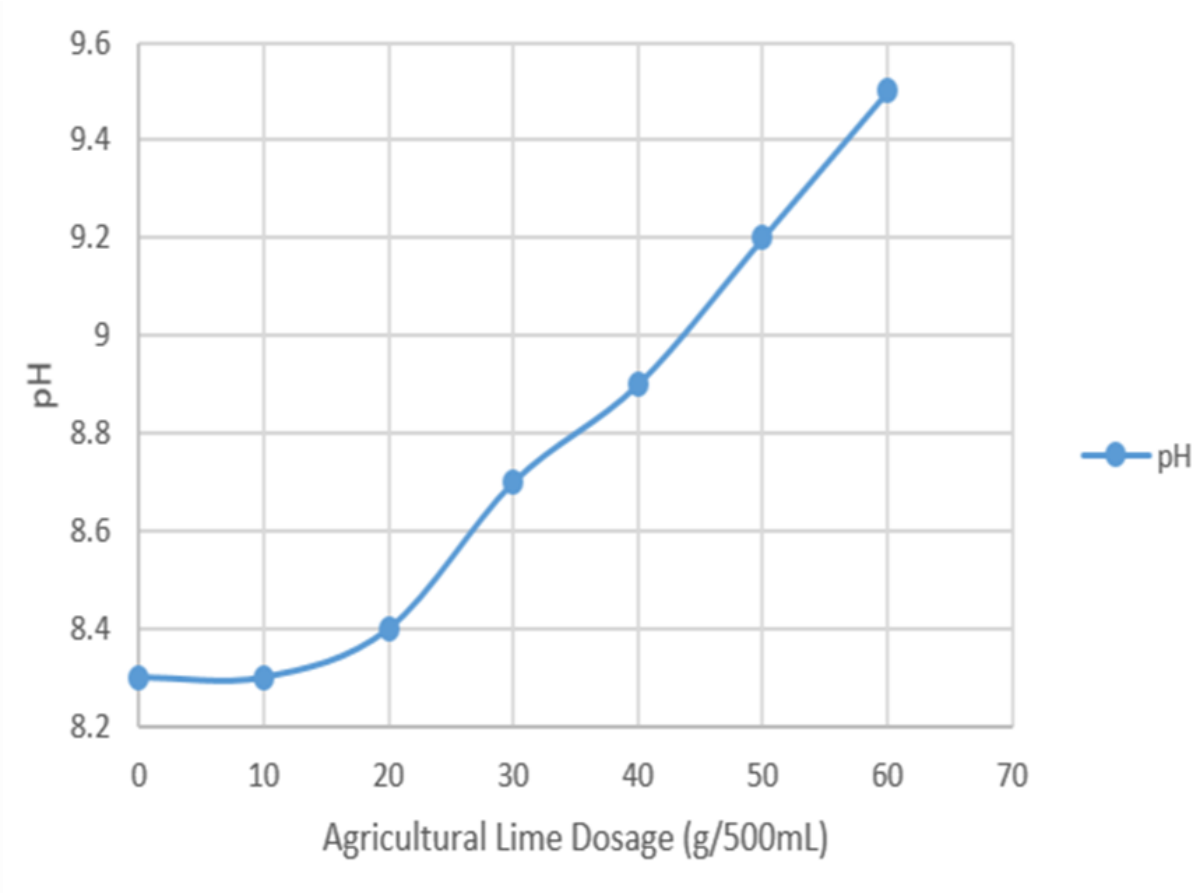


Figure 2: The effect of agricultural lime dosage on pH values in bio-slurry (after 3 days)

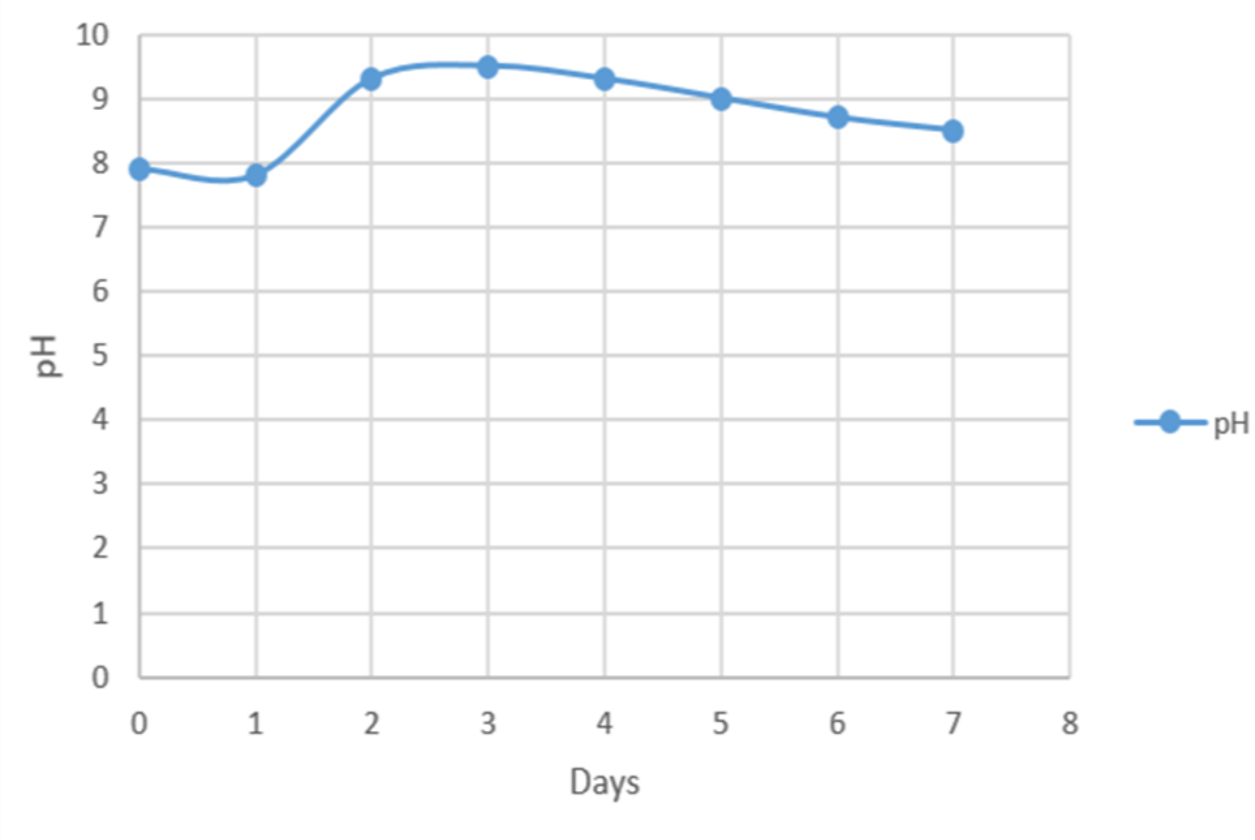


Figure 3: pH variation over days in bio-slurry containing the dosage of 60g/500mL. The initial pH was 7.9

Figure 2 suggests that the ideal agricultural lime dosage was 60g/500mL given that it resulted in a pH range between 9.0 – 10.0 after three days. Research suggests that this range would suppress pathogen activity and result in reduced concentrations of the pathogenic microorganisms in the bio-slurry. The dosage determined would inform the amount of agricultural lime required to treat the bio-slurry released from MBPS daily.

