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BIOSAND FILTRATION AS A GREEN APPROACH TO SEPTIC TANK EFFLUENT MANAGEMENT IN ACCRA TECHNICAL UNIVERSITY

BY

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DECLARATION

I do hereby declare that apart from references to other people's works, which have been duly acknowledged, this proposal is result of my own independent work. I further declare that this proposal has not been submitted for award of any degree in this institution or other universities elsewhere.

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DATE

DEDICATION

This work is dedicated to my wonderful wife Mrs. Elizabeth Gyesewaa Mensah, my mother Ms Margaret Ashitso Tetteh and Philip Mensah (Brother)

ACKNOWLEDGEMENT

I wish to express my greatest gratitude to God Almighty for His faithfulness to me. Indeed i can do all things through Christ who strengthens me.

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ABSTRACT

Introduction: Sewage and household effluents at Accra Technical University (ATU), Ghana have been discharged into the ocean for years. This degrades environmental media and is detrimental to ecological systems. The institution also lacks adequate water for non-edible purposes. The Biosand Filter (BSF) is an innovation on the slow sand filter which has found use in preventing the discharge of raw sewage into the environment. The study aimed to test the performance of a BSF on sewage tank effluent and assess the suitability of the filtrate for non-drinking purposes.

Method: Three modified interconnected BSF were constructed on-site, with last filter connected to a storage tank. The modification was the provision of an additional media (charcoal) in the second barrel. Samples were collected of raw STE (pre-filtrate) and after passing through the BSF (post-filtrate). Samples were analysed for physical and microbiological parameters at designated laboratories. Measured values of the parameters in pre- and post-filtration samples were compared with EPA (Ghana) reference values. The removal efficiency was determined as the difference between pre- and post-filtrate parameters and expressed as a percentage of the pre-filtrate.

Results: Most of the effluent parameters from the PBSF were within the EPA standards, while others were unacceptable. However, the ability of the BSF to effectively improve effluent quality was demonstrated by removing excess quantity of nutrients and coliforms varied significantly ($P<0.05$). Nitrogen (83.3%), Phosphorus (89.5%), TSS (71.3%), TDS (66.2%), Total coliform (99.9%), Faecal coliform (99.7%) and E. coli (97.6%).

Conclusion: BSF is effective for upgrading physical and microbial quality of sewage at household and institutional level, prior to discharge in the environment. It produced a filtrate that meets EPA standards for irrigation of non-edible crops.

Keywords: wastewater, sewage, effluent, biosand filter, Ghana, liquid waste

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LIST OF ABBREVIATIONS

APHA	-	American Public Health Association
ATU	-	Accra Technical University
BOD_5	-	Biological Oxygen Demand over a 5-day period
BSF	-	Biosand Filter
BSFE	-	Biosand Filtration Effluent
CAWST	-	Centre for Affordable Water and Sanitation Technology
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
EPA	-	Environmental Protection Agency
FAO	-	Food and Agricultural Organisation of the United Nations
IWMI	-	International Water Management Institute
MIB	-	2-methylisoborneol
NOM	-	Natural Organic Matter
NTU	-	Nephelometric Turbidity Unit
PVC	-	Polyvinyl Chloride pipes
STE	-	Septic Tank Effluent
TDS	-	Total Dissolved Solids
TSS	-	Total Suspended Solids
WHO	-	World Health Organisation

OPERATIONAL DEFINITIONS

BIOLOGICAL OXYGEN DEMAND: This is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. It is mostly commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation.

BIOSAND FILTER: This term is used to describe the plastic barrels that contains a vertical cross section of gravels, course and fine sand and charcoals that act as a granular medium for the filtration and removal of pathogens in a liquid medium (often water). This is the intervention of this research.

BLANKS: Three types were used in this study:

Field blank is a container of water ascertained to be free of the parameters to be tested for in the field samples. It is taken to the field and exposed to the atmosphere of the site for a period. Trip blank contains laboratory reagent water which is sealed in a container transported to and from the study site, alongside empty and full sample containers. Its purpose is to identify contaminants introduced during transportation to and from the laboratory.

Laboratory blanks are similar but confined to the laboratory, they can be compared with other blanks to identify contaminants that may have been introduced at the laboratory.

CHEMICAL OXYGEN DEMAND: It is a measurement of the oxygen required to oxidize soluble and particulate organic matter as well as inorganic chemicals in the effluent.

CHLORINE DEMAND: The difference between the amounts of chlorine added to a water system and the amount of free available chlorine or combined available chlorine remaining at the end of a specified time period.

EFFLUENT: the wastewater discharged from the septic tank. It consists of black water (that is urine, human excrement of faecal matter) and grey water (that is wastewater form the bathroom and kitchen).

EUTROPHICATION: This is normally the result of nutrient pollution caused by factors such as the release of sewage effluent into natural waters. It generally promotes algae growth and causes severe reduction in water quality. In the aquatic environment, enhanced growth of algae disrupts the normal functioning of the ecosystem, causing a variety of problems such as reduction in oxygen for fishes to survive (Agyemang, Awuah, Darkwah, & Arthur, 2013).

pH: This is a measure of how acidic or basic the effluent is. The scale of measurement ranges from 0-14, with 7 as its neutral and 0-6 as acidic range and 8-14 as its basic or alkalinity range.

SEPTIC TANK: This is the underground watertight chamber made of concrete blocks, which receives sewage through the inlet sewer pipe as influent and discharges the sewage through its outlet sewer pipe as effluent. It stores sewage and does primary treatment (mainly sedimentation) of the sewage.

SEWAGE: liquid or wet waste comprising excreta, urine, household (kitchen, bathroom, laundry) and industrial wastewater discharged through connected surface or underground pipe or sewer.

SEWERAGE: a network of interconnected pipes that receive and discharges sewage.

URBAN CIRCLE: it is used operationally to describe the general environment (water bodies, land, human and animal lives).

CHAPTER ONE

1.0 INTRODUCTION

There are inadequacies of sewage treatment, resulting in the discharge of raw effluent into the urban circle which is detrimental to the environment and human health (Gomes & Ebrary, 2009). For instance, in Ghana, it has been shown that out of the 44 wastewater treatment plants in Ghana, only 20 % are working, most of them are below design standard (IWMI, 2012). The pollution of water bodies with sewage has direct effects on aquatic ecosystems and indirectly affects human health through the food chain and consumption of contaminated water. It is in this regard that the Biosand Filter (BSF) has been introduced as a secondary intervention to prevent the discharge of raw sewage into water bodies (Mwabi, *et al.*, 2012).

The BSF is an innovation on traditional slow sand water filters which have been used for community water treatment for several years (CAWST, 2009). Developed by Dr. David Manz in the 1990s at University of Calgary, Canada, it was specifically designed for intermittent or household use. The filter is easy to use and can be designed locally because it is constructed using materials that are always available. BSFs are made up of a simple container with a lid, a vertical cross section layers of sand and gravel, which physically traps sediments, pathogens and other impurities from the water. A biofilm, which forms as a shallow layer sits above the sand column and contributes to the elimination of pathogens. The filter container can be made of concrete, plastic or any other water-proof, rust-proof and non-toxic material. The filter media consist of layers of sieved and washed sand and gravel (CAWST, 2009). It is this design feature that allows the formation of a biofilm layer and distinguishes the BSF from other slow sand filters, allowing for small-scale construction and intermittent use (Kikkawa, 2008). There is a standing water height of 5 cm above the sand layer, which is maintained by adjusting the height of the outlet pipe (Lantagne *et al.*, 2006; CAWST, 2009). The filtered water can be collected via a connected conduit to a container. The storage container should be placed on a block or stand, so that the container opens just under the outlet, minimising the risk for recontamination (CAWST, 2009).

Pathogens and suspended solids are removed through a combination of biological and physical processes that take place in the biofilm layer and within the sand layer. These processes include mechanical trapping, predation, adsorption, and natural death (Ngai *et al.* 2007; EAWAG/SANDEC, 2008; CAWST, 2009). Mechanical trapping and sieving is a process in which suspended solids and pathogens are physically trapped in the spaces between the sand grains. In adsorption and attachment, pathogens become attached to each other (which improves the ability to sieve them), to suspended solids in the water, and to the sand grains. With predation, pathogens are consumed by other microorganisms in the biological layer. This biological layer matures over one to three weeks, depending on volume of water put through the filter and the amount of nutrients and micro-organisms in the water. Natural death occurs when pathogens finish their life cycle or die because there is not enough food or oxygen for them to survive (Sobsey, *et al.*,2008; Stauber, *et al.*, 2012).

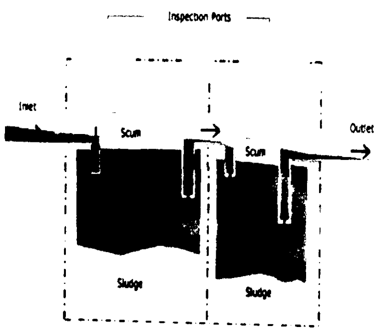


Figure 1.1: Cross-section of the septic tank

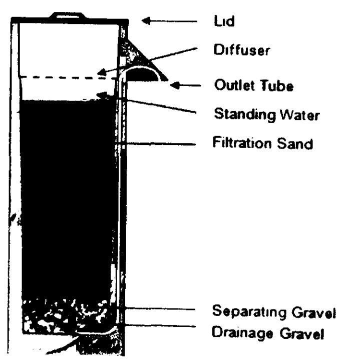


Figure 1.2: Cross-section of the Biosand filter

Figure 1.1 represents the cross section of the septic tank. It receives its contents from an inlet valve which comes from sewers connected to premises. In the study setting, the premises include the four block of flats, the Accra Technical University Lodge and the existing bungalows in Accra Technical University (ATU). The septic tank is designed to do on-site primary treatment. It allows separation of the sewage into scum, suspended solids, effluent which is the liquid content, and the sludge being the mud or solid organic matter (Tettey-Lowor, 2008).

The outlet valve allows the effluent to flow out of the tank. Figure 1.2 illustrates the composition of the BSF, consisting of a vertical cross section of the different layers of sand, starting from the fine to the granular. The effluent is introduced through the lid of the BSF and is allowed to undergo slow filtration till the filtrate collects underneath the filter bed. From here a perforated conduit connected from the bed received the filtered water through the process of capillarity (Fehrman, 2008).

1.2 PROBLEM STATEMENT

The timeframe for the Millennium Development Goals (MDG) elapsed without global achievement of the Goal 7 by 2015 (Targets 2 and 4) (UNEP, 2015). This was partly attributed to inadequate wastewater management resulting in 80% of the world's wastewater being discharged untreated. The failure in attaining MDG 7 was recognized in the post-2015 development agenda and led to the creation of the Sustainable Development Goal (SDG) 6. This was accompanied by the realisation that the focus on drinking-water and sanitation without due attention being paid to the end products of water and sanitation provision (i.e. wastewater) may have contributed to failure to attain the goal. According to the fourth World Water Development report, presently, only 20% of globally produced wastewater receives proper treatment (UNESCO, 2012). The improper disposal of domestic and industrial effluent poses a threat to water resources, the health of mankind and agricultural productivity. When toxic substances enter a body of water, these are dissolved, suspended in water or deposited as sediment in the water body. The resulting water pollution causes the quality of the water to deteriorate (see Figure 1.3) and affects aquatic ecosystems (Volterra *et al.*, 2002). Pollutants can also seep down and affect groundwater deposits. They enter groundwater, rivers, and other water bodies. Effluent discharged from septic tanks contain human pathogens such as bacteria, viruses and parasites. Additionally, large amounts of dissolved solids, nutrients (nitrogen, phosphorus), urea, heavy metals, and other particles have been found in the sewage (Gomes & Ebrary, 2009). The nutrients from effluent causes eutrophication in water bodies (Tettey-Lowor, 2008), promoting algal blooms. Some pathogens found in sewage such as *Salmonella spp. and Escherichia coli* are known to affect food safety adversely causing diarrhoeal diseases (Kahlown *et al.*, 2006).

