

**Kwame Nkrumah University of Science and Technology  
Kumasi, Ghana**

**Faculty of Chemical and Materials Engineering**

**Department of Materials Engineering**

**The Effects of a Non- Alcoholic Beverage Treatment Plant on Quality of Effluent**

**Master of Science Thesis**

**By**

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**May 2012**

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of Science and Technology**



**The Effects of a Non- Alcoholic Beverage Treatment Plant on Quality of Effluent**

**CERTIFICATION**

**By**

**Fred Ayim Ofosu, BSc. (Hons.)**

**Thesis submitted to**

**The Department of Materials Engineering,**

**Kwame Nkrumah University of Science and Technology**

**in Partial Fulfilment of the Requirements for the Degree of**

**MASTER OF SCIENCE**

**In**

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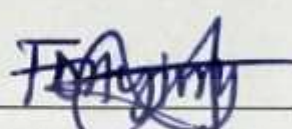


## CERTIFICATION

I hereby declare that this submission is my own work towards the M.Sc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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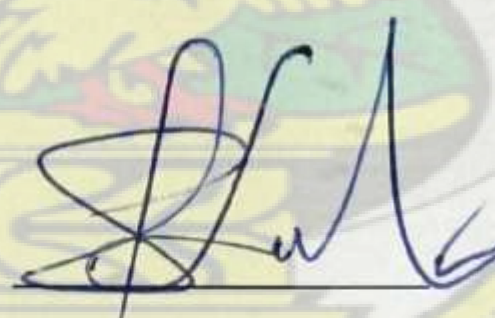
  
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## DEDICATION

*I dedicate this work to my family especially my Dad and Mum Mr. & Mrs. Ayim-Ampofo.*

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## ABSTRACT

The aim of the study was to assess the quality of wastewater effluent from a non-alcoholic Beverage Company and explore possible alternatives aimed at improving the quality of effluent discharged into the environment. The effluent samples were subjected to microbiological and physicochemical analyses. Wastewater was sampled before and after the treatment plant and after passing it through a sand filter bed which was designed and built as an additional treatment option to improve effluent quality. These were monitored for a period of six (6) months and the results compared with the Ghana Environmental Protection Agency (GEPA) standards. The mean physicochemical parameters for pH, TDS, Colour, TSS, Turbidity, Conductivity, DO, BOD, COD and Alkalinity recorded for the effluent wastewater treatment were 8.57, 1105.5 mg/l, 76.13 TCU, 47.30 mg/l, 20.35 NTU, 2267.2  $\mu\text{S}/\text{cm}$ , 5.37 mg/l, 48.70 mg/l, 98.30 mg/l and 456.1 mg/l respectively and that of the sand filter bed after treatment recorded a mean of 7.00, 529.9 mg/l, 50.70 TCU, 5.49 mg/l, 14.53 NTU, 963.2  $\mu\text{S}/\text{cm}$ , 3.33 mg/l, 26.42 mg/l, 46 mg/l and 276.3 mg/l. Removals of Iron, Lead, Cadmium, Copper and Zinc were 84.81%, 61.51%, 47.37%, 30.36% and 38.71% respectively for the effluent wastewater whilst the sand filter bed were 61.11%, 69.00%, 85.00%, 15.38% and 89.47% respectively. Mean indicator bacterial numbers (MPN/100ml) were  $9.7 \times 10^5$ ,  $5.1 \times 10^5$ ,  $1.6 \times 10^2$  and  $5.5 \times 10^4$  for Total Coliform, Faecal Coliform, Enterococci and *E-Coli* respectively for the effluent wastewater whilst that of the sand filter bed recorded a mean of  $5.2 \times 10^7$ ,  $9.6 \times 10^4$ ,  $1.0 \times 10^1$  and  $1.1 \times 10^4$  (MPN/100ml) respectively. The mean values obtained for indicator bacterial numbers were statistically not significant. Evaluation of the results revealed that the mean Total Coliforms for the sand filter bed was high hence the sand filter bed may not be effective in the removal of Total Coliforms if the bacterial load in the effluent wastewater is high. The



sand filter bed system as an additional low cost treatment facility is a better option for the treatment of industrial wastewater than using the effluent treatment plant (ETP) alone.

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

<b>WWTP</b>	Wastewater Treatment Plant
<b>ETP</b>	Effluent Treatment Plant
<b>BENB</b>	Balancing Equalizing and Neutralization Basin
<b>SBR</b>	Sequential Batch Reactor
<b>TCCBCGL</b>	The Coca-Cola Bottling Company of Ghana Limited
<b>GGBG</b>	Guinness Ghana Brewery Group
<b>KNUST</b>	Kwame Nkrumah University of Science and Technology
<b>TSS</b>	Total Suspended Solids
<b>TDS</b>	Total Dissolved Solids
<b>BOD</b>	Biochemical Oxygen Demand
<b>COD</b>	Chemical Oxygen Demand
<b>DO</b>	Dissolved Oxygen
<b>MPN</b>	Most Probable Number
<b>BPW</b>	Buffered Peptone Water
<b>AAS</b>	Atomic Absorption Spectrophotometer
<b>EPA</b>	Environmental Protection Agency
<b>GEPA</b>	Ghana Environmental Protection Agency
<b>INF</b>	Influent
<b>EFF</b>	Effluent
<b>SF</b>	Sand Filter
<b>STD DEV</b>	Standard Deviation
<b>STD ER</b>	Standard Error



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## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 BACKGROUND INFORMATION

Industrial activities are a major source of water pollution. Inadequate wastewater treatment by industries because of cost can lower water quality by increasing concentrations of pollutants such as organic matter, suspended particles, organic micro pollutants, phosphorus, ammonium or heavy metals, thereby causing adverse effects on human health (Prince *et al.*, 2006).