Figure 3 suggests that with 60g/500mL, the pH of the bio-slurry raises from neutral to the range of 9.0 – 10.0 and back to neutral within a period of seven days. This suggests that within seven days from treatment the bio-slurry would be safe for discharge into the environment and for use as a fertilizer.

Both findings suggest that the preliminary design of the treatment unit for pathogen suppression in bio-slurry using agricultural lime should put into consideration the required amounts of agricultural lime, the given daily volume of bio-slurry released, adequate mixing of the agricultural lime and the bio-slurry, and sufficient contact time of not less than 7days to facilitate the treatment.

This analysis is still ongoing so as to determine the daily concentrations of the pathogenic microorganisms during the course of agricultural lime treatment from day zero to day seven. This will better inform the treatment and the preliminary design.

4.3.3 Results and discussion: treated bio slurry

Parameters	**Units**	**Result**	**Max. Permissible Limit (NEMA, 2020)**
Bact: Escherichia Coli	CFU/100mL	279	400
Bact: Salmonella	CFU/100mL	49	400
Bact: Staphylococcus aureus	CFU/100mL	0	400
Ascaris lumbricoides eggs	No./L	0	<=1
pH	---	8.5 – 8.8	5.0 – 8.5
Potassium (K)	mg/L	79 ± 3.4	100
Temperature	^0C	26 ± 0.14	20 – 35
Total Dissolved Solids (TDS)	mg/L	5356 ± 245	700
Total Phosphorous (TP)	mg/L	42 ± 5.45	5

Figure 4 results of physicochemical and micro biological properties of bio slurry treated with agricultural lime

1. **Reduction of pathogenic microorganisms (E.coli and salmonella)**

The reduction of E.coli and salmonella shows the effectiveness of agricultural lime against pathogenic microorganisms. The application of agricultural lime raises pH creating inhospitable environments for pathogens, reducing their concentrations to that that is safe for the environment and agricultural use. Studies have demonstrated lime stabilization can significantly reduce pathogenic microorganism concentrations in bio slurry, achieving levels that are deemed safe for land

application according to standards. This is achieved through protein denaturing and membrane disruption: hydroxyl ions disrupt bacterial cell membranes through saponification of lipids this is enhanced by the oxidative stress from reactive oxygen species generated at high pH hence denaturing the cellular proteins, disrupting membrane integrity leading to inactivation of the microorganism.

2. **Persistence of Helminth Eggs**

The results show that helminth eggs persisted in the treated bio slurry. Helminth eggs, particularly Ascaris lumbricoides exhibit remarkable resilience to alkaline conditions given their structural resistance make of a three layered shell that shields the embryos from pH extremes, allowing them to remain viable for extended time periods even after the treatment process. A study reported that using lime for treatment of bio slurry that contained helminth eggs, reduced the number of these eggs by 53-56% but the viable eggs constituted to 44-53% of the total count. This indicates the need for additional or alternative treatment methods to achieve complete inactivation of helminth eggs (carlos. L.F, et al, 2023)

3. **Increase in Phosphorus Concentrations**

The results show that the concentrations of phosphorus increased after treatment of the bio slurry, this can be attributed to several factors; agricultural lime induced pH elevation can lead to the of organic phosphorus compounds becoming soluble in bio slurry, converting them into readily available inorganic forms. While this enhances the nutrient value of the bio slurry as a bio fertilizer, excessive phosphorus levels pose environmental risks notably eutrophication of water bodies due to run offs. Despite the fact that treatment of bio slurry with agricultural lime reduces

pathogen loads, it inadvertently increases the concentrations of phosphorus, necessitating careful management to prevent environmental contamination.

4.3.4 Concentrations of Pathogenic Microorganisms During Treatment with Agricultural Lime

- **E.coli**

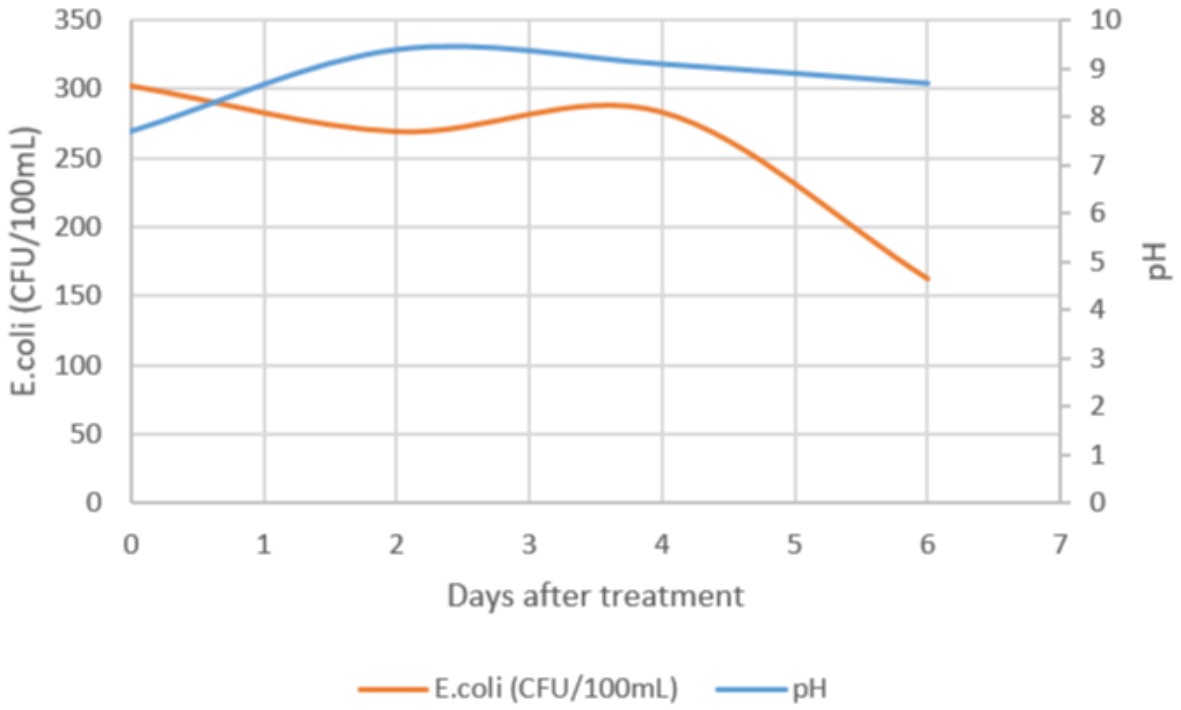


Figure 5 a graph showing the concentrations of E.coli with variations in pH

The above graph shows the trend/ behavior of E.coli, with variations in pH over a contact time of 6 days. It shows that quantities/ concentration of E.coli decreases with increase in pH.

Day 0: The initial pH of bio slurry, as shown in the graph is 8.5 and the quantity of E.coli is 300CFU/100ml.