Figure 1.3: A pictorial view of improper septic tank effluent management (Source: Tettey-Lowor, 2008)

Sewage and household effluents at ATU are discharged into the ocean. This often contributes to lack of aesthetics, release of toxic gases and odour pollution from the vast quantities of untreated effluent (Tettey-Lowor, 2008). This can pose an ecological hazard to aquatic life, creating an oxygen demand and fish kills. The odour pollution irritates the airways. There is growing concern over human activities that result in pollution of water bodies (in this case, the ocean and 'Korle' Lagoon), making them unsafe for natural use (Kahlown *et al.*, 2013). Though the effluent is a rich source of liquid fertilizer, treatment is required to keep it devoid of harmful biological and chemical constituents that may be detrimental to human and environmental health (FAO of The United Nations, 2016). The campus currently lacks adequate water supplies for non-edible purposes such as maintenance of the lawns. While wastewater holds the potential of addressing these needs, it is essential to ensure that it meets the accepted quality standards.

1.3 SIGNIFICANCE OF THE STUDY

The research contributes empirical evidence for the bacteriological and physio-chemical quality of septic tank effluent at ATU. The construction of the BSF as a secondary treatment and intervention will address the problem of raw human sewage being discharged into the environment with adverse consequences to health, which is recognized as a major global issue. This will also inform planning efforts and decision making in relation to effluent management and sewage pollution in the University. Furthermore, the unavailability of water for non-edible purposes might be addressed if the intervention produces water quality compatible with available standards. Wastewater can then be reused to meet this need.

1.4 RESEARCH QUESTIONS

This study sought to answer the following questions:

1. What are the baseline quantities of specific parameters (suspended solids, nutrients, organic matter, oxygen levels and pathogenic microbes) found in the septic tank effluent at the study site?
2. What are the quantities of specific parameters found in filtered effluent?
3. What is the percentage removal efficiency of the Biosand filter?
4. What is the percentage deviation from the standard reference level for the post-filtration parameters?

1.5 MAIN OBJECTIVE

To investigate the feasibility of Biosand filtration of septic tank effluent (STE) for non-drinking purposes at Accra Technical University.

1.6 GENERAL OBJECTIVE

1. To construct a plastic Biosand filter as a control unit in the treatment of septic tank effluent at ATU.

Using samples of STE in Accra Technical University under ambient conditions, this investigation seeks to:

1.7 Specific Objectives

2. Assess the quantities of specific parameters present in septic tank effluent (suspended solids, nitrates, phosphates, coliforms, pH levels and Dissolved Oxygen).
3. Assess the quantities of specific parameters (as specified earlier) present in effluent passed through a Biosand filter.
4. Estimate the percentage removal efficiency of filtered effluent in conformity to EPA and WHO standards for non-edible crops.

CHAPTER TWO

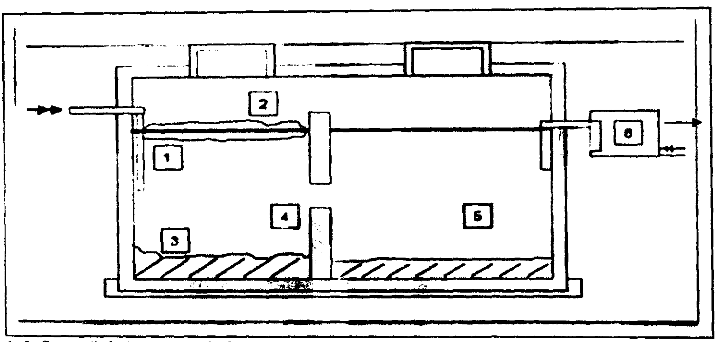
2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter takes a critical look at works that have been done and a review of published literatures was conducted to obtain standards for specific physico-chemical and biological parameters in septic tank effluent (STE), effectiveness of the Biosand Filter (BSF) in removal of the parameters and ecological and health impacts of pollutants present in STE.

2.2 THE SEPTIC TANK

Septic tanks usually consist of a one- or two-chamber system (Figure 2.1) that holds sewage for a short period of time. This allows the solids to settle as sludge in the bottom of the tank, where it undergoes anaerobic digestion, with oil and grease forming a scum at the top. Raw septic tank effluent contains suspended solids, dissolved Phosphorus (P) and nitrogen (N), and potentially contains pathogenic bacteria and viruses. Effluent quality is dependent upon the constituents of the raw wastewater that enters the septic tank and the degree of 'purification' that occurs within it. (Joseph *et al.*, 2008.)



1. Influent (inlet); 2. Scum
3. Sludge; 4. Buffer wall;
5. Secondary chamber; 6. Effluent (outlet)

Figure 2.1: A standard two chamber septic tank design installed in ATU

2.3 SPECIFIC PARAMETERS PRESENT IN SEPTIC TANK EFFLUENT

The maximum permitted discharge values of critical parameters in the effluent are normally provided by national regulations. The guideline values provided by the Environmental Protection Agency (EPA) of Ghana are shown in Table 2.1:

Table 2.1: Ghana EPA Guidelines for maximum permissible wastewater effluent discharge levels

Parameters	Units	EPA Guideline Value
pH		6-9
Temperature	°C	< 3 °C above ambient
Colour	TCU	200
Turbidity	NTU	75
Electrical Conductivity	µs/cm	1500
TSS	mg/l	50
TDS	mg/l	1000
BOD5	mg/l	50
COD	mg/l	250
Ammonia	mg/l	1.0
Nitrate	mg/l	50
Total Phosphorus	mg/l	2.0
E. coli	(cfu/100 ml)	10
Total Coliforms	(cfu/100 ml)	400

(Source: EPA GHANA, 2010).

2.4 PHYSICO-CHEMICAL PARAMETERS

2.4.1 Temperature

Septic tank effluent temperatures normally range between 10°C and 20°C, in general. Normally, the temperature of domestic and municipal sewage is slightly higher than the water supply because of heat added during the utilization of the water (Stauber, *et al.,* 2015; Gomes and Ebrary, 2009; Volterra *et al*., 2002). Temperature is important in STE because it affects the activities of bacteria present in effluent. An increase in temperature up to about 60°C in septic tank effluent decreases the oxygen concentration (Akpor, 2011; Nair and Ahammed, 2014).

2.4.2 Hydrogen-ion concentrations (pH)

According to Belhaj *et al.* (2011) cited by Marfo (2014), pH is a fundamental factor for water quality which mostly depends upon a variety of chemical factors such as dissolved gases, organic acids, humic actions and inorganic salts. The pH value of STE indicates whether it is acidic or alkaline in nature. The pH value of fresh domestic effluent is slightly more than that of the water supply to the community. Thus fresh domestic effluent is alkaline in nature having pH value between 7.3 and 7.5, which favours bacterial action. However, as time passes the pH value of STE tends to fall due to production of acids by bacterial action and the effluent tends to become acidic. Thus septic effluent is acidic in nature making it difficult to treat efficiently. A high concentration of either an acid ($pH<7$) or base ($pH>7$) is indicative of industrial sewage being mixed with domestic sewage (Nair and Ahammed, 2014). The measurement of pH value of STE is necessary because certain methods of STE management function effectively when the pH value of effluent is within a precise range. Since most microbial life occur within a narrow pH range (typically pH 6-9), the hydrogen-ion concentration is important to biological treatment (Kvernberg, 2012).

2.4.3 Total Dissolved Solids (TDS)

One cubic meter of effluent weighs approximately 1,000,000g and contained about 500g of solids. One-half of the solids are dissolved such as sodium and soluble organic compounds while the remaining 250g are insoluble (Marfo, 2014). The insoluble section comprises of about 125g of material that settled out of the liquid fraction in 30 minutes under inactive conditions (settleable solids). The remaining 125g remained in suspension for a very long time (suspended solids). Consequently, STE was highly turbid, with high suspended solids values, which indicates low permeability of light and oxygen. (Venkatesh, *et al.*, 2015)

2.4.4 Total Suspended Solids (TSS)

Total suspended solids give an indication of the amount of solid matter floating in the septic tank effluent (Jeong, *et al.*, 2016). In general, effluent contains solids of variable types and sizes. Larger matters and coarse materials are normally removed in the first stage of the Biosand filtration process (Kvernberg, 2012). The TSS derived from the total solids content (TS) cover all types of solids found in an effluent flow. It is normally a mixture of floating matter, settleable matter, colloidal matter and matter in solution. Typically, 60 % of the suspended solids are settleable. The TSS values are widely used to determine treatment efficiency for conventional treatment processes and to assess the need for effluent filtration in the case of reuse applications (Jeong et al., 2016).

2.4.5 Total Phosphorus

Phosphorus is usually present as phosphate in water medium (Joseph *et al.*, 2008). Phosphorus is found in effluent in three principal forms: orthophosphate ion, polyphosphates or condensed phosphates and organic phosphate. Naturally bound phosphorus emanates from body and food waste but after biological decomposition of these solids it is finally converted to orthophosphates.

Polyphosphates are used in synthetic detergents, and contribute as much as one-half of the total phosphates in effluent. According to (Jeong et al., 2016), the phosphorus concentrations of post-treatment or post-filtration effluent are usually within the range of 3-7 mg/L, which mostly consists of orthophosphate and organic phosphorus. Other sources of phosphorus aside from human waste includes animal wastes, industrial waste, soil erosion and fertilizers. Phosphorus just like nitrogen is an essential nutrient for growth of biological life. Raw effluent normally holds a large fraction of phosphorus, and as it makes a significant contribution to eutrophication when led untreated into a natural water body, it should be removed or reduced during filtration and treatment. Phosphorus constitutes a resource that can be utilized for irrigation to help sustain food security (Jeong et al., 2016).

2.4.6 Nitrogen contents

Nitrogen is an essential nutrient for the growth of microbes, plants and animals. Since it plays an essential role in the synthesis of protein, it is a necessity in biological treatment processes (Kahlown et al., 2006). The content of nitrogen in the effluent of septic tank is an environmental concern, as it contributes to eutrophication. On the other hand, if reuse of the STE for irrigation is desirable, the nitrogen content should be conserved as it makes an important nutrient for this purpose. The nitrogen content of STE is in the form of nitrogenous compounds present in it (Marfo, 2014; Kahlown *et al.*, 2006). The principal nitrogenous compounds present in domestic effluent are proteins, amines, amino-acids and urea which are organic compounds, and ammonium salts which are inorganic compounds. Ammonia nitrogen or free ammonia results from the bacterial decomposition of the nitrogenous organic matter. It exists in septic tank effluent as either ammonium ion (NH_4^-) or ammonia (NH). This affects the pH of effluent when the Ammonia is either in a high toxic or low toxic form. In an aerobic environment bacteria can oxidize the ammonia to nitrites and nitrates and the relative amount of ammonia present in the effluent is thus an indicator of the age of the effluent (Gomes and Ebrary, 2009; Volterra *et al.*, 2002).