Industrial wastewater in Ghana is generated from breweries, textile, chemical and pharmaceuticals and mining industries. Most of these industries empty their wastewater into nearby drains, streams and rivers without treatment. It is only natural for industry to presume that its wastewater can best be disposed of in the domestic sewer system. However, city authorities should not accept any wastewater discharges into the domestic sewer system without first learning the facts about the characteristics of the wastewater, the sewage system's ability to handle them, and the effects of the wastewater upon all components of the city disposal system (Tchobanoglous *et al.*, 2003).

Industry views wastewater treatment as an imposed necessity which it employs when it is compelled to, especially when wastewater's effect on the receiving watercourse is readily visible or when public approval and claim will be gained for the expenditure and effort (Riikonen, 1992).



Industry should attempt to treat its wastewater at the lowest cost that will yield a satisfactory effluent for the particular receiving stream, which may necessitate considerable study, research, and pilot investigations. Planning ahead will provide time to make appropriate decisions. Conversely, lack of planning on minimizing wastewater treatment costs may mean that a sudden demand for an immediate solution will cause industry to decide to cease production (Riikonen, 1992).

Non-alcoholic Beverage companies in Ghana produce drinks throughout the year. Their bottling plants among others treat high levels of polluted wastewater. Industrial effluents are required to meet the National Effluent Quality Guidelines/Standards prescribed by the Ghana Environmental Protection Agency prior to discharge into natural water bodies (Prince *et al.*, 2006).

In keeping with legal obligations and the corporate policy of the world-wide non-alcoholic Beverage International family to satisfy stringent environmental policy requirements of countries within which they operate, the wastewater discharges from the plant are often treated in a fully automated 1500 meter cube per day capacity Biological Wastewater Treatment Plant (WWTP) before discharge into receiving streams.

In many countries, the need for regular or periodic environmental inspections on wastewater treatment plants is geared towards supporting and strengthening the protection of both the environment and the public health, since the pollution generated from the industrial establishments has a negative impact not only on the environment, but also on the health of the individuals. Therefore, it is noted that most of the



procedures that could be implemented by industrial establishments to reduce the negative environmental impacts, will also lead to reducing the effects that present a threat to the health of workers within the plants and the public living in areas affected by the various emissions from the plants ( Riikonen, 1992). In this respect, the effectiveness of the inspection on industrial wastewater treatment plants will lead to the protection of the environment and the protection of workers and public health.

The wastewater from these industries if adequately treated and managed can meet specific needs and purposes such as toilet flushing, cooling water, watering of lawns, cleaning of production floors and other applications. The second benefit of wastewater reuse is that it leads to reduced water consumption and treatment needs, with associated cost savings. In many applications, reusing wastewater is less costly than using freshwater, with savings stemming from more efficient water consumption and a reduced volume of additional wastewater treatment, as well as associated compliance cost savings. The infrastructure requirements for advanced wastewater treatment may also be reduced. By meeting some of the water demand through wastewater reuse and efficiency improvement, additional infrastructure requirements and the resulting financial and environmental impacts can be reduced or, in some cases, eliminated altogether (Burton *et al.*, 2003).

## **1.2 JUSTIFICATION OF THE STUDY**

All industrial wastewaters affect in some way, the normal life of streams. Streams can assimilate a certain quantity of waste beyond which it becomes polluted. A polluted stream, therefore, generally means that the stream contains an excessive amount of



specific pollutants. The main polluting materials include among others organic matter, suspended solids, colour, toxic chemicals and microorganisms (Newmerow, 1998).

Several hundreds of millions of cedis are been spent monthly on water alone for industrial productions. This poses a challenge to the beverage industries and therefore the need to find an alternative reuse of the treated wastewater before discharging into the environment (Prince *et al.*, 2006).

Industrial wastewater treatment has been handled with difficulty causing preventable outbreaks. Very little has been done because of lack of proper methods and expertise in the field. Industrialists feel that wastewater treatment is costly and will affect their marginal profits (Prince *et al.*, 2006).

Sand filters which are structural devices that treat volumes of wastewater and return the flow through an underdrain back to the conveyance system have been seen as a wastewater treatment option. This is because sand filters use physical straining, solids settling, and adsorption processes to reduce pollutant concentrations in wastewater to acceptable levels.

### **1.3 OBJECTIVE OF THE STUDY**

The study will assess the quality of effluent from a non-alcoholic Beverage company and explore possible alternatives aimed at improving the quality of effluent discharged into the environment.