Day 0 to day 2: it was observed that pH rose to a range between 9 and 10 and the concentration of E.coli starts decreasing from 300 to 283 CFU/100ml

Day 3 to day 6: as seen from the graph, the pH starts to tend back to neutral but alkaline conditions are still sustained hence E.coli colonies is still dropping further to 163CFU/100ml by day 6.

This proves that the alkaline conditions created by addition of bio slurry influenced the downward regression of the graph showing concentration of E.coli in bio slurry, this is achieved through protein denaturing and membrane disruption: hydroxyl ions disrupt bacterial cell membranes through saponification of lipids this is enhanced by the oxidative stress from reactive oxygen species generated at high pH hence denaturing the cellular proteins, disrupting membrane integrity leading to inactivation of the microorganism.

The pH is noticed to have reduced back to a neutral value by the 6^{th} day, this makes it safe for discharge according to NEMA standards for discharge of bio slurry into the environment, this value of pH is especially suitable for bio slurry used in agriculture, this is because agricultural soil is very sensitive to high levels of alkalinity or acidity, this affects crop yield.

- **Salmonella**

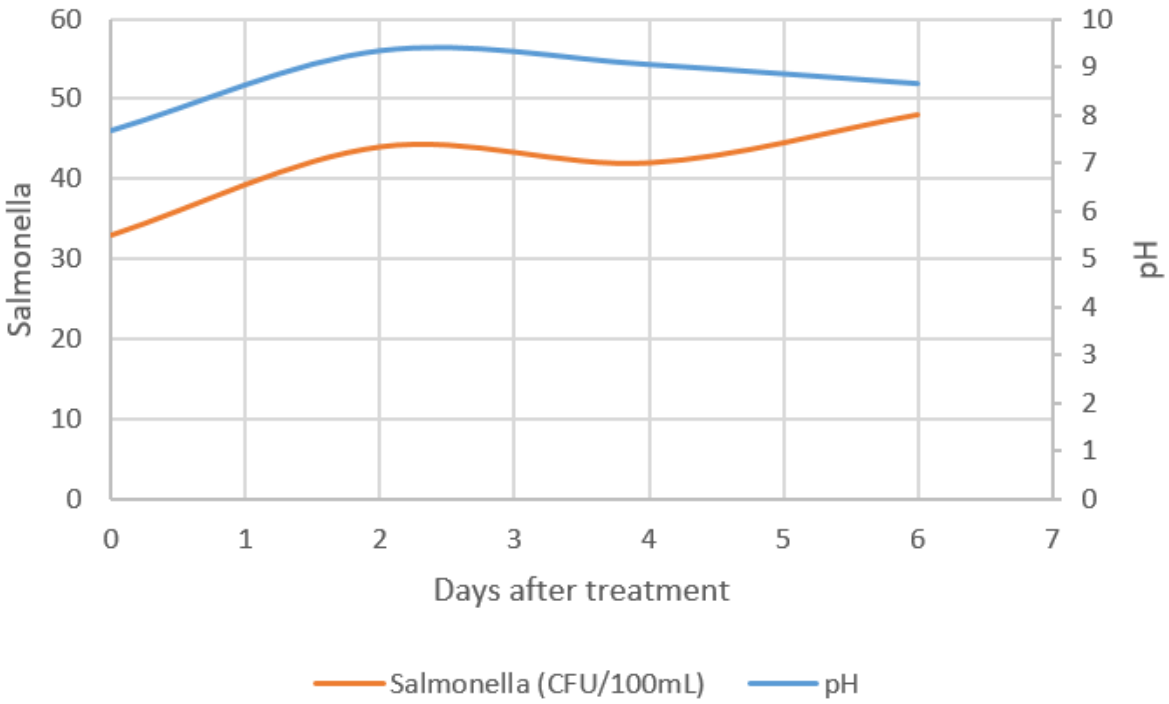


Figure 6 a graph showing the concentrations of salmonella with variations in pH

The above graph shows the trend/ behavior of salmonella, with variations in pH over a contact time of 6 days. It shows that quantities/ concentration of salmonella decreases with increase in pH.

Day 0: The initial pH of bio slurry, as shown in the graph is 8.2 and the quantity of salmonella is 33CFU/100ml.

Day 0 to day 2: it was observed that pH rose to a range between 9 and 10 and the concentration of salmonella still increasing rapidly from 30 to 45 CFU/100ml, this is after application of agricultural lime in bio slurry.

Day 2 to day 3: as seen from the graph, the pH is still increasing in that range of 9 to 10, alkaline conditions hence affect the salmonella colonies and they start dropping from 44CFU/100ml to 41CFU/100ml.

Day 3 to day 6: as pH tends back to neutral from 9.6 to 7,6, the salmonella colonies are seen to have a slower progression compared to between day 0 and day 2 due to the sustained effect of the agricultural lime.

4.3.5 Experimental Runs of Bio Slurry Treatment with Agricultural Lime Run Through the Prototype.

This was carried out to firstly test for the efficiency of the baffle mixing structure to test for its ability to homogeneously mix agricultural lime in bio slurry and also to check for the efficiency of the cascading design throughout the treatment of bio slurry.

Figure 7 Prototype of a cascading design set up of the bio sluryy treatment unit

Similar results were obtained with that from treatment carried out in laboratory equipment as seen in the previous segment. pH was monitored alongside trends of E.coli and salmonella colonies as shown in the graphs below;

4.3.6 Concentrations of Pathogenic Microorganisms During Treatment with Agricultural Lime

- **E.coli**

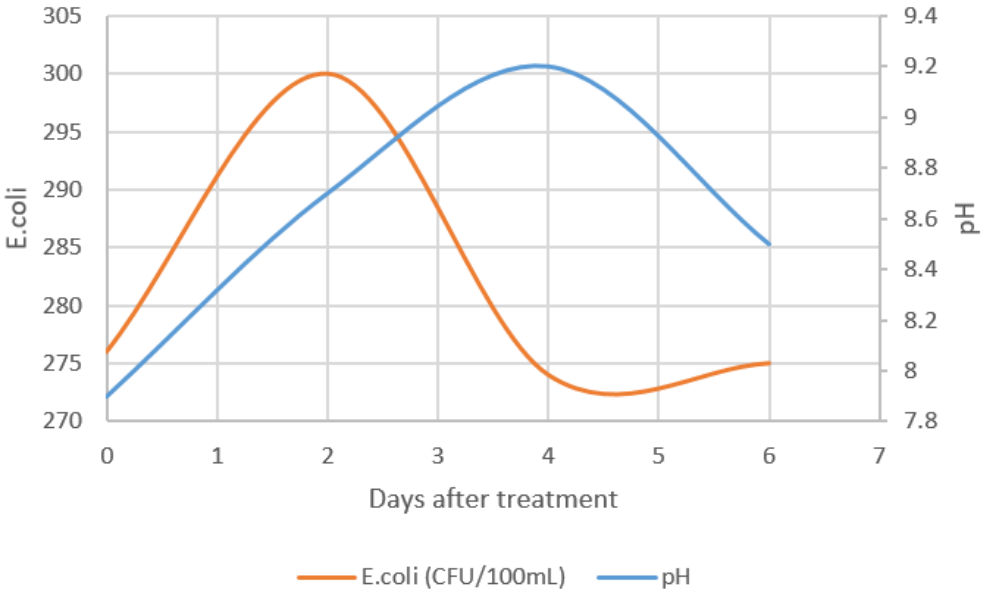


Figure 8 A graph showing the concentrations of E.coli with variations in pH

Figure 6 shows;