2.4.7 Dissolved Oxygen (DO)

Dissolved oxygen describes the amount of oxygen in dissolved state in effluent (Fehrman, 2008). According to (Rangwala *et al.*, 2011), effluent has generally no dissolved oxygen which is moot. Its presence in STE indicates the effluent is fresh and its presence in the effluent management indicates that substantial oxidation has been accomplished by the Septic Tank Effluent Management methods.

2.4.8 Biochemical Oxygen Demand (BOD)

Septic tank effluent is composed of a variety of inorganic and organic substances. The BOD test measures the amount of oxygen consumed to oxidize the organic constituents of sewage during a specified period of time, usually 5 days at 20 °C and so is called $BOD_{5(20)}$. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20°C, the BOD_5 can be determined (Kahlown *et al.*, 2006). The oxygen provides energy for the decomposition process. The more contaminated the waste water is, the higher the $BOD_{5(20)}$, therefore it indicates the amount of organic contamination in waste water. Effluents high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes. BOD is one of the most commonly measured constituents of effluent (Volterra *et al.*, 2002).

2.5 MICROBIOLOGICAL PARAMETERS

2.5.1 Total Coliforms and Faecal coliforms

STE usually contains millions of microorganisms per millilitre. However many of these organisms are harmless. Few disease-causing microorganisms called pathogens invade some part of the host and either grow and multiply or produce toxin which interferes with normal body processes. They are divided into categories with the most common groups associated with water pollution being bacteria, viruses, protozoa, helminths (intestinal worms) and algae. These can exist naturally or can occur as a result of contamination from human or animal waste. Contact with the contaminated water may lead to disease such as typhoid, cholera and gastrointestinal disorders (Keriata *et al.*, 2004).

Coliform tests are helpful for assessing whether sewage effluent has received adequate treatment and the quality is suitable for reuse or irrigation for non-edible crops (Jeong et al., 2016). Coliform are a family of bacteria common in soils, plants and animals. As they are very abundant in human wastes, coliform bacteria are much easier to locate and identify in effluent than viruses and other pathogens. For this reason, coliform bacteria are used as indicator organisms for the presence of other, more serious pathogens. Coliforms are frequently monitored as total or faecal coliforms (WHO, 2006b). Total coliform (TC) is described as a large group of anaerobic, non-spore forming, rod -shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C (Joel, 2016). Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in soils, plants and in intestines of warm-blooded (humans) and cold-blooded animals. Some pathogens enter the human body through the skin but more commonly they are ingested with drinking water. Faecal coliform (FC) is a subgroup of TC that comes from the intestines of warm-blooded animals. However, since they do not include soil organisms, they are preferable to TC as an indicator organism.

According to (WHO, 2006) Guidelines wastewater for agricultural use states that as an indicator organism faecal coliform *Escherichia coli (E-coli)* provides conclusive evidence of recent faecal pollution and should not be present in water meant for human consumption. It is generally assumed that the higher the number of coliform organisms found in a 100 ml sample, the higher the risk for waterborne disease. They are measured by running the standard total coliform test at an elevated temperature (44 °C).

2.6 EFFECTIVENESS OF BIOSAND FILTER FOR REMOVAL OF BIO-PHYSICO-CHEMICAL CONSTITUENTS IN EFFLUENT

It has been reported that BSF effectively removes giardia cysts, cryptosporidia oocysts, water-borne parasites including bacteria and viruses, minerals including iron (and iron bacteria), manganese, sulphur smell and other obnoxious odours, colour, poor taste, and small particles (silt, clay and organic materials) from source waters (Stauber, *et al.*, 2012). In addition to the laboratory studies, there have also been a significant number of field tests carried out on the BSF. Results from field tests have been summarized in a few publications (Earwaker, 2006; Kikkawa *et al.*, 2008; Sisson et al., 2013). Peer-reviewed and grey literature on BSF performance in laboratory and field sites have all shown the effectiveness of the BSF. It must be noted that, while there have been many results showing the effectiveness of the treatment that the BSF provides, the results are affected by raw water quality, and aspects of the BSF itself such as the filter ripening and operating conditions (Young-Rojanschi and Madramootoo, 2014). For physical quality, (Sisson et al., 2013) had reported filtrate quality of less than 1NTU in laboratory studies. Laboratory studies have shown that the BSF is capable of removing more than 5 log10 units of Giardia and 99.98 % for Cryptosporidium (Kikkawa, *et al*, 2008; Mwabi *et al.*, 2012). Other laboratory tests have shown reduction of 99.5 % of bacteria, once the biolayer has ripened (Lee, 2001). After successive evaluation of the effectiveness of the

Biosand filter, it has been found out the system was effective in eliminating and decontaminating the wastewater from *Eschericia coli* for irrigation (Ingram *et al.*, 2012).

2.7 FILTERED EFFLUENT FOR ODOUR REDUCTION AND IMPROVED CLARITY

2.7.1 Odour Reduction

It has been observed that the effluent from three filters showed improvement in the taste and odour of raw water. (Centre for Affordable Water and Sanitation Technology (CAWST), 2009). It was speculated that biodegradation of geosmin (earthly smell) and 2-methylisoborneol (MIB) were dependent on the respiratory activity of the biofilter microorganisms (Tellen, *et al.*, 2010). The degradation of geosmin and MIB by bacteria attached to different filter media, have been utilized in the sewage filtration processes. Instances of increased odour of sewage commonly occurred during the warm periods, when microbiological activity is high and effluent water measured high levels of Natural Organic Matter (NOM). This suggests that NOM is a possible cause of odour in water. However, the odour was absent the sewage was filtered by the BSF (Kikkawa et al., 2008). According to (Kikkawa et al., 2008) there was higher removals at higher influent concentrations of MIB by BSF which suggested that the removal was due to the effective mechanism of the Biosand filter. Based on the results of his study, the reduction of odour by the BSF is said to be a signal for cleaning time. According to (Ingram et al., 2012), the precipitated insoluble complexes of the hydroxide species of iron with NOM in did not give any odour problems, as the effluent water measured low levels of NOM.

2.7.2 Turbidity Removal

Turbidity of the treated water improved with time and remained around 1.2 NTU throughout the filter operation for both the filtration runs (Duke, *et al.*, 2006) Turbidity removal takes places due to the straining mechanism within the pores of the filter media. Particles too large to fit between the sand grains are strained out at the sand surface. As particles accumulate the size of the pore opening at the sand surface is reduced allowing even smaller particles to be removed by straining (Yung, 2003). This particle accumulation is also responsible for reduced filtration rate in the filter.

Just as in the case of the natural soil profile, which has the capability of purifying runoff water for replenishing underground aquifers, so is the same mechanism used by the Biosand filter to improve the clarity and quality of wastewater, this was agreed by (Joel, 2016) who treated wastewater with slow sand filter.

2.8 ECOLOGICAL AND HEALTH IMPACTS OF POLLUTANTS IN SEPTIC TANK EFFLUENT

The common waterborne microorganisms that cause human disease come from animal and human faecal waste. These contain a wide variety of viruses, bacteria, and protozoa that may get washed into drinking water supplies or receiving water bodies (Kris, 2007). Microbial pathogens are considered to be critical factors contributing to numerous waterborne outbreaks. Contaminated water is a vehicle for several waterborne diseases, such as cholera, typhoid fever, shigellosis, salmonellosis, campylobacteriosis, giardiasis, cryptosporidiosis and Hepatitis A (WHO, 2004). The density and diversity of these pollutants can vary depending on the intensity and prevalence of infection in the sewered community. The detection, isolation and identification of the different types of microbial pollutants in effluent are always difficult, expensive and time consuming. To avoid this, indicator organisms are always used to determine the relative risk of the possible presence of a particular pathogen in STE (Paillard *et al.,* 2005). Viruses are among the most important and potentially most hazardous pollutants in effluent. They are generally more resistant to treatment, more infectious, more difficult to detect and require smaller doses to cause infections (Okoh *et al.,* 2007). Bacteria are the most common microbial pollutants in effluent. They cause a wide range of infections, such as diarrhoea, dysentery, skin and tissue infections. Disease-causing bacteria found in water include different types of bacteria, such as *E. coli*, *Listeria*, *Salmonella*, *Leptosporosis* among others. The major pathogenic protozoans associated with effluent are *Giardia* and *Cryptosporidium*. They are more prevalent in effluent than in any other environmental source (Fehrman, 2008; Kikkawa *et al.*, 2008).

Eutrophication also leads to the production of algal blooms and plant growth in streams, ponds, lakes, reservoirs and estuaries, and along shorelines (Tettey-Lowor, 2008; Venkatesh *et al.*, 2015; Volterra *et al.*, 2002). Algal blooms are responsible for depletion of dissolved oxygen and contribute to serious water quality problems. Eutrophication of water sources may also create environmental conditions that favour the growth of toxin-producing cyanobacteria (Gomes and Ebrary, 2009). The environmental hazards are to a large extent related to eutrophication. Eutrophication occurs when a natural water body is overloaded with phosphorus and nitrogen, causing extensive algal growth. Decomposition of algae requires large amounts of oxygen. This results in less available oxygen in the water body, causing fish kills (Jeong et al., 2016).

Health hazards are associated with pathogenic microbial agents from effluent that are not removed before the effluent is discharged into the environment. The greater the quantity of pathogenic agents transmitted to the environment, the greater are the risk of disease outbreaks (Marfo, 2014). Chronic exposure to such toxins produced by these organisms can cause gastroenteritis, liver damage, nervous system impairment, skin irritation and liver cancer in animals (WHO, 2006). In extension, recreational water users and anyone else coming into contact with the infected water is at risk (Resource Quality Services, 2004). According to Rangwala et al., (2011), an overflow of sewage has the potential to pose environmental hazards such as polluting water bodies, breeding ground of insects and rodents. The conditions of the receiving environment will dictate the exposure risk. The scale of the damage depends on the volume and duration of the overflow and receiving environment characteristics. It has been reported that the development of ecological effluent management helps to attain high environmental quality, high yields in food and fibre, low consumption, good quality, high efficiency production and full utilization of wastes (Mwabi *et al.*, 2012).

CHAPTER THREE

3.0 METHODOLOGY

3.1 STUDY AREA

The study was carried out at Accra Technical University. The school is divided into two areas: the Commercial and Residence. The research was undertaken at the Residence, known as the 'The Block of Flats'. The Block of Flats in ATU consists of Flat A, B, C, D, existing Bungalows and the Demonstration Block (ATU Lodge). These various premises have sewerage system linking the wastewater and excrement all to one septic tank, west of flat 'D'. The study was conducted at the final storage site where all sewers from the various Blocks of residence converge and empty into the septic tank.

The commercial section of the University has a student population of about thirteen thousand nine hundred, about five hundred staff, including lecturers and administrative and other staff. The residential portion has a population of 300 inhabitants, including flats A to D, the existing bungalows and the ATU Lodge.