#### **1.3.1 Specific Objectives**

1. To determine the efficiency of a non-alcoholic beverage company Effluent Treatment Plant (ETP)







## **CHAPTER TWO**

### **2.0 LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

The basic function of wastewater treatment is to speed up the natural processes by which water is purified. There are two basic stages in the treatment of wastes, primary and secondary, which are outlined here. In the primary stage, solids are allowed to settle and removed from wastewater. The secondary stage uses biological processes to further purify wastewater. Sometimes, these stages are combined into one operation, (Diamant, 1990).

The major aim of wastewater treatment is to remove as much of the suspended solids as possible before the remaining water, called effluent is discharged back to the environment. As solid materials decay, it uses up oxygen, which is needed by the plants and animals living in the water (Prince *et al.*, 2006).

#### **2.2 WHAT IS WASTEWATER?**

Nature has an amazing ability to cope with small amounts of water wastes and pollution, but it would be overwhelmed if we didn't treat the billions of gallons of wastewater and sewage produced every day before releasing it back to the environment.

Treatment plants reduce pollutants in wastewater to a level nature can handle (Foster, 2000).

Wastewater is a term applied to any type of water that has been utilized in some capacity that negatively impacts the quality of the water. Common examples of



wastewater include water that is discharged from households, office and retail buildings, and manufacturing plants. Wastewater may also refer to any water that is utilized in an agricultural facility and is no longer considered fit for human consumption (Foster, 2000).

Wastewater also includes storm runoff. Although some people assume that the rain that runs down the street during a storm is fairly clean, it isn't. Harmful substances that wash off roads, parking lots, and rooftops can harm our rivers and lakes (Foster, 2000).

### **2.2.1 Why Treat Wastewater?**

It's a matter of caring for our environment and for our own health. There are a lot of good reasons why keeping our water clean are an important priority:

#### *Fisheries*

Clean water is critical to plants and animals that live in water. This is important to the fishing industry, sport fishing enthusiasts, and future generations (Eckenfelder, 2000).

#### *Wildlife Habitats*

Our rivers and ocean waters teem with life that depends on shoreline, beaches and marshes. They are critical habitats for hundreds of species of fish and other aquatic life.

Migratory water birds use the areas for resting and feeding (Eckenfelder, 2000).



### *Recreation and Quality of Life*

Water is a great playground for us all. The scenic and recreational values of our waters are reasons many people choose to live where they do. Visitors are drawn to water activities such as swimming, fishing, boating and picnicking (Eckenfelder, 2000).

### *Health Concerns*

If it is not properly cleaned, water can carry disease. Since we live, work and play so close to water, harmful bacteria have to be removed to make water safe.

The major aim of wastewater treatment is to remove as much of the suspended solids as possible before the remaining water, called effluent, is discharged back to the environment. As solid material decays, it uses up oxygen, which is needed by the plants and animals living in the water. "Primary treatment" removes about 60 percent of suspended solids from wastewater. This treatment also involves aerating (stirring up) the wastewater, to put oxygen back in. Secondary treatment removes more than 90 percent of suspended solids (Prince *et al.*, 2006).

## **2.3 WASTEWATER MINIMISATION**

Industrial activities have traditionally consumed large amounts of resources and energy, e.g. freshwater and raw materials, resulting in significant emissions to the environment.

These industrial emissions have led to local and global environmental pollution problems.



Therefore, the reduction of wastewater from industrial activities is paramount for the survival of human civilization (Ujang, 2000). Wastewater minimisation in an industrial setup is a systematic attempt to achieve the following goals:

- reduce freshwater consumption
- minimize wastewater discharges by reducing wastewater flow rates
- reduce costs in terms of wastewater management (Ujang, 2000).

## **2.4 WHAT IS IN WASTEWATER?**

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment. Sewer can be found in wastewater; even industrial sewage contains many potential pollutants. The wastewater components that should be of most concern to industries and communities are those that have the potential to cause disease or detrimental environmental effects (Prince *et al.*, 2006).

### **2.4.1 Organisms**

Many different types of organisms live in wastewater and some are essential contributors to treatment. A variety of bacteria, protozoa, and worms work to break down certain carbon-based (organic) pollutants in wastewater by consuming them. Through this process, organisms turn wastes into carbon dioxide, water, or new cell growth (Prince *et al.*, 2006).



Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment. Most wastewater treatment systems are designed to rely in large part on biological processes (Prince *et al.*, 2006).

#### **2.4.2 Pathogens**

Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals that are infected with or are carrier of a disease (Prince *et al.*, 2006).

#### **2.4.3 Organic matter**

Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, food and from agricultural, commercial and industrial sources (Prince *et al.*, 2006).

Organic compounds normally are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which they can be consumed and broken down by organisms. However, even biodegradable materials can cause pollution. In fact, too much organic matter in wastewater can be devastating to receiving waters (Prince *et al.*, 2006).

Large amounts of biodegradable materials are dangerous to lakes, streams, and oceans, because organisms use dissolved oxygen in the water to break down the wastes. This can reduce or deplete the supply of oxygen in the water needed by aquatic life, resulting



in fish kills, odours, and overall degradation of water quality. The amount of oxygen organisms need to break down wastes in wastewater is referred to as the biochemical oxygen demand (BOD) and is one of the measurements used to assess overall wastewater strength (Prince *et al.*, 2006).