- Increase of pH of bio slurry with increase in days after application of agricultural lime
- the decrease of the concentrations of E.coli with increase in pH

- **salmonella**

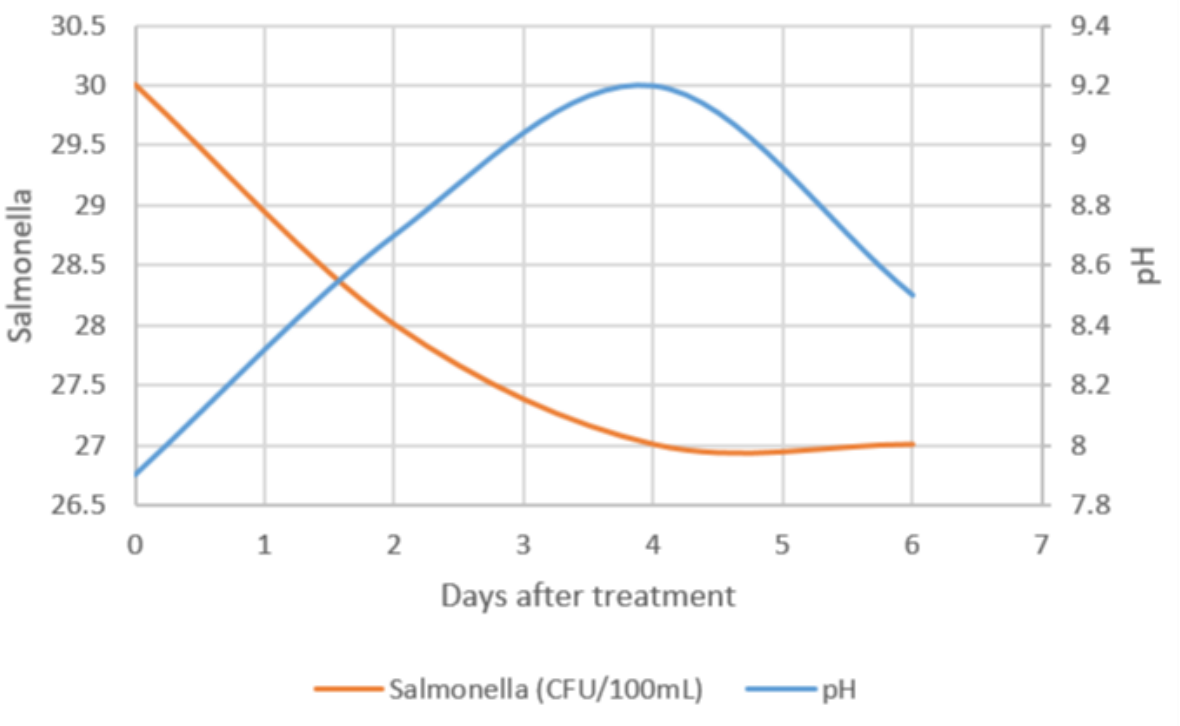


Figure 9 A graph showing the concentrations of salmonella with variations in pH

Figure 7 shows;

- Increase of pH of bio slurry with increase in days after application of agricultural lime
- the decrease of the concentrations of salmonella with increase in pH

4.4 Design of the treatment unit for pathogen suppression using agricultural lime

The design of the treatment unit was informed by the results obtained from the preceding objectives. The design was guided by and in accordance to the SAFL baffle design guide (2023), water supply design manual, exponential decay model (2013).

The considerations made included

- Bio slurry discharge projections
- Sizing of the agricultural lime dosage chamber
- Cascading design
- The required amount of agricultural lime for daily treatment
- Design of the baffle mixing chamber
- The death rate constant
- CAD drawing showing the layout of the treatment unit
- Bio slurry discharge projections

4.4.1 Bio Slurry Discharge Projections

A 20year design life projection was considered with reference to the current quantity of bio slurry released daily and the current population of female pupils at MBPS, as outlined below;

Current quantity of bio slurry discharged: 30L twice a day = 30L x 2 = 60L

Current population of female pupils = 500 pupils

Population projection equation $P_n = P_t\ (1 + r/100)^n$

Where

- P_n is the projected population
- P_t is the current population
- r is the rate of growth
- projected number of years

$P_n = P_t\ (1 + r/100)^n$

$P_n = 500\ (1 + 3/100)^{20}$

P_n = 903 pupils

Therefore, in 20 years, the population of female pupils is projected to over 900pupils

4.4.2 Projections of bio slurry discharge

Given that from 500 students, 60L of excreta and water are flushed into the bio digester daily

Therefore 900 pupils will produce (60/500 x 900) L per day = 108 per day

Hence the projected bio slurry discharge was considered to be 110L per day

4.4.3 Sizing of the Agricultural Lime Dosage Chamber

- The dosage chamber was designed to receive bio slurry from the outlet chamber of the bio digester, considering the current and projected quantities of daily bio slurry discharge, the dosing chamber was designed in consideration of a daily discharge of 110L as calculated below.

Convert 110L to m^3

1 m^3 = 1000L

110L = (1/1000) x 110 = 0.11 m^3

- For the dimensions of the internal chamber 0.8m x 0.5m x 0.3m, in order of length x width x height
- Thickness of the chamber walls was taken to be 0.2m masonry in header bond coated with 0.02m thick plaster
- For the number of treatment chambers that will hold the bio slurry for the required contact time which was determined to be 7 days from the second objective, therefore, 7 chambers will be required, one for each of the treatment till the 7^{th} day.

4.4.4 Amount of agricultural lime required for daily treatment to suppress pathogens in bio slurry

From objective 2 of this study, it was determined by a jar test analysis that the ideal quantity agricultural lime required to suppress pathogens in bio slurry is 60g/500ml.

Converting 60g/500ml to L gives us 60g/0.5L

For 60L of bio slurry

= (60g/ 0.5L) x 60

= 7200g

=7.2kg

Therefore, a daily dose of 7.2 kg of agricultural lime is required for daily treatment

4.4.3 Death Rate Constant for agricultural lime treatment

Exponential decay model: $N_t = N_0 e^{kt}$

Where;

- N_t is the number of surviving pathogens

- N_0 is the initial number pathogens
- K is the death rate constant
- T is time

N_t = 220CFU/100ml

N_0 = 624 CFU/100ml

t = 7 days

computing for k

$N_t = N_0 e^{kt}$

$220 = 624e^{7k}$

k = 14.89% which is approximately 15% per day

This shows that 15% of the pathogenic microorganism get suppressed daily

This death rate constant can be used for further studies conducted on treatment of bio slurry for MBPS using agricultural lime.