PICTORIAL CROSS SECTION OF OF THE STUDY AREA (ATU)

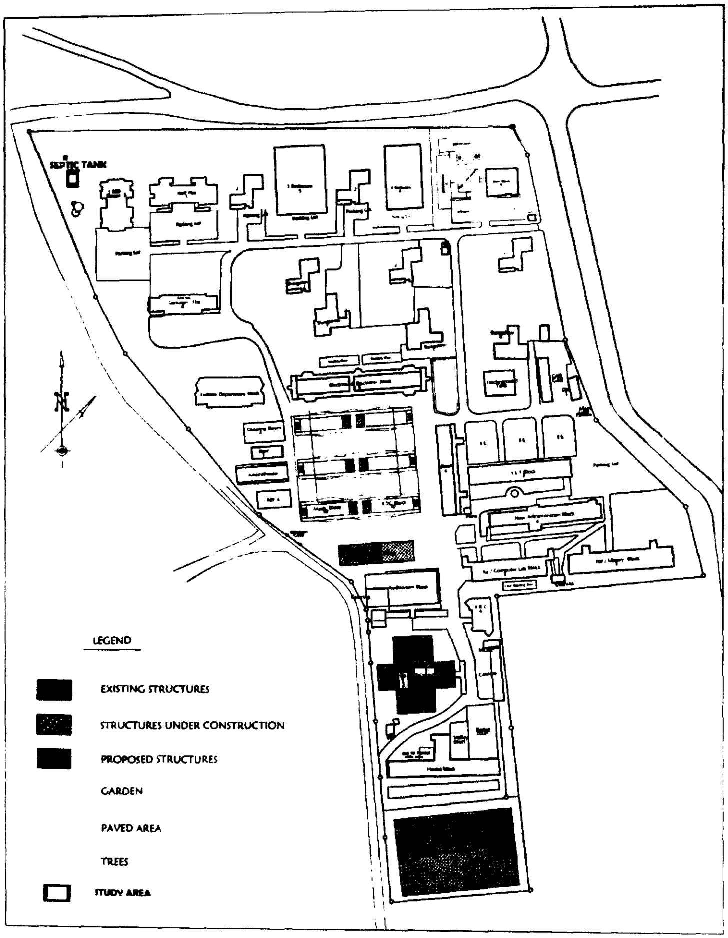


Figure 3.1:Cross-section of the study area showing position of the septic tank.
(Source: Development Directorate, ATU)

3.2 STUDY DESIGN

The research design is a pre-test and post-test experimental study in which an intervention was introduced, being a biosand filter (BSF), which changed the status quo of a sewage system. Changes in specific parameters after the effluent had undergone Biosand filtration were measured.

3.3 PROCEDURES IN CONSTRUCTION OF THE BIOSAND FILTER

The media (fine sand, course sand gravels and charcoal) were sieved and washed thoroughly with clean pipe borne water until clarity of drained filtrate from the media was obtained. The diffuser basin was prepared by punching several holes in a local plastic basin to simulate a sieve and control flow rate of influent to the Biosand filter system. Three plastic barrels were connected in series by plastic (polyvinyl chloride) pipes secured with stop-corks.

The filtration media were gently introduced into each barrel containing the following: a combination of gravel, course sand and fine sand called 'biosand' (barrel 1); a combination of biosand and charcoal called 'biocharsand' (barrel 2); and the storage tank (barrel 3) respectively. This formed a filter system which was then connected to the wastewater source using similar pipes and reducers. Clean pipe borne water was poured into the first barrel to help wash through the entire system. The stages in the construction are shown in the chart (Figure 3.2) and a cross section of a typical biosand filter can be found in the diagram that follows (Figures 3.3, Figure 3.4 and Plate 3.1).

To maintain the biosand filter, periodic maintenance was required. This was done by pouring clean, pipe borne water through the filter system to wash backlog and avoid clogging the media. The storage tank was washed thoroughly with pipe borne water and a chlorine solution between each sample collection. Laboratory analysis was conducted to ascertain the quality of water produced.

3.4 Sample Collection

The pre-samples were collected from the septic tank. The post-samples were collected from the storage tank of the filter system.

1. Prior to collection, the 500 ml bottles were washed with sterile water and air dried.
2. The pre-intervention sample was septic tank effluent (STE) and it was collected from the septic tank.
3. The post-intervention sample was biosand filtrate effluent (BSFE) and it was collected from the storage tank of the filter system.
4. The Control was obtained from the Ecolab at the University of Ghana and consists of distilled water in one gallon. Control samples were used as field blanks to ensure there were no contamination of samples from the field and laboratory environment.
5. All sample were conveyed to the laboratory on-site using a carrier bag. The samples collection were done in two consecutive weeks (week 1 and week 2)

At the laboratory the samples were stored in refrigerator for 48 hours in week 1 and within 24 hours in week 2. The delay in processing the samples obtained in week 1 was due to laboratory maintenance procedures.

Table 3.1: various sample collection at different times.

SAMPLING	PRE-INTERVENTION	POST-INTERVENTION	CONTROL
WEEK 1	STE 1	BSFE 1	CONTROL 1
WEEK 2	STE 2	BSFE 2	CONTROL 2

A brief step-by-step overview of the construction procedure is given below. The complete construction and installation detail is provided in the appendix.

Stage A - Obtain tools and materials

↓

Stage B - Locate the Sand, Gravel and Charcoal

↓

Stage C - Prepare Sand, Gravel and Charcoal

↓

Stage D - Construct the two filter media and storage

↓

Stage E - Construct the Diffuser basin

↓

Stage F - Installation of the system

↓

Stage G - Connect the system with Septic tank sewer

↓

Stage H - Operation and Maintenance and Follow-up

(It is normally recommended to chlorinate the bucket and sand)

Figure 3.2: Steps in the construction of a Biosand Filter

Source: *Field, 2017*

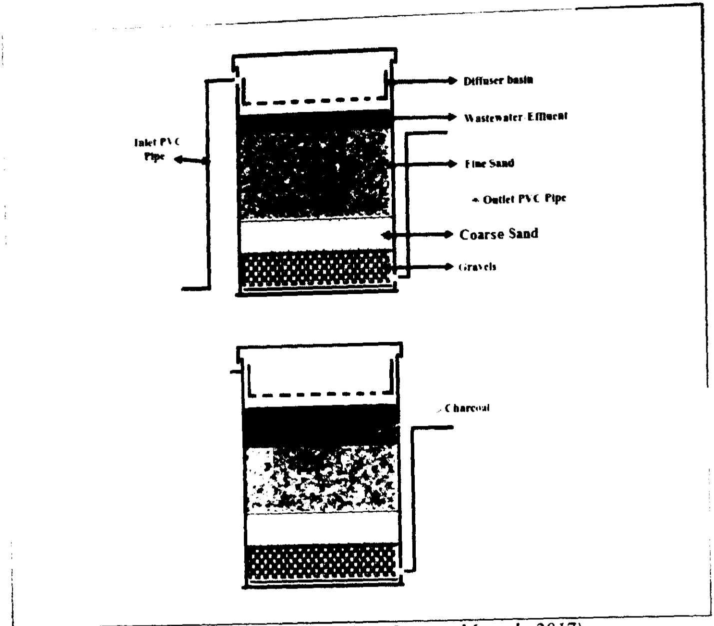


Figure 3.3. A cross section of a biosand filter (Source: Mensah, 2017)

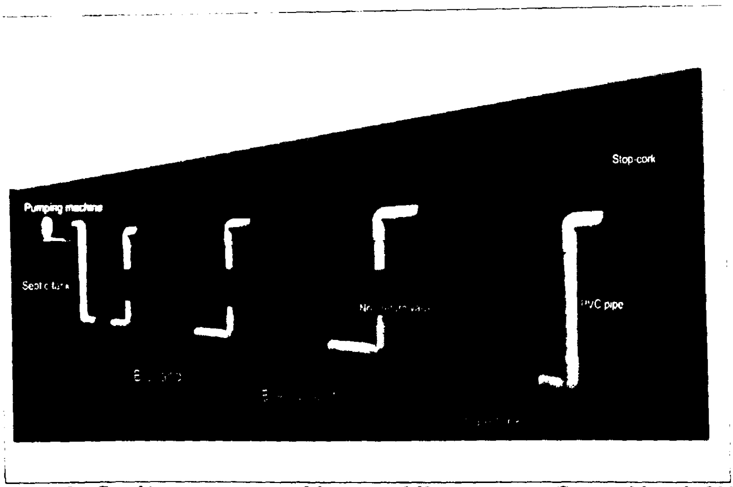


Figure 3.4 Graphic representation of the Biosand filtration system (Source: Mensah, 2017)

The final set-up of the Biosand filter at the construction site, yet to be connected to the septic tank underground sewer (Plate 3.1).

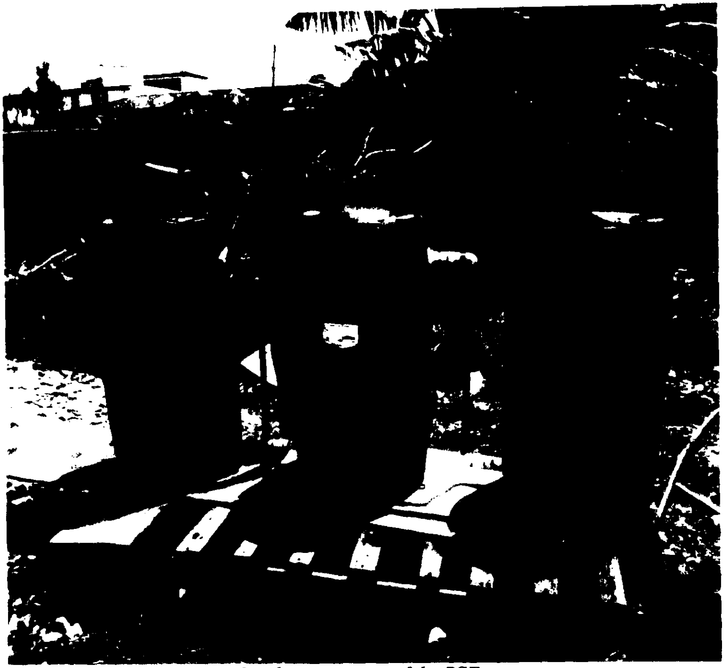


Plate 3.1: Showing the completed construction of the BSF

3.5 Data Collection Tools and Parameters of Interest

The data collection tools and outcome of interests are summarized in table 3.2 below. These include the parameters of interest and the laboratory instruments and equipment used for determining the outcomes.