Some organic compounds are more stable than others and cannot be quickly broken down by organisms, posing an additional challenge for treatment. This is true of many synthetic organic compounds developed for agriculture and industry.

#### **2.4.4 Oil and grease**

Fatty organic materials from animals, vegetables, and petroleum also are not quickly broken down by bacteria and can cause pollution in receiving environments. When large amounts of oils and greases are discharged to receiving waters from community systems, they increase BOD and they may float to the surface and harden, causing aesthetically unpleasant conditions. They also can trap plants, and other materials, causing foul odours, attracting flies and mosquitoes and other disease vectors. In some cases, too much oil and grease causes septic conditions in ponds and lakes by preventing oxygen from the atmosphere from reaching the water (WHO, 1993). On site systems also can be harmed by too much oil and grease, which can clog onsite systems drain field pipes and soils, adding to the risk of system failure (Prince *et al.*, 2006).

#### **2.4.5 Inorganics**

Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are common in wastewater from both residential and non-residential sources. They can originate from a variety of



sources, storm water, and inflow and infiltration from cracked pipes and leaky manhole covers (Prince *et al.*, 2006).

Most inorganic substances are relatively stable, and cannot be broken down easily by organisms in wastewater (Prince *et al.*, 2006). Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment. For this reason, extra treatment steps are often required to remove inorganic materials from industrial wastewater sources. For example, heavy metals which are discharged with many types of industrial wastewaters are difficult to remove by conventional treatment methods. Although acute poisonings from heavy metals in drinking water are rare in the country, potential long-term effects of ingesting small amounts of some inorganic substances over an extended period of time are possible (Prince *et al.*, 2006).

#### **2.4.6 Nutrients**

Wastewater often contains large amounts of the nutrients nitrogen and phosphorous in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there normally is an excess available in treated wastewater. In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow quickly depleting oxygen in the water and deprived of oxygen, fish and other aquatic life die, emitting foul odours (Prince *et al.*, 2006).

Nutrients from wastewater have also linked to ocean “red tides” that poisons fish and cause illness in humans. Nitrogen in drinking water may contribute to miscarriages and



is the cause of serious illness in infants called methemoglobinemia or “blue baby syndrome” (Prince *et al.*, 2006).

#### **2.4.7 Solids**

Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. The solids must be significantly reduced by treatment or they can increase BOD when discharged to receiving waters and provide places for microorganisms to escape disinfection. They also can clog soil absorption fields in onsite systems (Prince *et al.*, 2006).

##### *Settleable solids:*

Certain substances, such as sand, grit, and heavier organic and inorganic materials settle out from the rest of the wastewater stream during preliminary stages of treatment. On the bottom of settling tanks and ponds, organic material makes up a biologically active layer called sludge that aids in treatment (Prince *et al.*, 2006).

##### *Suspended solids:*

Materials that resist settling may remain suspended in wastewater. Suspended solids in wastewater must be treated, or they will clog soil absorption systems or reduce the effectiveness of disinfection systems (Prince *et al.*, 2006).

Dissolved solids-small particles of certain wastewater materials can dissolve like salt in water. Some dissolved materials are consumed by microorganisms in wastewater, but others, such as heavy metals, are difficult to remove by conventional treatment.



Excessive amounts of dissolved solids in wastewater can have adverse effects on the environment (Prince *et al.*, 2006).

#### **2.4.8 Gases**

Certain gases in wastewater can cause odours, affect treatment, or are potentially dangerous. Methane gas, for example, is a by-product of anaerobic biological treatment and is highly combustible. Special precautions need to be taken near septic tanks, manholes, treatment plants, and other areas where wastewater gases can collect.

The gases hydrogen sulphide and ammonia can be toxic and pose asphyxiation hazards. Ammonia as a dissolved gas in wastewater also is dangerous to fish. Both gases emit odours, which can be a serious nuisance. Unless effectively contained or minimised by design and location, wastewater odours can affect the mental well being and quality of life of residents (Prince *et al.*, 2006).

## **2.5 NON-ALCOHOLIC BEVERAGE WASTEWATER TREATMENT PLANT**

The wastewater treatment plant is the batch type and consists of four main components; the pre-treatment tank, balancing equalizing and neutralizing basin (BENB), the sequential batch reactor (SBR1) and sequential batch reactor 2 (SBR2) (TCCBCGL, 2007).



#### *Pre-Treatment Tank:*

The pre-treatment tank is an underground rectangular concrete tank of capacity 180 m<sup>3</sup> and consists of three main chambers. In the first chamber preliminary wastewater treatment is achieved by the removal of wastewater constituents that may cause maintenance or operational problems with the treatment operations, processes and ancillary systems. Examples of preliminary operation are screening for the removal of debris, crown corks, straw and rags, grit removal for the elimination of coarse suspended matter that may cause wear or clogging of equipment, and floatation for the removal of small quantities of oil and grease. The second chamber, the neutralization basin is equipped with an automatic pH meter which corrects the pH of the wastewater by dosing sulphuric acid as at when it becomes necessary. It also contains mechanical agitators which continuously stir the wastewater to ensure a uniform pH within the chamber. The third chamber, the neutralized tank, has submerged pumps that automatically pump the wastewater when it gets to a set maximum limit (TCCBCGL, 2007).