4.4.5 Consideration of the Cascading Design of the Treatment Unit

This design was configured in consideration of the daily treatment chambers that were connected in series allowing water to flow sequentially from one chamber to another

Flow development was accomplished due to the pressured head of 0.3m and gravity action.

This flow was designed to be controlled by valves that regulate the flow of bio slurry through the successive treatment chambers.

4.4.6 Baffle mixing design considerations

A horizontal flow baffle structure was considered for mixing agricultural lime

Baffle mixing channel dimensions: length x width x height

=1m x 0.2m x 0.2m

Height of the baffle

Channel height = 0.2m

Baffle height = 0.5m x 0.2m

= 0.1m

Length of the baffle

Channel width = 0.2m

= 0.5m x 0.2m

= 0.1m

Spacing in between baffles

A spacing of 0.15m was considered

Thicknesses of the Baffle and channel wall

A thickness of 0.02m was considered for both components

Horizontal inclination angle of the baffle

An inclination of 60^0 was considered

Number of baffle pairs

Given that the channel length is 1m with an allowance of 0.05m at each end of the channel for flow development

Effective length

= (1m - 0.05m – 0.05m)

= 0.9m

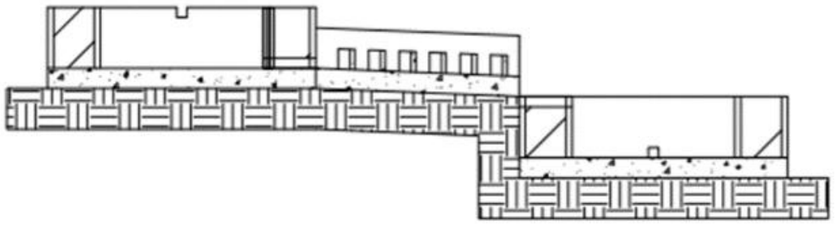
Number of baffle pairs

= effective length/ baffle spacing

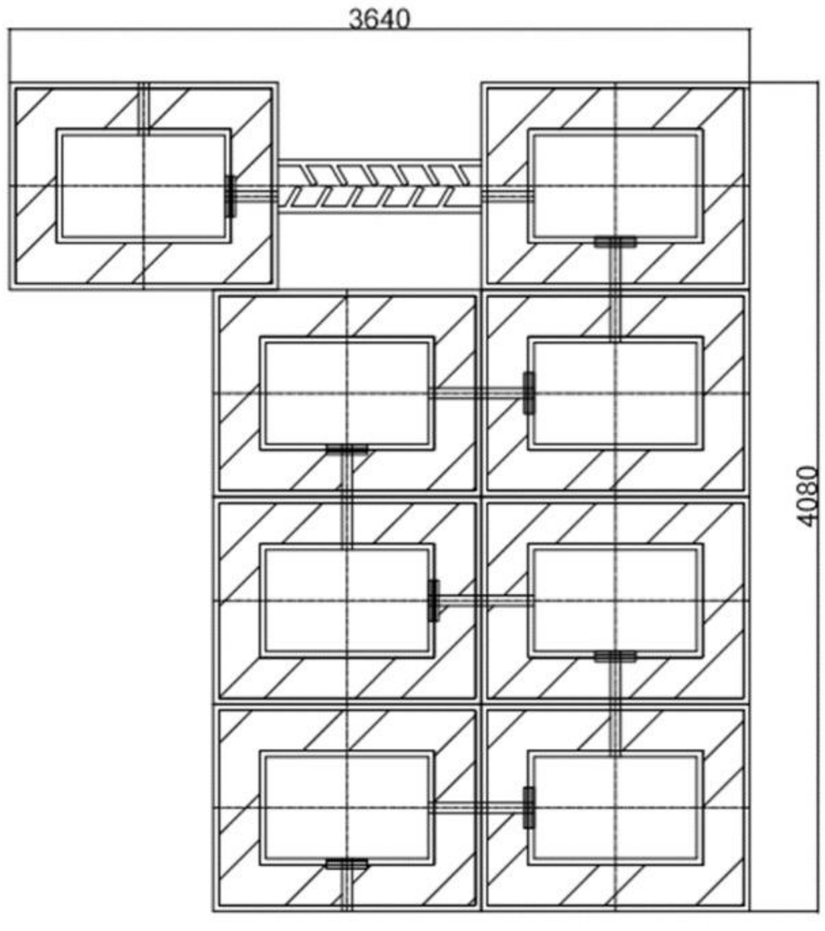
= 0.9m/0.15m

= 6 baffles pairs

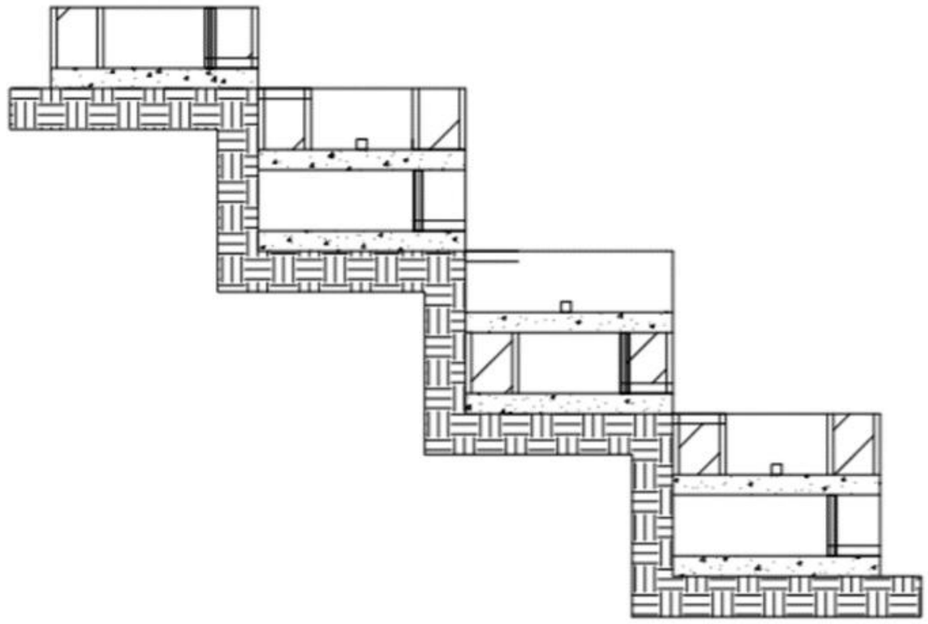
The above information was used to come up with CAD drawing that shows a layout of the bio slurry treatment unit.



BAFFLE CHAMBER SECTION



PLAN



END ELEVATION

TITLE:	DESIGN OF THE TREATMENT UNIT FOR BIO-SLURRY USING AGRICULTURAL LIME
DESIGN BY:	SIDA CYNTHIA PARIYO REG. NO. S21B32/063 KOMAGUM EMMANUEL OBONG REG. NO. S21B32/023
SCALE:	1:30

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Bio slurry has several parameters these include macro nutrients, pH, TDS, TSS, volatile solids, BOD, COD, total organic and inorganic matter and microbiological parameters, however this research mainly focused on the microbiological parameters, and the macro nutrient because the treated bio slurry was to be used as a bio fertilizer and pH due to the fact that the treatment mechanism used capitalizes on Ph.