Table 3.2: Sample treatment and field analysis

PARAMETERS	PURPOSE OF ANALYSIS	INSTRUMENT/EQUIPMENT FOR ANALYSES
Temperature	To assess the temperature of the $STE1^A$ and $STE1^B$; $BSFE1^A$ and $BSFE1^B$; and the Controls	Laboratory Thermometer (0-100), Hg-in-glass
Total and Faecal Coliforms and E. coli	To assess the presence and concentration of coliform bacteria in $STE1^A$ and $STE1^B$; $BSFE1^A$ and $BSFE1^B$; and the Controls	Autoclave, Petri dishes, funnel storage bottles, laminar flow, forceps, chamber, loops, Bunsen burner, HiChrome ™ brilliant green lactose bile broth, lactose broth, EC broth
Hydrogen ion concentration (pH)	To assess the acidity and alkalinity of $STE1^A$ and $STE1^B$; $BSFE1^A$ and $BSFE1^B$; and the Controls	pH meter (Hatch Sen Ion™/ Wagtech)
Dissolved Oxygen (DO), Biochemical oxygen demand (BOD_5)	To assess the level of DO and BOD in five days.	BOD bottle, conical flask, burette.
Total suspended solids (TSS)	To count levels of solids in 100ml of the samples.	Conical flask, funnel, hot air oven, dessicator
Nutrients	To assess the level of Phosphorus and $STE1^A$ and $STE1^B$; $BSFE1^A$ and $BSFE1^B$; which are major contributors to *Eutrophication*.	Autoclave, Petri dishes, storage bottles, laminar flow chamber, loops, Bunsen burner,

3.4 METHODS

3.4.0 LABORATORY ANALYSES

3.4.1 DETERMINATION OF TEMPERATURE

The thermometer was immersed in the various samples (namely; $STE1^{A}$, $STE1^{B}$, $BSFE1^{A}$, $BSFE1^{B}$, Control1 and Control2) for two minutes respectively for expansion of the mercury. The height of rise in mercury is reached on graduation on the glass. The height reached was read from the meniscus and then recorded. For each immersion, the thermometer was rinsed with deionized water. The process of determining the temperature level was done twice for each sample. The level of temperature is important determinant for bacteria action within the samples.

Ice-Packing and Transport

The samples were ice-packed in order to avoid temperature rise which also increases the rate of chemical and biological reactions. The samples were taken in the ice-packed containers and transported within 24 hours to the Accra Technical University, Science Laboratory Technology Lab for the chemical and microbiological analyses.

3.4.2 PHYSICO-CHEMICAL ANALYSIS

The experimental laboratory analysis for the physicochemical and microbiological quality parameters were carried out as prescribed by the Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF, 2012; APHA, 1995).

3.4.2.1 Determination of Dissolved Oxygen

Sample Collection

The bulk samples were collected in four different 500ml sterilized plastic bottles. The three categories of samples (STE1, BSFE1 and Control1) were transferred to narrow-necked BOD or incubation bottles of 280 ml capacity. Each sample was allowed to fill the bottle full before insertion of an accurately-fitting glass stopper to avoid inclusion of air bubbles.

Procedure for Analysis

The stopper of the specially-filled Biological Oxygen Demand (BOD) bottle was removed carefully to minimize exposure to air. Two (2) millilitres of Manganese (II) sulphate ($MnSO_4$) solution or "Winkler (I)" was added using a pipette; the reagent was discharged well below the surface. Similarly, 1ml of the KI-NaOH solution or "Winkler (II)" was also added. The stopper was placed on the bottle to ensure that no air becomes entrapped. The bottle was inverted several times in order to distribute the precipitate uniformly. When the precipitate settled leaving the supernatant clear, it was agitated again. Two (2) millitres of concentrated H_2SO_4 was added to dissolve the precipitate (which turned an intense yellow colour) and the stopper was placed back. The stopper was replaced and mixed until the precipitate dissolved. Using a measuring cylinder, 100ml of the acidified sample was measured into 500ml conical flask. Using starch as an indicator it was titrated against 0.050M $Na_2S_2O_3.5H_2O$. The titration was repeated for 2 other 100ml aliquots of both the filtered sewage and septic tank effluent sample and the results were tabulated. A colour change from blue to colourless gave the endpoint. The Dissolved Oxygen (DO) was then derived from the formula with the volume of aliquots used.

$$\text{DO (mg/l)} = \frac{\text{Titre (average)}}{\text{Sample Volume}} \times 101.2$$ (APHA, 1998).

3.4.2.2 Determination of Biochemical Oxygen Demand

Three incubation or BOD bottles of 280ml capacity were filled with the three categories of samples; thus STE1A, BSFE1A and Control 1A was stored at room temperature for 5 days (incubation period). The same procedure outlined above for the determination of Dissolved Oxygen was followed to determine the titre for BOD. The difference in DO and the dilution factor was used to calculate BOD_5 as indicated below:

$$BOD_5 \text{ (mg/l)} = \frac{D1-D2}{P}$$

Where: D1 = DO of effluent sample immediately after preparation, mg/l

D2 =DO of effluent sample after 5 day incubation at 20°C, mg/l

P = Decimal volumetric fraction of sample used (Standard methods, 1998).

3.4.2.3 Phosphate Determination by Stannous Chloride Method

One hundred (100) ml of sample free from colour and turbidity was taken and 0.05 ml (one drop) of phenolphthalein indicator was added. Strong acid (H_2SO_4) was added to decolourise the effluent sample and diluted to 100 ml with distilled water and phenolphthalein indicator was added. Four (4.0) ml of Molybdate Reagent I and 0.5 ml (10 drops) of Stannous Chloride reagent I (prepared from dissolving 2.5 g of fresh $SnCl_2.H_2O$ in 100 ml glycerol) were added while thoroughly mixing after each addition. The absorbance was measured at a wavelength of 690nm using the Spectrophotometer- UV/VIS T 60 by PG Instruments after 10 minutes but before the 12th minute. The Spectrophotometer was standardized with a blank solution. The readings were recorded and the process was repeated for the other effluent samples.

3.4.2.4 Nitrate Determination (Nitrogen by Hydrazine Reduction method)

Ten (10) ml of the various categories of samples ($STE1^A$, $BSFE1^A$, and Control 1) samples was introduced into a test tube with the aid of a pippete. 1.0 ml of 0.3M NaOH was added and mixed gently. 1.0 ml of reducing mixture which was prepared by adding 20 ml Copper Sulphate ($CuSO_4$) working solution and 16 ml hydrazine Sulphate to 20 ml 0.3M NaOH, was added and mixed gently. The mixture was heated at 60°C for 10 minutes in a water bath and then cooled to room temperature, after which 1.0 ml of colour developing reagent was added. It was shaken to mix and the absorbance was read at 520nm with the Spectrophotometer- UV/VIS T 60 by PG Instruments. The readings were recorded and the process was repeated for the other three samples ($STE1^B$, $BSFE1^B$, Control 2).

3.4.2.5 pH Determination using pH Meter

The pH of each sample was determined with a Hatch Sen Ion™/ Wagtech digital pH meter. The pH meter was calibrated with 4.0, 7.0 and 10.0 pH buffers. A 100mL aliquot of each sample was measured into a beaker and the pH determined using the pH meter. The pH of the raw sample was determined on site and that of the filtered sample was done immediately after filtration.

The pH was measured and the value was recorded. The procedure was repeated for the other samples.

3.4.2.6 Determination of Total Dissolved and Conductivity

These were measured using the WPA CMD510 Conductivity meter. The electrode for the measurement of Total Dissolved Solids (TDS) was rinsed with distilled water and blotted dry. The samples were swirled and the electrode placed in the sample, ensuring that the entire sensing edge was submerged. The TDS and Conductivity modes were selected. The values displayed on the screen were recorded in ppm for TDS and µS/m for the Conductivity (Plates 3.2 and 3.3):

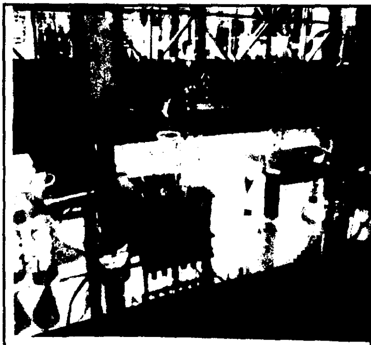


Plate 3.2: Total Dissolved Solids and conductivity Analysis process in the laboratory

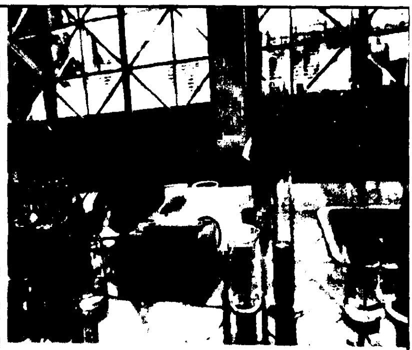


Plate 3.3: WPA CMD510 Conductivity meter

3.4.2.7 Total Suspended Solids

The Filtration apparatus was assembled. The filter was moisture with 10ml deionized water to seat it. The sample bottle was vigorously shaken and 100ml of the effluent sample was transferred onto the funnel. The filter was washed with three successive 10ml volume of distilled water for complete filtration. The filter was carefully removed from the holder and transferred into a weighing dish and was dried at 105°C for one hour with the Carbolite furnace. The dry cycle was repeated until weight loss of less than 1.0g was obtained. The analytical procedure was repeated using 500ml of control standard.

A glass fiber dish was placed on the membrane filter and vacuum was applied. The disc was washed with three successive 20ml volume of distilled water. All traces of the water were removed by continued application of vacuum after water has passed through. The washing was discarded. The filter was removed from the filtration apparatus and transferred to a glass petri dish as support. It was dried in an oven at 105°C for one hour. The filter was cooled in a desiccator and weighed immediately (Plate 3.4 and 3.5)

Plate 3.4: Filtering samples for TSS analysis

Plate 3.5: pre-weighing of filter paper

The calculation was done using the following equation: (APHA, 1998)

$$\frac{A - B}{\text{Sample Volume (ml)}} \times 1000000 \text{ (a constant factor)}$$

Where A = weight of residue + dish in grams

B = weight of dish in grams

3.4.3 MICROBIOLOGICAL ANALYSIS

3.4.3.1 Enumeration of Total Coliforms and E.coli

The estimation of total coliforms were done using the Most Probable Number (MPN) test, which uses serial dilutions method in multiple test tubes for the dilution and analyses. The ten dilution with three test tubes were at pipetted at initial stages and inoculated dilutions were done at the latter stage. Each samples was apportioned three test tubes each. Serial dilution of 10^{-1} to 10^{-12} were prepared by filling 12 test tubes with 9 ml brilliant green bile broth labelled 10^{-1} to 10^{-12} to start the total coliform process (Plate 3.6). One millilitre of effluent samples were pipetted to the first test tube labelled 10^{-1}. The removable end of the pipette was discarded. The dilution in the first test tube was mixed thoroughly by turning the content upside down and up severally. One milliliter of the first test tube was transferred to the second test tube labelled 10^{-2} with aid of a fresh pipette, and the removable end discarded. The second dilution was turned up and down to ensure thorough dilution was obtained. Using a fresh pipette, 1ml of the second dilution (10^{-2}) was transferred to the third test tube labelled 10^{-3}. The process was repeated for all samples (including STE1, BSFE1 and Control 1).

Similar process was done for another dilution set. This time, the medium filled in the test tubes are lactose broth with inverted Durham tubes; which starts the process for assessing E. coli. These dilutions were incubated at 35°C for 24 hours. The test tubes showing high fermentation, colour change and gas formation after 24 hours gave indication of a probable positive bacteria coliforms. This aided in confirming Total coliforms. It was recorded and compared to the MPN table for multiple tubes. The dilutions containing the lactose broth were then transferred to the E. coli (E-C) medium and incubated for 24 hours under 35°C. One milliliter of each dilution from the lactose broth was then transferred to three test tubes each in a Tryptone water for 24 hours. After this, two drops of Kovak's reagent were added and a pink ring formed on the surface of tubes confirmed the presence of E. coli (Plate 3.7). The values were recorded and compared with MPN table for multiple tubes method.