#### *Balancing Neutralization and Equalization Basin:*

The balancing, neutralization and equalization basin is the second component of the wastewater treatment plant. It is circular in shape, has a capacity of 780 m<sup>3</sup> and is made of stainless steel. It is employed to neutralize the wastewater pumped from the pre-treatment tank and to receive and balance shocks such as high pH and temperature. The basin is automatically controlled (TCCBCGL, 2007).



### *Sequential Batch Reactor 1:*

The sequential batch reactor 1 is the third component of the wastewater treatment plant and receives neutralized wastewater from the balancing neutralizing and equalizing basin. It is circular in shape, has a capacity of 780 m<sup>3</sup> and is made of stainless steel. It contains bacteria employed to remove or reduce the concentration of organic and inorganic compounds. The removal of carbonaceous biochemical oxygen demand, coagulation of nonsettleable colloidal solids and stabilization of organic matter are accomplished biologically through the activities of bacteria. Bacteria convert the colloidal and dissolved carbonaceous organic matter into various gases and cell tissue. Because cell tissue has a specific gravity slightly greater than that of water, the resulting cells are removed from the treated water by gravity settling. The reactor is automatically operated and desludging is done periodically (TCCBCGL, 2007).

### *Sequential Batch Reactor 2:*

The sequential batch reactor 2 is the final component of the wastewater treatment plant. It is similar in shape and size to the sequential batch reactor 1 and is also made of stainless steel. It is employed to further breakdown organic and inorganic compounds present in the wastewater from the sequential batch reactor 1. It is automatically operated. Discharge of effluent wastewater as well as desludging is done periodically (TCCBCGL, 2007).

## **2.6 TREATMENT PROCESS**

There are three general treatment methods for industrial wastewaters: Physical, chemical and biological treatment. Physical treatment methods consist of processes



such as membrane technologies, carbon adsorption, distillation, filtration, ion exchange, oil and grease skimming, oil/water separation, sedimentation, steam stripping, and solvent extraction. Membrane technologies, such as ultrafiltration and microfiltration are currently popular physical treatment technologies (Prince *et al.*, 2006). Chemical treatment methods include: Chemical oxidation, chemical precipitation, chromium reduction, coagulation, cyanide destruction, dissolved air flotation, electrochemical oxidation, flocculation, hydrolysis, and neutralization (pH control). Biological treatment methods include: biological nitrogen removal, bioaugmentation, activated sludge, extended aeration, anaerobic processes, rotating biological contactors and sequencing batch reactors (Prince *et al.*, 2006).

### 2.6.1 Primary Treatment

As industrial wastewater enters a plant for treatment, it flows through a screen, which removes large objects such as rags and sticks that might clog pipes or damage equipment. After screening, it passes into a grit chamber, where cinders, sand and small stones settle to the bottom. A grit chamber is particularly important in communities with combined sewer systems where sand and gravels may wash into sewers along with storm water (Burton *et al.*, 2003).

After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids. These solids are minute particles that can be removed from sewage in a sedimentation tank. When the speed of the flow through one of these tanks is reduced, the suspended solids will gradually sink to the bottom where they form a mass of solids called raw primary biosolids formerly sludge. Biosolids are usually removed from tanks by pumping, after which it may be



further treated for use as a fertilizer, or disposed of in a landfill or incinerated (Burton *et al.*, 2003).

Sedimentation is currently the most widely used primary treatment operation. In a sedimentation unit, solid particles are allowed to settle to the bottom of a tank under quiescent conditions. Chemicals may be added in primary treatment to neutralize the stream or to improve the removal of small-suspended solid particles. Primary reduction of solids reduces oxygen requirements in a subsequent biological step and also reduces the solids loading to the secondary sedimentation tank (Prince *et al.*, 2006).

Primary treatment alone has proved to meet some industries demands for higher water quality in order to comply with environmental regulations for effluent discharge to various water bodies (Burton *et al.*, 2003).

#### **2.6.2 Secondary Treatment**

The secondary stage of treatment removes about 90% of the organic matter sewage by making use of bacteria in it. The principal secondary treatment techniques used in secondary treatment are the trickling filter and the activated sludge process (Burton *et al.*, 2003).

After effluent leaves the sedimentation tank in the primary stage it flows or is pumped to a facility using one or the other of these processes. A trickling filter is simply a bed of stones from three to six feet deep through which sewage passes (Burton *et al.*, 2003).



More recently, interlocking pieces of corrugated plastic or other synthetic media have also been used in trickling beds. Bacteria gather and multiply on these stones until they can consume most of the organic matter. The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria (Burton *et al.*, 2003).

Secondary treatment generally involves a biological process to remove organic matter through biochemical oxidation. The particular biological process selected depends upon such factors as quantity of wastewater, biodegradability of waste and availability of land. The principal secondary treatment techniques used are the activated sludge process and the trickling filter (Burton *et al.*, 2003).

In the activated sludge process, wastewater is fed to an aerated tank where microorganisms consume organic wastes for maintenance and for generation of new cells. The resulting microbial floc (activated sludge) is settled in a sedimentation vessel called a clarifier or thickener. A portion of the thickened biomass is usually recycled to the reactor to improve performance through higher cell concentrations (Burton *et al.*, 2003).