The conclusions of this study are based on the findings obtained after carrying out the specific objectives of this study.

5.1.1 Specific objective 1: physicochemical properties of bio slurry

From laboratory analyses carried out, it was concluded that the human excreta based bio-slurry at Mukono Boarding Primary School is unsafe for use as a bio fertilizer or discharge into the environment, given that the concentrations of E.coli and helminth eggs are beyond the permissible limits by NEMA, therefore pretreatment before use as a bio fertilizer and discharge into the environment is required.

5.1.2 Specific objective 2: the pH adjustment properties of agricultural lime

The effectiveness of lime treatment is directly related to the pH achieved and maintained.

It was established that agricultural lime possesses pH adjustment properties

Firstly, a flame test was carried out to confirm calcium ion sin agricultural lime, this is because calcium ions aid in creating alkaline conditions

From laboratory analyses carried out using jar tests, the quantity of agricultural lime required to adjust the pH of bio slurry to arrange of 9-10, is 60g/500ml. at this pH, the concentration of pathogens reduced and was observed to be within the permissible limits for discharge and use as a bio fertilizer.

This pH range was achieved in a span of 3 - 4 days and observation continued for 3 more days and the pH was observed to reduce to below 8.5, and the pathogen concentration still kept going down.

In conclusion 60g of agricultural lime is required to raise the pH of 500ml of the bio slurry in study to a range of 9-10 within an average of a 4-day period for pathogen suppression, furthermore, the treated bio slurry is required to go through a retention period of 3 additional days such that it's pH reduces to below 8.5 which is within the pH range suitable for bio slurry release into the environment according to NEMA.

5.1.3 Specific objective 3: to develop an agricultural lime treatment model for pathogen suppression in bio slurry

Using data from the preceding specific objectives as well as the exponential decay model, it is concluded that with the recommended dosage of agricultural lime, there is a 15% death rate of pathogens in bio slurry.

The cascading design for the treatment unit and baffle mixing design for mixing of agricultural lime with bio slurry is ideal for pathogen suppression. The design allows for pathogen suppression while maintaining a practical and scalable approach for implementation, with bio slurry transfer to the subsequent chambers using gravitational flow making it energy efficient.

5.2 RECOMMENDATIONS

A pilot study of the use of the bio slurry at MBPS that has been treated using agricultural lime should be used as a bio fertilizer for all crops except crops that are eaten with little or no cooking such as leafy greens.

A study on the use of agricultural lime for pathogen suppression in bio slurry obtained from other categories of feed stock such as food waste, animal dung or droppings, among others should also be carried out.

In order to enhance the effectiveness of the agricultural lime treated bio slurry from MBPS, the following recommendations should be considered.

- Further research should be carried out on dilution of the bio slurry for the reduction of phosphorus content in bio slurry, to comply with the NEMA standards for the maximum permissible limits. This may involve assessment of various dilution ratios or exploring additional treatment processes. Phosphorus is a nutrient crucial in quality crop yield, however very high concentrations lead to nutrient imbalance in soil and eutrophication in surface water sources as a result of nutrient loading due to surface run off from agricultural fields.
- Helminth suppression strategies in bio slurry need to be employed. Agricultural lime, being an effective suppressant for pathogenic microorganisms, is not rigorous enough to destroy/deactivate helminth eggs, therefore further research is recommended for complete elimination of helminth eggs in bio slurry while ensuring that the bio slurry retains its properties that make it viable for use as a bio fertilizer after the treatment for elimination of helminth eggs.

- Additional treatment is also recommended for the reduction of TDS of the bio slurry after treatment with agricultural lime. This is to ensure that the concentration of TDS in bio slurry complies with NEMA standards for effluent discharge and use of bio slurry as a bio fertilizer.

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APPENDIX A: RESEARCH WORKS

Figure 10: Weight measurements of agricultural lime for Jar Test analysis

Figure 11: Execution of Jar Test analysis

Figure 12: Insertion of bio-slurry from jar into pH meter for pH measurement

Figure 13: Measurement of pH

Figure 14 Hima Cement Agricultural Lime (HOLCIM, 2025).

Figure 15 fixed dome bio digester with outlet chamber

Figure 16 Collection of bio slurry sample from outlet chamber

APPENDIX B: LABORATORY DATA SHEETS

UGANDA CHRISTIAN UNIVERSITY
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FACULTY OF ENGINEERING, DESIGN, AND TECHNOLOGY
Department of Engineering and Environment

ENVIRONMENTAL QUALITY LABORATORY
Laboratory test report

Certificate Number: EQL001S		
Client Name: 1. Sida Cynthia Pariyo 2. Komagum Emmanuel Obong	**Sample Receipt Date:** 10th October, 2024	**Analysis Start Date:** 11th October, 2024
Client Address & Contact Physical Address: Mukono Phone No.: +256 776 250214 Email: N/A	**Date of Analysis Completion:** 14th October, 2024	**Date of issue of the Certificate:** **16th October, 2024**
Client Sample ID	**Tests conducted**	
1. L-102024 2. L-112024	Surface Water Wastewater	
Sample type and location:	Digestate /	---
State of the sample on delivery:	Liquid samples	---

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16 OCT 2024
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Department of Engineering and Environment

LAB RESULTS FOR: pH, Turbidity, E. Coli and Salmonella *Spp*.

1. **Lab Experiment:**

S/N	Sample	Parameter			
		pH	Turbidity (NTU)	E. Coli (CFU/100ml)	Salmonella (CFU/100ml)
1	Bio-slurry	8.39	175.2	$21x10^5$	$14x10^3$
2	Surface Water (Nakawolole Stream)	7.25	5.09	293	22

Eddie Ojara
Laboratory Instructor

Rodgers Tayebwa
Head of Department - Engineering & Environment

UGANDA CHRISTIAN UNIVERSITY
H.O.D
16 OCT 2024
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

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FACULTY OF ENGINEERING, DESIGN, AND TECHNOLOGY
Department of Engineering and Environment

ENVIRONMENTAL QUALITY LABORATORY
Laboratory Test Certificate

Certificate Number: EQL255J		
Sample: Bio-slurry	**Sample ID No.:** EQL/01/25/0832	
Sample Description: Said to be "Bio-Slurry"		
Party's Ref No: Nil	**Certificate Issue Date:** 10th Feb 2025	
Client Name & Address: 1. Sida Cynthia Pariyo 2. Komagum Emmanuel Obong **Physical Address:** Mukono **Client's Contact** Phone No.: +256 776 250214 Email: N/A	Job Code:	: JAR AND FLAME TEST
	Sample Received On	: 27th Jan 2025
	Date of Testing	: 1st Feb 2025
	Completion Date	: 8th Feb 2025
Sample Condition:	Liquid sample packed in plastic bottles	