3.4.3.2 Enumeration of Faecal Coliforms

The Faecal coliforms were assessed following the same procedure for the total coliforms as described in Section 3.4.3.1 above. The tubes with the lactose broth and inverted Durham tubes which were incubated at 35°C for 24 hours. The clear signs of fermentation, gas formation in inverted Durham tubes and colour change was indicative of Faecal coliform. The dilutions in test tube that showed positive or negative reactions were counted for as the MPN, with reference to the MPN table for multiple tubes method.

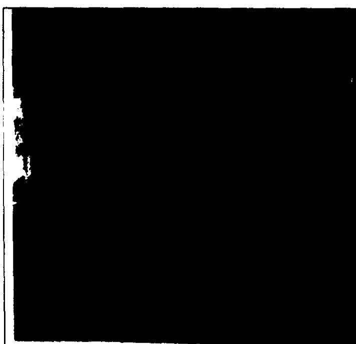


Plate 3.6: Showing brilliant green bile broth dilution for assessing Total Coliforms

Plate 3.7: Showing lactose broth dilution for assessing Faecal Coliforms & 1st stage for E. coli assessment

3.5 QUALITY CONTROL MEASURES

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. The samples were carefully handled to avoid any external influences that could interfere with the integrity of the sample and hence contaminate it. Triplicate determination of the samples were made and the data was presented as means. Glassware were properly cleaned, and reagents were of analytical grades. Deionized water was used throughout the study.

For the spectrophotometric analysis, reagent blank determinations were used to correct the instrument readings. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/standard reference material (SRM-1570) of National Institute of Standard and Technology, USA were used. With the exception of temperature, multi probe meters were calibrated together using the same standard and procedures Electrical conductivity was calibrated against 0.005, 0.05 and 0.5M standard potassium chloride solution; pH was calibrated with standard buffer at pH of 4 and 9.2. The dissolved oxygen (DO) was calibrated against zero solution of sodium sulphate. Temperature was checked against standard mercury thermometer for consistency.

Appropriate labelling of samples with relevant information including: location, date and time of sample collection, researcher ID, and tests required. Water proof markers were used to avoid misclassification of samples due to wearing off of labels from handling (APHA/AWWA/WEF, 2012)

3.6 STATISTICAL ANALYSES

Measurements of physico-chemical and microbiological parameters in the samples were generated using Microsoft Excel, 2013. The percentage removal efficiency of the Biosand filter was determined by deducting the BSF value from the STE value for each parameter using the formula indicated below:

Step 1: STE1-BSF1 = D1

Step 2: $\frac{D1}{STE1} \times 100$

The removal efficiency was a proxy indicator for performance of the BSF in the study. The data were imported into Stata version 14.1. Significant differences between samples (STE and BSF) were determined for each parameter using the paired t-test. Also, a one sample t-test was used to determine the significant difference between post-filtrate (BSFE) values and EPA/WHO standards. Statistical significance was assumed at 95% confidence interval when the p-value < 0.05.

3.7 ETHICAL CONSIDERATIONS

Institutional review of ethics was undertaken by the Ghana Health Services Ethical Review Board, Accra. Clearance to conduct the study was obtained from the Interim Vice Chancellor of ATU. Field staff can be exposed to biological agents from sewage while constructing the BSF and fetching samples. Therefore, safety training was offered for the three labourers and a plumber before the BSF construction and sample collection procedures were undertaken. This promoted the use of personal protective equipment and hand hygiene. Field staff signed a consent form before they participated in the study. Personal protective equipment, soap, water and hand sanitizers were provided. There was no conflict of interest and the research was solely funded by the researcher.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

Results obtained from the study showed that effluent from the septic tank and effluent from the Biosand filter as well as control samples (field blanks) presented typical variations in contaminant concentrations with time. However, high contaminant concentrations were obtained for the sewage samples whereas the filtrate from the BSF showed lower concentrations. Plates 4.1 and 4.2 show the physical change in state of the sewage after it has undergone filtration.

Plate 4.1: From the left: Effluent Samples fetched from STE (pre-intervention), Middle: BSFE (pre-intervention) sample and Right: Control

Plate 4.2: Effluent Samples fetched from STE, BSFE and Control in Lab

The use of the multiple test tube in decade dilution (Plate 4.3) for determining coliforms showed foaming which is a clear indication of the possible presence of coliforms. This method was used to determine the Total coliform in the control, post-and pre- filtration samples respectively (Refer to Table 4.1 for the MPN counts).

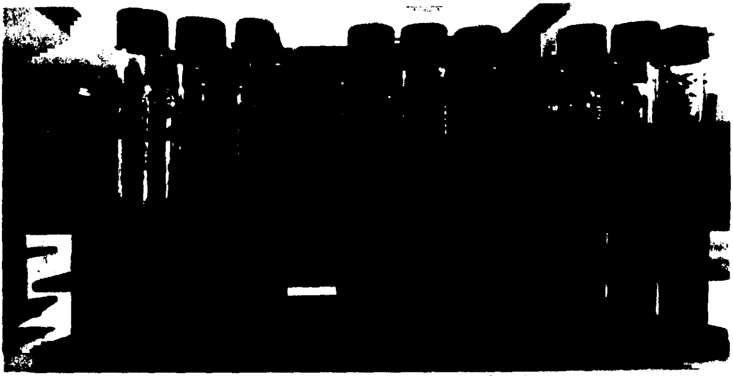


Plate 4.3: Assessment of Total Coliforms in brilliant green broth

Plate 4.4 below show the reaction of the faecal coliforms to the lactose broth. The colour change from amber to pale amber as displayed, is indicative of faecal coliform with the sample after 24 hours at 48°C (Refer to Table 4.1 for the MPN counts).

Plate 4.4: Results of Faecal Coliforms in test tubes with Lactose broth

The E. coli counts were determined by the Tryptone water and after 24 hours, a drop of Kovac's reagent were added to the dilution. The results show pink ring formed on the surface of the dilution in the test tube (Plate 4.5). This is a clear indication of the presence of E. coli in the samples.

Plate 4.5: Laboratory analysis for E. coli in STE (test tubes 1st to 6th from left to right) and BSFE (the 7th test tube)

4.2 Calculating the percentage removal efficiency of Biosand Filter

The pre-post filtrate values showed significant variations. The percentage removal efficiency of the BSF indicates the proportion of material in the septic tank effluent (as measured by the parameters) that is removed after passing septic tank effluent through the biosand filter. It is expressed as a percentage. The counts and removal efficiencies of the physical parameters (Tables 4.1) and microbiological parameters (Tables 4.2) are presented below. Tables 4.1 and 4.2 show measurements from the samples taken in the first and second weeks of data collection, mean and their test statistic at (95%) Confidence Interval. Heavy organic pollution in septic tank effluent resulted in an undetectable concentration of dissolved (Table 1). Removal efficiencies were highest for phosphorus (89.5%), colour (87.1%), nitrogen (83.3%), TSS (71.3%) and TDS (66.2%). Temperature, pH and TSS in the filtrate exceeded guideline values.

Table 4.1: Laboratory analyses values for physico-chemical parameters, before and after filtration.

SAMPLES	STE 1	STE 2	MEAN STE	STD ERR	BSFE 1	BSFE 2	MEAN BSFE	STD ERR	D1 = STE-BSFE	% R.E. = D1/STE × 100	P. VALUE (T-TEST)
Temperature (°C)	28.2	27.8	28	0.2	26.4	26.2	26.3	0.1	1.7	6.1	0.0169
pH	8.5	8.9	8.7	0.2	7.7	7.7	7.7	0	1.0	11.5	0.0377
TSS (mg/100ml)	250	258	254	4.0	70	76	73	3.0	181	71.3	0.0008
TDS (ppm)	443	447	445	2.0	143	158	150.5	7.5	294.5	66.2	0.0007
Conductivity(μS/cm)	887	894	890.5	3.5	683	574	628.5	54.5	262	29.4	0.0408
Colour (TCU)	85	87	86	1.0	11	14	12.5	1.5	73.5	85.5	0.0006
DO (mg/l)	0	2.0	1.0	1.0	2.23	5	3.615	1.385	-2.615	-261.5	0.2655
BOD (mg/l)	0	179	89.5	89.5	0.18	12	6.09	5.91	83.41	93.2	0.4506
Nitrogen (mg/l)	142.8	167	154.9	12.1	22.8	29	25.9	3.1	129	83.3	0.0092
Phosphorus(mg/l)	62.44	63.81	63.125	0.685	6.38	6.84	6.61	0.23	56.515	89.5	0.0002

*Results were comparable with a second sample run one week later (see appendix).

TSS = total suspended solids, TDS = total dissolved solids, DO = Dissolved oxygen, BOD^5 = Biological oxygen demand, STE = septic tank effluent, BSFE = biosand filter effluent %R.E. = Percentage Removal Efficiency

The variations between the pre-filtrate and post-filtrate effluent were significant. Removal efficiency was high for all microbiological parameters with all filtrate values being below guideline values (Table 4.2).

Table 4.2: showing the Percentage removal efficiency of Coliforms for the BSF in relation to the STE values.

SAMPLES	STE 1	STE 2	MEAN STE	STD ERR	BSFE 1	BSFE 2	MEAN BSFE	STD ERR	D1 = STE-BSFE	% R.E. = D1/STE × 100	P. VALUE (T-TEST)
Total Coliform (MPN/100ml)	920000	920000	920000	0	900	1700	1300	400	918700	99.9	0.0000
Faecal Coliform (MPN/100ml)	350000	300000	325000	25000	600	1200	900	300	324100	99.7	0.0059
E-Coli (MPN/100ml)	1400	1100	1250	150	20	39	29.5	9.5	1220.5	97.6	0.0148

MPN = most probable number, E-Coli = *Escherichia coli*

4.3 One Sample T-Test Statistic of BSFE and EPA Guidelines

Tables 4.3 and 4.4 below compared the post-filtrate sample values with EPA guideline values of physico-chemical and microbiological parameters. This was assumed at statistical significance of 95% confidence interval when p-value was <0.05.

The tables further show the standard errors for the various parameters. The margin of standard error was calculated to indicate the strength of variation of values between the post-intervention values compared with the standard guidelines.

The t-test results showed that, most values from the Biosand filtrate were statistically significant when compared with the standard guideline values.