Trickling filters (bio-filters) are beds packed with rocks, plastic structures, or other media. Microbial films grow on the surface of the packing and remove soluble organics from the wastewater flowing over the packing. Excess biological growth washes off the packing and is removed in a clarifier (Burton *et al.*, 2003).

The trend today is towards the use of the activated sludge process instead of trickling filters. The activated sludge process speeds up the work of the bacteria by bringing air



and sludge heavily laden with bacteria into close contact with wastewater. After the wastewater leaves the settling tank in the primary stage, it is pumped into an aeration tank, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, bacteria break down organic matter into harmless by-products. The sludge now activated with additional billions of bacteria and other tiny organisms can be used again by returning it to the aeration tank for mixing with air and new wastewater. From the aeration tank, the partially treated wastewater flows to another sedimentation tank for removal of excess bacteria (Gosselink *et al.*, 2000).

### **2.6.3 Tertiary Treatment**

Many industrial effluent standards require tertiary or advanced wastewater treatment to remove particular contaminants or to prepare the water for reuse. Some common tertiary operations are removal of phosphorus compounds by coagulation with chemicals, removal of nitrogen compounds by ammonia stripping with air or by nitrification - denitrification in biological reactors, removal of residual organic and colour compounds by adsorption on activated carbon and removal of dissolved solids by membrane processes (reverse osmosis and electrodialysis). To complete tertiary treatment, effluent from the sedimentation tank is usually disinfected with chlorine before being discharged into receiving waters. Chlorine is fed into the water to kill pathogenic bacteria and to reduce odor. Done properly, chlorination will kill more than 99 percent of the harmful bacteria in the effluent. Many industries now require the removal of excess chlorine before discharge to surface waters by a process called dechlorination. Alternatives to chlorine disinfection, such as ultraviolet light or ozone, are also being used in situations where chlorine in treated sewage effluents may be harmful to fish and other aquatic life.



Tertiary treatment is intended primarily for upgrading the quality or polishing of effluent and to remove further the suspended solids, BOD and excess nutrients (Burton *et al.*, 2003).

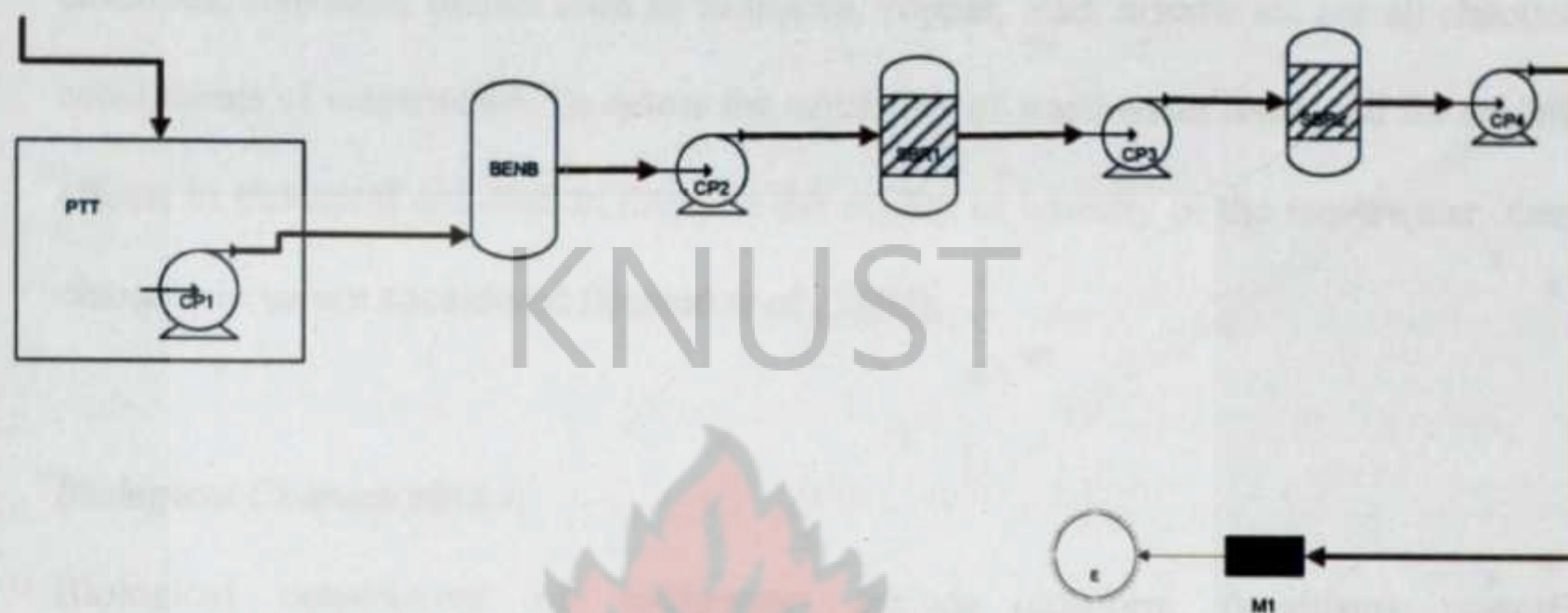


Figure 2.1: Process Flow Sheet of an Industrial Wastewater Treatment Plant

## 2.7 CHARACTERISTICS OF WASTEWATER

Tchobanoglous, Burton and Stensel (2003), characterized wastewater into physical, chemical and biological constituents.