FLAME TEST RESULT

Sample	No.1	No.2	No.3
Flame Colour	Orange	Orange	Orange

JAR TEST RESULTS AT TEMPERATURE RANGE 24.9°C to 26.4°C

1st February, 2025 3:30PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.2	8.0	8.1	7. 7	7.8	7.8	7.9
1st February, 2025 4:00PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.3	8.0	8.1	7. 7	7.8	7.7	7.9
1ST February, 2025 4:15PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.2	8.1	8.1	7.7	7.9	7.8	7.9
1st February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.2	8.2	8.1	7.7	7.9	7.7	7.8
3RD February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.3	8.3	8.4	8.6	8.8	9.0	9.3

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Department of Engineering and Environment

4TH February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.3	8.3	8.4	8.7	8.9	9.2	9.5
5TH February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.1	8.3	8.5	8.7	8.9	9.2	9.3
6TH February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.066667	8.2	8.5	8.7	8.7	8.7	9.0
7TH February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.0	8.2	8.6	8.6	8.6	8.5	8.7
8TH February, 2025 4:30 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	7.966667	8.1	8.4	8.4	8.3	8.3	8.5

Eddie Ojara
Laboratory Instructor

Tom More Nwanje
Head of Department - Engineering & Environment

UGANDA CHRISTIAN UNIVERSITY
H.O.D
11 FEB 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

End of Report

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY - BUGOLOBI

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

Student: CYNTHIA Sida Pariyo (S21B32/063) &

EMMANUEL Komagum Obong (S21B32/023)

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 29/11/2024

Waste water Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled: 28.11.2024	National Standards for Effluent Discharge
Bact: Escherichia coli	CFU/100mL	600	Not Specified
Bact: Salmonella	CFU/100mL	100	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	1	Not Specified
pH	----	8.007	5.0 -8.5
Potassium: K	mg/L	81.5	Not Specified
Temperature	°C	21.6	Not Specified
Total Dissolved Solids (TDS)	mg/L	2624	700
Total Phosphorous (TP)	mg/L	37.012	5.0

Helminth egg: Prorodon

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

Analysed by: Julius. W (QCO) &

Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION

05 DEC 2024

WATER QUALITY MANAGEMENT DEPT.
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE COPORATION

CENTRAL LABORATORY - BUGOLOBI

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Student: SIDA Cynthia Pariyo (S21B32/063)

KOMAGUM Emmanuel Obong (S21B32/ 023)

Address: Uganda Christian University

Mukono (Uganda)

Date Sampale Tested: 31/01/2025

Waste water Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 29.01.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	480	Not Specified
Bact: Salmonella	CFU/100mL	76	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	4	Not Specified
pH	....	7.946	5.0 - 8.5
Potassium: K	mg/L	86.1	Not Specified
Temperature	℃	21.8	Not Specified
Total Dissolved Solids (TDS)	mg/L	2630	700
Total Phosphorous (TP)	mg/L	39.4	5.0

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

Analysed by: Julius. W (QCO) & 31/01/2025

Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION

31 JAN 2025

WATER QUALITY MANAGEMENT DEPT

THE CENTRAL LABORATORY

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KOMAGUM Emmanuel Obong (S21B32/023)

Address: Uganda Christian University

Mukono (Uganda)

Date Sampale Tested: 05/02/2025

Waste water Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 03.02.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	520	Not Specified
Bact: Salmonella	CFU/100mL	106	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	2	Not Specified
pH	---	8.014	5.0 - 8.5
Potassium: K	mg/L	83.9	Not Specified
Temperature	℃	22.6	Not Specified
Total Dissolved Solids (TDS)	mg/L	2590	700
Total Phosphorous (TP)	mg/L	43.9	5.0

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

Analysed by: Julius. W (QCO) & 05/02/25

Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION

05 FEB 2025

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Mukono (Uganda)
Date Sampale Tested: 26/02/2025

Sample 1: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 26.02.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	320	Not Specified
Bact: Salmonella	CFU/100mL	36	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	—	7.73	5.0 - 8.5
Potassium: K	mg/L	82.9	Not Specified
Temperature	℃	26.5	Not Specified
Total Dissolved Solids (TDS)	mg/L	5519	700
Total Phosphorous (TP)	mg/L	37.7	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) &
Komagum Emmanuel Obong

26/02/2025

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26 FEB 2025
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Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:27/02/2025

Sample 2: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 27.02.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	284	Not Specified
Bact: Salmonella	CFU/100mL	30	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	---	7.63	5.0 - 8.5
Potassium: K	mg/L	83.6	Not Specified
Temperature	℃	26.2	Not Specified
Total Dissolved Solids (TDS)	mg/L	5604	700
Total Phosphorous (TP)	mg/L	36.5	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 27/02/2025
Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION
27 FEB 2025
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Date Sampale Tested: 28/02/2025

Sample 1: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 28.02.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	258	Not Specified
Bact: Salmonella	CFU/100mL	42	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	3	Not Specified
pH	—	9.30	5.0 - 8.5
Potassium: K	mg/L	80.1	Not Specified
Temperature	℃	24.3	Not Specified
Total Dissolved Solids (TDS)	mg/L	4826	700
Total Phosphorous (TP)	mg/L	30.4	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 27th/02/2025
Komagum Emmanuel Obong

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28 FEB 2025
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Date Sampale Tested:01/03/2025

Sample 2: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 01.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	280	Not Specified
Bact: Salmonella	CFU/100mL	46	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	1	Not Specified
pH	....	9.40	5.0 - 8.5
Potassium: K	mg/L	82.4	Not Specified
Temperature	℃	26.0	Not Specified
Total Dissolved Solids (TDS)	mg/L	5520	700
Total Phosphorous (TP)	mg/L	36.2	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 01/03/2025
Komagum Emmanuel Obong

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01 MAR 2025
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Mukono (Uganda)
Date Sampale Tested: 03/03/2025

Sample 1: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 03.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	286	Not Specified
Bact: Salmonella	CFU/100mL	38	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	1	Not Specified
pH	....	9.00	5.0 - 8.5
Potassium: K	mg/L	82.3	Not Specified
Temperature	℃	25.4	Not Specified
Total Dissolved Solids (TDS)	mg/L	5201	700
Total Phosphorous (TP)	mg/L	31.2	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 03/03/2025
Komagum Emmanuel Obong

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Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:03/03/2025

Sample 2: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 03.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	280	Not Specified
Bact: Salmonella	CFU/100mL	47	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	...	9.12	5.0 - 8.5
Potassium: K	mg/L	81.2	Not Specified
Temperature	℃	26.0	Not Specified
Total Dissolved Solids (TDS)	mg/L	5578	700
Total Phosphorous (TP)	mg/L	35.7	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 03/03/2025
Komagum Emmanuel Obong

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Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested: 05/03/2025

Sample 1: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 05.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	278	Not Specified
Bact: Salmonella	CFU/100mL	47	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	----	8.50	5.0 - 8.5
Potassium: K	mg/L	75.3	Not Specified
Temperature	℃	25.9	Not Specified
Total Dissolved Solids (TDS)	mg/L	5114	700
Total Phosphorous (TP)	mg/L	47.0	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 05/03/2025
Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION
05 MAR 2025
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Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:05/03/2025