Table 4.3: Mean Physico-chemical values for BSFE samples compared with EPA (USA/ Ghana) and WHO standards for wastewater for non-edible crop irrigation

SAMPLES	μ BSFE	EPA	D2 = μBSFE-EPA	STD. ERR	Pr(|T| > |t|) (P-Value)
Temperature (°C)	26.3	25	1.3	0.1	0.0489
pH	7.7	7.5	0.2	0	*****
TSS (mg/100ml)	73	50	23	3.0	0.0826
TDS (ppm)	150.5	1000	-849.5	7.5	0.0056
Conductivity (μS/cm)	628.5	1500	-871.5	54.5	0.0398
Colour (TCU)	12.5	200	-187.5	1.5	0.0051
DO (mg/l)	3.615	50	-46.385	1.385	0.019
BOD (mg/l)	6.09	50	-43.91	5.91	0.0852
Nitrogen (mg/l)	25.9	75	-49.1	3.1	0.0401
Phosphorus (mg/l)	6.61	7	-0.39	0.23	0.3392

*D2 = difference between the mean Biosand filtrate values and the standard guideline values; *the value cannot be determined*

Table 4.4: Mean Microbiological values for BSFE samples compared with EPA (USA/ Ghana) and WHO standards for wastewater for non-edible crop irrigation

SAMPLES	μ BSFE	EPA	D2 = μBSFE-EPA	STD ERR	Pr(|T| > |t|) (P-Value)
Total Coliform (MPN/100ml)	1300	1000	300	400	0.5903
Faecal Coliform (MPN/100ml)	900	1000	-100	300	0.7952
E-Coli (MPN/100ml)	29.5	126	-96.5	9.5	0.0625

**D2 = difference between the mean Biosand filtrate values and the standard guideline values*

CHAPTER FIVE

5.0 DISCUSSION

5.1 INTRODUCTION

This chapter discussed the similarities or disparities in effluent from septic tanks and effluent which has undergone some treatment, or highly concentrated water sources that were filtered using the Biosand filter. Furthermore, the values recorded for the assessed parameters were compared with standard guideline values by EPA. Physico-chemical parameters discussed are: pH, total suspended solids (TSS), total dissolved solid (TDS), Nutrient (consisting nitrogen and phosphorus), Biochemical Oxygen Demand (BOD). Microbiological parameters discussed are: Total coliform, Faecal coliform and *Escherichia coli*.

5.2 PHYSICO-CHEMICAL PARAMETERS

5.2.1 pH

Effect of pH on septic tank and the Biosand filter is evident. Venkatesh *et al.*, 2015 reported that coliforms were reduced to zero (0) in the final effluent when the pH was above 10.7. However, pH values above the recommended guidelines have been associated with many adverse effects. One of the most significant impacts of pH in water is the effect that it has on the solubility and thus the bioavailability of other substances such as ammonia (WHO,2006). The quality of pH was significantly improved (Table 4.1). From the results, post-filtered effluent was in a pH range of 7.7 to 8.2. This range meets the standard reference level recommended by EPA guideline of 6 to 9, indicating that pH of the filtrate will not have any adverse effect on non-edible crops.

5.2.2 Total suspended solids

Suspended solids occur naturally in septic tanks as a result of the bye-product of the breakdown of organic matter in the sewage stream and erosion, transport of material from the bottom of the septic tank. Accra Technical University and Municipal effluents are responsible for a long-term continuous input of suspended solids to the urban circle. From the results changes in TSS concentrations from septic tank effluents to Biosand filter effluent was high. This was evident in a higher mean removal percentage of 71.3%. This was significant at C.I. of 95% at ($p<0.0008$), an indication that the reduction was as a result of the filtration process within the Biosand system. However, effluent parameter exceeded the EPA guideline value of 50 mg/l.. This result is in line with work done by (Agyemang *et al.*, 2013). Septic tank effluents often have a high level of suspended solids composed mostly of algal cells, grey water solids and human excrement. Accumulation of sludge is a major contributing factor to these changes in TSS. Suspended solids released into the urban circle, mainly effluent discharges, can cause a number of direct and indirect environmental effects, including reduced sunlight penetration restricting of spawning grounds and physical harm to fish. The organic and inorganic contaminants released as TSS are harmful to human health and the environment. Also, algae often use an oxygen demand in water bodies and the growth and survival of some species may be affected. However, significant change was observed in TSS values after the effluent underwent BSF. This is an indication that TSS has been reduced in the STE and can be reused for non-edible crops. Therefore, septic tank effluent can be improved upon by BSF prior to irrigation or even discharge to water bodies (Steinmann, *et al.*, 2003).

5.2.3 Total Dissolved Solids

Total dissolved solids in sewage indicate the ability of the sewage to dissolve the organic and inorganic constituents. A high concentration of dissolved solids increase the density of dissolving water and reduces the solubility of oxygen gas, creating danger for aquatic life (Kahlown *et al.*, 2006). From the results, the total dissolved solid concentrations were significantly reduced by the BSF. This significant reduction was evident in a percentage removal efficiency of 66.2%. Furthermore, BSF effluent concentrations were below the Ghana EPA effluent guideline of 1000mg/L. High TDS can reduce water clarity, hinder photosynthesis, and lead to increased water temperatures (Volterra *et al.*, 2002).

5.2.4 Nutrients

Specific nutrients, such as nitrogen and phosphorus, are necessary for plant production in various ecosystems. Nonetheless, an oversupply of nutrients can lead to the growth of large algal blooms and extensive weed beds resulting in ***Eutrophication*** (Akpor, 2011). Furthermore, in water bodies, the addition of nutrients leads to excessive enrichment, which intends may result in deoxygenation of the receiving water (Meena, *et al.*, 2010). Discharging raw sewage rich in nutrients into water bodies leads to a number of problems on the receiving water bodies, including impact on human health and marine ecosystem (Volterra *et al.*, 2002). Therefore, the quality of nutrients maintained at a level that protects aquatic life and health of water users.

Nitrogen

The reduction of Nitrogen in effluent for non-edible crops irrigation is important to reduce ammonia toxicity to the urban circle, reduce the oxygen demand in receiving water bodies, prevent acidification of ground water aquifers due to nitrification in the soil and reduce the potential for surface water eutrophication (Gomes and Ebrary, 2009). It was evident that there were high levels of nitrogen in the septic tank effluent, however a reduction was achieved after it underwent the BSF. A percentage removal of 83.3% was recorded for the BSFE. However, the high concentrations of nitrogen in the septic tank is significantly affected by increased sludge deposition. Though, nitrogen is needed for plant growth and survival, a seemingly high presence in water for irrigation may pose adverse health effects to human and environmental health (WHO, 2015). However, Biosand filter effluent nitrogen concentrations were less than a third of the EPA standard of 75 mg/L and this implies that the Biosand filtered effluent presents less significant risk of polluting the receiving non-edible crops, soil, underground water and other forms of environmental hazard.

Phosphorus

Phosphorus was high in septic tank effluent samples but concentrations were significantly reduced after they were passed through the Biosand filters. The decrease from STE to BSFE was with a percentage reduction of 89.8% meeting the standard reference level of EPA (7mg/L). This is a good justification to state that BSF was effective in ensuring phosphorus meets standard values for non-edible crop irrigation. Phosphorus is an essential macronutrient that is a limiting factor to plant growth. It triggers eutrophic conditions which include the prolific growth of algae and other aquatic plants. Algal growths can have detrimental impacts on aquatic life and at high concentrations, can be lethal (Mishra, *et al.*, 2010). The absorption of sunlight by algal blooms reduces the amount of light reaching aquatic plants in sediment. If an algal bloom is prolonged, aquatic plants will die. Large amounts of decaying algae result in the consummation of large quantities of oxygen by the bacteria and fungi that break it down. This results in the dramatic reduction of oxygen concentrations in aquatic environment, particularly at night (Fehrman, 2008; Gomes & Ebrary, 2009).

5.2.5 Biochemical oxygen demand

Faecal sludge from septic tanks contains a large variety of organic substances in different concentrations. Since there is no treatment of sewage and no proper maintenance of the septic chamber (which acts as a primary treatment) in Accra Technical University, bacterial decomposition would place a high demand on oxygen. The BSF effluent concentrations for BOD did not meet the required EPA standard of 50 mg/L. To meet standard reference level for non-edible crops irrigation, it should be aerated by exposing the BSFE to air.

5.3 MICROBIOLOGICAL PARAMETERS

The Biosand filters removed a significant percentage (99.7 %) of coliform bacteria as reported by (Kikkawa *et al.*, 2008). Although high septic tank effluent counts for coliforms were recorded for total, faecal coliforms and E. coli, significant changes in filtrate values were evident. For each sample parameter, a high percentage removal of 99.9%, 99.7% and 97.6% were recorded for total coliforms, faecal coliforms and E. coli respectively, this performed better than similar study by (Abuenyi 2010). What accounted for the better reduction in coliforms and E. coli concentrations were extra the second BSF introduced, exposition of filtrate to solar radiation, high concentrations of dissolved O_2, presence of predators and retention time of BSF (Mwabi *et al.*, 2012; Wendt *et al.*, 2015). The BSF effluent counts were within WHO recommended guideline of 1000 MPN/100ml of effluent for irrigation for non-edible crops. The coliforms and E. coli values for post-filtrate samples were all not significant at C.I. = 95% and when p-value < 0.05; (TC = 0.5903, FC = 0.7952 and E. coli = 0.0625). Though the septic tank primarily treats sewage, concentrations of microbes were still high in the post-filtration effluent in relation to standard requirements for wastewater discharge in to water bodies. Therefore running the BSF in series would help further reduce the coliform levels in filtrate.

5.4 Summary Discussion

Table 5.1 below compares the percentage removal efficiency of the modified biosand filtration system and other septic tank effluent treatment across different studies.

The reason that accounted for a better removal efficiency in the dual biosand filtration system was the second additional system (biocharsand).

The results of similar treatment system are summarized in the Table 5.1.

Table 5.1: comparison of removal efficiency contaminant in septic tank effluent across different methods

PARAMETERS	The Present Study (ATU)	Abuenyi, 2010 (KNUST)	Olutiola *et al.*, 2010 (Nigeria)
Temperature (°C)	6.1	***	***
pH	11.5	***	***
TSS (mg/100ml)	71.3	96.85	***
TDS (ppm)	66.2	67.33	***
Conductivity (µS/cm)	29.4	***	***
Colour (TCU)	85.5	***	***
DO (mg/l)	-	***	***
BOD (mg/l)	93.2	91.84	83.9
Nitrogen (mg/l)	83.3	73.07	39.1
Phosphorus (mg/l)	89.5	24.81	37.5
Total Coliform (MPN/100ml)	99.9	97.39	52.7
Faecal Coliform (MPN/100ml)	99.7	96.61	85.4
E-Coli (MPN/100ml)	97.6	***	

*** = *Not determined by researchers*

5.5 Limitations of the study

The total number of samples for most parameters in this study was 13. To increase the validation of the findings, the sampling regime could have been carried out over a longer period. This would have made the data series statistically stronger. Still, the decision to end the sampling at the given time was due to a clear trend in the findings for microbial analyses.

Analyses of Biochemical Oxygen Demand, Turbidity were made, but as the results was not released in time hence, they were not used in the study. Daily sewage from household and commercial activities in the institution could alter samples collected from the septic tank, these were not taken for more than a few days, as the Biosand filter isolated for the purpose was filled with new STE several times during the sampling period. With these additions to the study, a more comprehensive analysis of re-use possibilities could have been achieved.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study set out to achieve the following objectives:

1. To construct a plastic Biosand filter as a control unit in the treatment of septic tank effluent at ATU.
2. Assess the quantities of specific parameters present in septic tank effluent (suspended solids, nitrates, phosphates, coliforms, pH levels and Dissolved Oxygen).
3. Assess the quantities of specific parameters (as specified earlier) present in effluent passed through a Biosand filter.
4. Estimate the percentage removal efficiency of filtered effluent in conformity to EPA and WHO standards for non-edible crops.

Based on the four main research objectives, the Biosand filter has been found to be a successful septic tank effluent treatment technology for Accra Technical University, Ghana and proves an attractive option for similar tertiary institutions and has proven to meet standard for non-edible crop irrigation.