### *Physical Characteristics:*

The physical constituents of wastewater include temperature, turbidity, colour, suspended solids, conductivity, settleable solids and total chemical solids, etc. These characteristics are used to assess the reuse potential of wastewater and to determine the most suitable type of operation and processes for its treatment (Burton *et al.*, 2003).



### *Chemical Characteristics:*

The chemical constituents of wastewater include nutrients such as free ammonia, nitrates, nitrites, total phosphorus, etc. These parameters are used to measure the nutrients present and the degree of decomposition in the wastewater. Alkalinity, pH, chlorides, sulphates, metals such as cadmium, copper, lead, arsenic etc are all chemical constituents of wastewater. To assess the suitability of wastewater reuse and for toxicity effects in treatment and also to measure the acidity or basicity of the wastewater, these characteristics are considered (Burton *et al.*, 2003).

### *Biological Characteristics:*

Biological constituents of wastewater include coliform organisms, specific microorganisms and toxicity. These characteristics are used to assess the presence of pathogenic bacteria, specific organisms present and to detect the level of toxicity, whether acute toxic unit or chronic toxic unit (Burton *et al.*, 2003).

#### **2.7.1 Colour**

The colour of water is the result of the different wavelengths that is not absorbed by the water itself or the result of particulate and dissolved substances present (Chapman and Kimstach, 1992). Fresh water is usually of a light brownish grey colour. However, as the travel time in the collection system increases and more anaerobic conditions develop, the colour of the wastewater changes sequentially from grey to dark grey and ultimately to black Tchobanogolous, Burton and Stensel (2003).

Colour is partly due to suspended solids (apparent colour) and partly due to dissolved solids (true colour). Hence natural minerals such as ferric hydroxide and manganese



oxide impact colour to water (Annang, 2000). In most cases the grey, dark grey and black colour of the wastewater is due to the formation of metallic sulphides, which form as the sulphides produced under anaerobic conditions react with the metals in the wastewater. Colour is measured by the Lovibond Nesslerizer disc (Okoh, 2010)

### **2.7.2 pH and Alkalinity**

pH, also a potential of hydrogen is defined as the negative logarithm of hydrogen-ion concentration (Pankratz, 2000). The hydrogen-ion concentration is an important quality parameter of both natural waters and wastewaters. The usual means of expressing the hydrogen-ion concentration is pH. On the 0 to 14 pH scale, a value of 7 at 25 °C represents a natural condition. Decreasing values indicate increasing hydrogen ion concentration (acidity) and increasing values indicate decreasing hydrogen ion concentration (alkalinity) (Okoh, 2010).

Tchobanoglous, Burton and Stensel (2003) observed that the concentration range suitable for the existence of most biological life is quite narrow and critical; it is from 6 to 9. Wastewater with an extreme concentration of hydrogen-ion is difficult to treat by biological means. If the concentration is not altered before discharge, the wastewater effluent may alter the concentration in the natural water. Most organisms have adapted to live in water at a specific pH and may die if it changes slightly. The toxicity level of ammonia to fish, for example, varies tremendously within a small range of pH values. pH is measured using a portable pH meter in the field or at an investigation site.



Alkalinity is the acid neutralization capacity of a solution. It is the sum of all titrable base by an acid. Hydroxyl ions are present in sample as a result of dissociation of solute which reacts with standard acid. Alkalinity thus depends on the end-point pH used (Okoh, 2010).

### **2.7.3 Temperature**

The temperature of wastewater is an important parameter because of its effects on chemical reactions and reaction rates, aquatic life and the suitability of the water for beneficial uses. Temperature varies with climatic fluctuations and responds to factors such as seasons, time of day, air circulation, cloud cover and depth and flow of water in the natural system (Annang, 2000). Wastewater temperatures, as high as 30 to 35 °C have been reported for countries in Africa and Middle East (Metcalf and Eddy, 2003). Increased temperature, for example, could cause a change in the species of fish that could exist in the receiving water body (Okoh, 2010).

In addition, oxygen is less soluble in warm water than in cold water and this could result in serious depletion of dissolved oxygen concentration in the dry season or summer months. It is realized that a sudden change in temperature could result in high rate of mortality of aquatic life and abnormal growth of undesirable water plant and wastewater fungus. Temperature is measured using a thermometer (Okoh, 2010).



#### **2.7.4 Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)**

BOD<sub>5</sub> is a measure of the quantity of dissolved oxygen used by microorganisms in the oxidation of organic matter. Micro-organisms utilize dissolved oxygen in water to oxidize polluting biodegradable organic matter, thereby giving an indication of the pollution load present. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20°C, the BOD can be determined (Standard Methods, 1998). The most serious limitation is that the five days period may or may not correspond to the point where the soluble organic matter that is present has been used.

COD measures biodegradable and non biodegradable organic matter of wastewaters. Some organic substances are resistant to biological degradation (e.g. tannic, cellulose, benzene). COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution. COD is attractive as the test yield results within two hours (Okoh, 2010).