Sample 2: Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 05.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	280	Not Specified
Bact: Salmonella	CFU/100mL	50	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	8.81	5.0 - 8.5
Potassium: K	mg/L	82.1	Not Specified
Temperature	℃	26.1	Not Specified
Total Dissolved Solids (TDS)	mg/L	5601	700
Total Phosphorous (TP)	mg/L	36.1	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 05/03/2025
Komagum Emmanuel Obong

NATIONAL WATER AND SEWERAGE CORPORATION
05 MAR 2025
WATER QUALITY MANAGEMENT DEPT
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Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
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Date Sampale Tested:05/03/2025

Sample 1: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 05.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	240	Not Specified
Bact: Salmonella	CFU/100mL	28	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	—	7.79	5.0 - 8.5
Potassium: K	mg/L	76.3	Not Specified
Temperature	℃	26.6	Not Specified
Total Dissolved Solids (TDS)	mg/L	5604	700
Total Phosphorous (TP)	mg/L	35.1	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 05/03/2025
Komagum Emmanuel Obong

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

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Student: SIDA Cynthia Pariyo (S21B32/063)
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Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:06/03/2025

Sample 2: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 06.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	312	Not Specified
Bact: Salmonella	CFU/100mL	32	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	7.90	5.0 - 8.5
Potassium: K	mg/L	78.2	Not Specified
Temperature	℃	26.1	Not Specified
Total Dissolved Solids (TDS)	mg/L	5616	700
Total Phosphorous (TP)	mg/L	48.0	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) &
Komagum Emmanuel Obong

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

NATIONAL WATER AND SEWERAGE COPORATION
CENTRAL LABORATORY - BUGOLOBI
P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.

Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:07/03/2025

Sample 1: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 07.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	236	Not Specified
Bact: Salmonella	CFU/100mL	26	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	9.35	5.0 - 8.5
Potassium: K	mg/L	78.6	Not Specified
Temperature	℃	26.3	Not Specified
Total Dissolved Solids (TDS)	mg/L	5601	700
Total Phosphorous (TP)	mg/L	36.0	5.0

Remarks: The results for the water samples tested were as above.
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Date Sampale Tested:07/03/2025

Sample 2: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 07.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	300	Not Specified
Bact: Salmonella	CFU/100mL	30	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	8.10	5.0 - 8.5
Potassium: K	mg/L	78.0	Not Specified
Temperature	℃	26.4	Not Specified
Total Dissolved Solids (TDS)	mg/L	5608	700
Total Phosphorous (TP)	mg/L	45.0	5.0

Remarks: The results for the water samples tested were as above.
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Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:10/03/2025

Sample 1: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 10.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	240	Not Specified
Bact: Salmonella	CFU/100mL	20	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	9.10	5.0 - 8.5
Potassium: K	mg/L	76.2	Not Specified
Temperature	℃	26.5	Not Specified
Total Dissolved Solids (TDS)	mg/L	5626	700
Total Phosphorous (TP)	mg/L	35.8	5.0

Remarks: The results for the water samples tested were as above.
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Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:10/03/2025

Sample 2: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 10.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	308	Not Specified
Bact: Salmonella	CFU/100mL	34	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	9.30	5.0 - 8.5
Potassium: K	mg/L	78.6	Not Specified
Temperature	℃	26.2	Not Specified
Total Dissolved Solids (TDS)	mg/L	5602	700
Total Phosphorous (TP)	mg/L	46.0	5.0

Remarks: The results for the water samples tested were as above.
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10th/03/202-

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Student: SIDA Cynthia Pariyo (S21B32/063)
KOMAGUM Emmanuel Obong (S21B32/ 023)
Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:12/03/2025

Sample 1: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 12.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	241	Not Specified
Bact: Salmonella	CFU/100mL	20	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	....	8.45	5.0 - 8.5
Potassium: K	mg/L	76.8	Not Specified
Temperature	℃	27.1	Not Specified
Total Dissolved Solids (TDS)	mg/L	5698	700
Total Phosphorous (TP)	mg/L	37.4	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) &
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12th/03/2025

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Address: Uganda Christian University
Mukono (Uganda)
Date Sampale Tested:12/03/2025

Sample 2: Prototype Treated Bio Slurry Quality assessment lab results

Parameters	Units	Mukono Boarding Primary School Wastewater (Bio-Slurry) Sampled 12.03.2025	National Standards for Effluent Discharge
Bact: Escherichia coil	CFU/100mL	311	Not Specified
Bact: Salmonella	CFU/100mL	34	Not Specified
Bact: Staphylococcus aureus	CFU/100mL	0	Not Specified
Helminth Eggs	No./L	0	Not Specified
pH	—	8.61	5.0 - 8.5
Potassium: K	mg/L	79.1	Not Specified
Temperature	℃	26.1	Not Specified
Total Dissolved Solids (TDS)	mg/L	5643	700
Total Phosphorous (TP)	mg/L	46.4	5.0

Remarks: The results for the water samples tested were as above.
Analysed by: Julius. W (QCO) & 12/03/2025
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UGANDA CHRISTIAN UNIVERSITY

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FACULTY OF ENGINEERING, DESIGN, AND TECHNOLOGY
Department of Engineering and Environment

ENVIRONMENTAL QUALITY LABORATORY

Laboratory Test Certificate

Certificate Number: EQL256MA	
Sample: Bio-slurry	**Sample ID No.:** EQL/03/25/0332
Sample Description: Said to be "Bio-Slurry"	
Party's Ref No: Nil	**Certificate Issue Date:** 17th March 2025
Client Name & Address: 1. Sida Cynthia Pariyo 2. Komagum Emmanuel Obong **Physical Address:** Mukono **Client's Contact** Phone No.: +256 776 250214 Email: N/A	Job Code: : JAR AND FLAME TEST Sample Received On : 9th Feb 2025 Date of Testing : 10th Feb 2025 Completion Date : 17th Feb 2025
Sample Condition:	Liquid sample packed in plastic bottles

UGANDA CHRISTIAN UNIVERSITY H.O.D 14 MAR 2025 DEPARTMENT OF ENGINEERING AND ENVIRONMENT

FLAME TEST RESULT

Sample	No.1	No.2	No.3
Flame Colour	Orange	Orange	Orange

JAR TEST RESULTS AT TEMPERATURE RANGE 24.9°C to 26.2°C

10th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
Ph	8.1	8.2	8.2	8.3	8.5	8.6	8. 7
11th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	7.9	8.1	8.4	8.5	8.6	8.9	8.9
12th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.1	8.3	8.4	8.6	8.8	9.0	9.2
13th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.2	8.3	8.6	8.7	8.9	9.2	9.4
14th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.1	8.3	8.4	8.5	8.6	9.0	9.3

CamScanner

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15th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	8.0	8.2	8.3	8.4	8.6	8.7	9.0
17th February, 2025 5:00 PM							
Dose/ 500Ml	0g	10g	20g	30g	40g	50g	60g
pH	7.6	7.7	7.8	8.0	8.0	8.4	

Eddie Ujara
Laboratory Instructor

Tom [illegible] Mwanje
Head of Department - Engineering & Environment

UGANDA CHRISTIAN UNIVERSITY
H.O.D
14 MAR 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

End of Report