The concentration of specific contaminants in the septic tank effluent were higher than recommended levels across the parameters, while they were lower in the Biosand filter effluent. Filtering with the BSF showed optimum percentage removal of total suspended solids, total dissolved solids, faecal coliform, total coliform, E. coli and to some extent phosphate and nitrate levels. The change in pH and colour recorded an impressive improvement as the turbid sewage became much clearer after going through the BSF system. Assessment for conformity with combinations of WHO, EPA Ghana and USA values for use with non-edible crops indicated that the post-filtration values were either lower than EPA limits or within range for most parameters.

6.2 RECOMMENDATIONS

1. To the Institution

Based on the absence of an on-site sewage treatment plant and to minimize pollution from discharge of septic tank effluent directly into surface water, the Biosand Filter can be used to upgrade physical and microbial quality of sewage at household and institutional level, prior to discharge in the environment.

This would prevent potential hazards to aquatic life and human health. For this purpose, a separate study on the cost-benefit analysis would prove useful. The study must take into account periodic maintenance of the filter system by flushing with clean water to ensure efficiency and periodic laboratory analysis required to ascertain water quality to standards.

The use of the biosand filter offers potential benefits of recycling wastewater for irrigation of non-edible crops and can be applied in settings faced with similar need.

2. Recommendation for future research

This study has uncovered a number of gaps in the literature that may require further study. Recommended areas of further study include the following:

- The present study did not address to quantification of pharmaceuticals.
- The analyses of heavy metals in pre-intervention (septic tank effluent) and post-intervention (Biosand filtrate effluent).

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APPENDICES

Appendix 1

1.1 INFORMED CONSENT

Project title

BIOSAND FILTRATION AS A GREEN APPROACH TO SEPTIC TANK EFFLUENT MANAGEMENT IN ACCRA TECHNICAL UNIVERSITY.

Institutional Affiliation

The Department of Biological Environmental and Occupational Health Sciences of Public Health, College of Health Sciences, University of Ghana

Background

I am a student from the University of Ghana, School of Public Health and carrying out a research study on Biosand filtration as a green approach to septic tank effluent management in Accra Technical University.

Procedure

This study was conducted in Accra Technical University and the researcher employed the services of a research assistant, conservancy labourers and a plumber to assist in the sampling procedures and construction of the Biosand filtration system.

Risk and benefits

There is no personal gain in participating in this study. It is however expected that the findings from the study will help improve the proper management of septic tank effluent in Accra Technical University.

Aside the time that was spent in the construction and sampling of effluent for laboratory analysis, there is no expected risk in participating in this study.

Right to Refuse

Participation in this study is voluntary and all right are reserved to you opting to participate. You are at liberty to withdraw from the study at any time you deem not appropriate for you to participate.

Hitherto, I will encourage you to fully participate since your services are very important to us.

Dissemination of Results

The final report of this study will be hopefully published in journals and a copy will be submitted to the university.

Cost and/or Payments to Subject for Participation in Research

There will be a little cost for participating in this research in the form of allowance for research assistants and labour employed.

Ethical approval

The study has been received and approved by Ghana health services, Noguchi Memorial Institute for Medical Research and Environmental Protection Agency, Ghana.

1.2 CONSENT FORM

I have read the foregoing information/the foregoing information has been read to me or translated to me and I have fully understood it. I consent voluntarily to participate in this study.

Name of participate ....

Signature/thumbprint ....

Name of witness ....

Signature/thumbprint of witness ....

Signature of Researcher ....

Date ....

Appendix 2

BUDGET

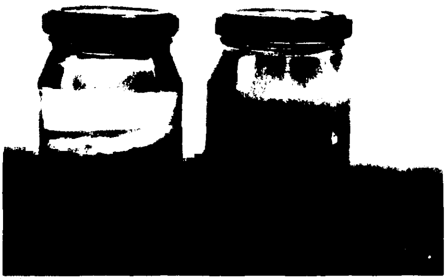
ITEM	PURPOSE	COST (GH₵)
Plastic drum with lid	Filter Container	650.00
Plastic Basin	diffuser bowl	15.00
PVC Pipe (2 inches)	connective pipe from sewage pump	20.00
PVC Pipe (1.5 inches)	connective pipes among filter containers	15.00
PVC Pipe (1 inch)	Stand pipe	10.00
PVC Pipe fittings (1 inch)	Stand pipe	10.00
6 elbows		5.00
3 caps		2.00
4 Adapters		3.00
3 bulkhead fitting		5.00
Floating Valve	Control the level of effluent	7.00
Sieve	To sieve sand	2.00
Gravel	media	10.00
Coarse sand	media	10.00
Fine sand	media	10.00
Charcoal	media	2.00
Labour	**For plumbing works in the installation of pipes**	400.00
PVC glue	Piping connections	5.00
Teflon tape	Piping connections	2.00
Nails	Punching holes in plastic pipes	0.50p
Miscellaneous		100
PPEs	For protection against hazardous agents	500
Sampling	To analyses of effluent before & after intervention	1,865.00
TOTAL		**3,653.50p**

Appendix 3

CONSTRUCTING THE BIOSAND FILTER

Preparing the Media

1. Sieve the gravel, coarse sand, fine sand and charcoal
2. Wash the gravel, coarse sand, fine sand and charcoal

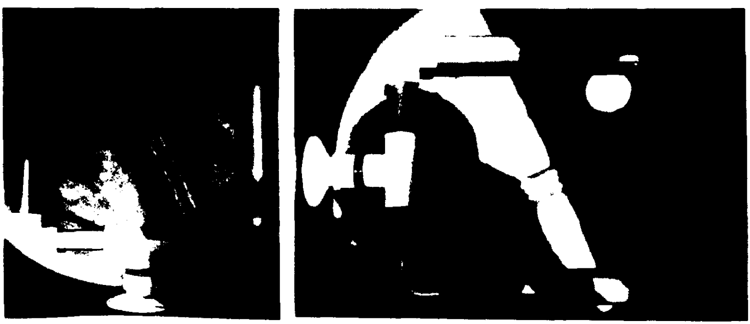


1st on the left Washed sand and 2nd to right is raw sand

Construction of the Biosand filter:

a) Cut the PVC pipe (1 inch) in lengths of two 8 inches, ¾ inch to lengths of 2 inches

b) Connect the 3 (1inch) elbows, to the 8" and 2" length PVC pipe with the ¾inch to the T-joint and an adapter as shown in *Figure 3.1.*



Interconnected PVC pipes receiving base

Use PVC glue for the connection.

c) On the 8" pipe, mark locations 2 inches from both ends and cup them. The 8" PVC pipe and an adapter as shown in Pic 3.1 above. This would be the interior pipe in the filter.

d) Heat up a small nail and melt 10 holes (2 mm diameter) at the locations you have marked in (c). The size of the holes would be the limiting factor of the flow rate.

e) Open holes in the drum for setting the inlet and outlet valves for the three drums with a drill. First, mark the locations on the three drums.

i) The inlet hole for the first drum should be 33 inches from the bottom and 4 inches from the bottom as outlet.

ii) The inlet hole for the second drum should be 20 inches from the bottom and 4 inches from the bottom as outlet.

iii) The inlet hole for the third drum should be 15 inches from the bottom and 4 inches from the bottom as outlet.

f) Heat the copper pipe with a fire, and connect with 1 inch elbow to ¾ inch PVC to the ¾ copper pipe. The copper pipe should face downwards.

g) Glue the standpipe to the outer side.

4. After all the inter-connections among the three drums, now connect the system to the septic tank underground pipe.

i) Dig to expose the underground sewer pipe.

Showing connection of BSF and main sewage discharge line in ATU

ii) Cut out a 6" gap and then connect with the 4"×1′ bushing.

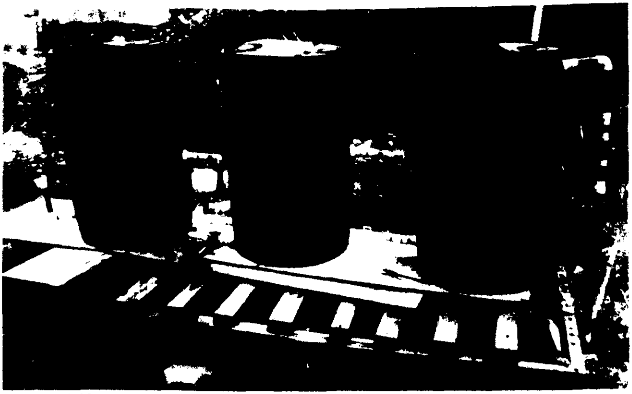
iii) Connect a 2" PVC pipe with the aid of a 2" bend from the top of the bushing to the Biosand filter system via the first.

iv) Heat up a 1′× ¾′ reducer to connect the supply pipe to the inlet 1 inch pipe of the first drum.

v) Join (iv) above with a ¾′ copper stop cork pipe to help control the flow rate of the supply.

Check for visual leakage from the outside, especially near the bulkhead fitting. Check the flow rate.

This should be 300-500ml/min. If the flow rate is too fast, there may be a leakage in the pipe connection. Check to see if there is no flow when you close the two holes in the interior pipe using the valve socket or stop cork.



Biosand filter under construction

5. Construct the diffuser basin:

Purchase a plastic basin of the correct diameter to fit the plastic drum. Heat a small nail (1-2 mm in diameter), and melt holes into the basin. The holes should be small and evenly distributed.

6. Filter installation:

a) Set the container on a flat and stable surface. The filter should not be moved or disturbed after installation.

b) Pour water into the Biosand filter system.

c) Slowly add gravel until it covers the interior PVC pipe. In this case it was 10 inches deep.

d) Add coarse sand on top of the gravel so that it would form a layer of 20 inches

e) Add water until the normal water level of 70 inches in drum.

f) Add fine sand until it adds up to form 30 inches above gravel but 20inches below the water level.

Appendix 4

EPA (GHANA AND US) STANDARD FOR DISCHARGING WATER INTO URBAN WATER BODIES

PARAMETERS/DESCRIPTION	Maximum Permissible Levels New Facilities	Maximum Target (Permissible) Level (Existing Facilities)
*p*H	6 - 9(in the range of)	6 - 9(in the range of)
Temperature*	<3oC above ambient	<3oC above ambient
Colour (TCU)	20	100
BOD (mg/L)**	50	200
COD (mg/L)	250	250
Total Dissolved Solids (mg/L)	1000	1000
Total Suspended Solids (mg/L)	50	50
Turbidity (NTU)**	75	75
Conductivity (μS/cm)**	1500	1500
Total Coliform (MPN/100ml)	400	400
Faecal Coliform (MPN/100ml)	10	10
Nitrate (mg/L)	75	100
Phosphorus (mg/L)	2	10

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

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The Ghana Health Service Ethics Review Committee has reviewed and given approval [illegible] your Study Protocol

GHS-ERC Number	GHS-ERC: 131/02/17
Project Title	Biosand Filtration as a Green Approach to Septic Tank Effluent [illegible] in Accra Technical University
Approval Date	23rd March, 2017
Expiry Date	22nd March, 2018
GHS-ERC Decision	Approved

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months.
- Reporting of all serious adverse events related to this study to the ERC within three [illegible] seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings

[illegible] note that any modification of the study without ERC approval of the amendment is invalid.

[illegible] may observe or cause to be observed procedures and records of the study [illegible]

[illegible] identification number in all future correspondence in relation to this approval [illegible]

SIGNED..
DR. CYNTHIA BANNERMAN
(GHS-ERC CHAIRPERSON)

[illegible], Ghana Health Service, Accra