#### **2.7.5 Total Dissolved Solids (TDS)**

Total dissolved solids mainly consist of inorganic salts like carbonates, bicarbonates, chlorides, sulphates as well as small amounts of organic matter and dissolved gases. It is noted that mere determination of the dissolved solids does not give a clear picture of the type of pollutant present in the water. However many dissolved substances are undesirable in water and they impact displeasing colour, taste and odour (Okoh, 2010).



Water with a high content of dissolved solids has a laxative or sometimes reverse effect on the human body and it takes time for people to adjust to it. The estimation of total dissolved solids is useful in determining the suitability of water for drinking, cleaning purpose as well as agriculture and other processes (Okoh, 2010).

#### **2.7.6 Total Suspended Solids (TSS).**

All waste streams have some suspended solids. The suspended solids are a collection of organic and inorganic materials of various sizes and density. The size and density ranges are from 3-5 mm to 0.001 mm and from 0.8-2.65 gm/cm<sup>3</sup> and higher. Some wastes streams; including paper plants, food wastes, and some petrochemical processes, have Total Suspended Solids loads in excess of 1000 mg/L (Okoh, 2010).

The solids generally have a biodegradable component and may have active biomass. The particles could be large and others could be smaller and tend to be indistinguishable and invisible in the water (Russell, 2006). Total suspended solids test results are used routinely to assess the performance of conventional treatment processes and the need for further effluent filtration for reuse applications (Metcalf and Eddy, 2003).

#### **2.7.7 Total Solids**

Substances can exist in aqueous solution in either the dissolved or the undissolved state. The residue that is left after evaporating a sample of water at 105 °C is referred to as the total solids value of that sample. It is generally regarded as everything that was in the sample that was not water; however, any of the substances originally present, organic or



inorganic that volatilized at 105 °C or less will not be in the residue (Metcalf and Eddy, 2003).

#### **2.7.8 Turbidity**

Turbidity refers to the light-scattering properties of a sample. Turbidity can be described as “haziness” or “milkyiness” and is caused by fine particles scattering light at more or less 90 degrees to the direction from which the light enters the sample. Turbidity is not to be confused with colour, nor colour with turbidity. Turbidity is normally measured using an electronic device in which a beam of ordinary white light is directed through a certain path length of the sample. Photometers placed at right angles to the direction of travel of the light beam detect the amount of light diverted, which is directly proportional to the turbidity, expressed in Nephelometric Turbidity Units (NTUs) (Okoh, 2010).

#### **2.7.9 Conductivity**

Conductivity is the ability of water to conduct electrical current. The principle used to measure conductivity is simple, two plates (cells) are placed in the sample and a potential is applied across the plates and current is measured. Generally, the potential in the form of sine wave conductivity is determined for the voltage and current values according to Ohm's law. Since the change on the ions in solution facilitates the conductance of an electric current, the conductivity of a solution is proportional to its concentration (Metcalf and Eddy, 2003).



#### **2.7.10 Dissolved Oxygen (DO)**

Oxygen is very essential to all aquatic life. The oxygen concentration of natural water bodies varies with temperature, atmospheric pressure, salinity, turbulence and photosynthetic activity of algae and plants. The solubility of oxygen decreases as temperature and salinity increases and as pressure decreases (Annang, 2000).

Waste discharges high organic matter and nutrients and this could cause a decrease in DO due to respiration during breakdown of organic matter. Determination of DO is very important in water quality assessments as it influences most chemical and biological processes in aquatic environments. Concentrations below 5 mg/l may affect the functioning and survival of biological communities and below 2 mg/l may lead to death of most fishes (Chapman and Kimstach, 1992).

#### **2.7.11 Phosphorus**

Phosphorus is usually present in natural water as phosphates. In aqueous solution, phosphorus exists as orthophosphate, polyphosphate and organic phosphate. The orthophosphate,  $\text{H}_2\text{PO}_4^-$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{HPO}_4^{2-}$  are available for biological metabolism without further breakdown. Phosphorus is a plant nutrient needed for growth and a fundamental element in the metabolic reactions of plants and animals hence its use in fertilizers (Okoh, 2010).

Sources of phosphorus include human and animal wastes (i.e. sewage), industrial waste, soil erosion and fertilizers. Excess phosphorus causes extensive algal growth called “blooms,” which are a classic symptom of cultural eutrophication and lead to decrease oxygen levels in natural water (Okoh, 2010).



### **2.7.12 Ammonia Nitrogen and Total Nitrogen**

Nitrogen occurs in natural waters as nitrate ( $\text{NO}_3$ ), nitrite ( $\text{NO}_2$ ), ammonia ( $\text{NH}_3$ ), and organically bound nitrogen. As aquatic plants and animals die, bacteria break down large protein molecules contain nitrogen into ammonia. Sewage is the main source of nitrates added by humans to water bodies. Another important source is fertilizer, which could be carried into natural waters by storm water runoff (Okoh, 2010).

Excessive nitrate stimulate growth of algae and other plants, which later decay and increase biochemical oxygen demand as they decompose. When ammonia oxidizes to nitrate, it requires substantial amounts of oxygen. The first oxidation is to nitrite by *Nitrosomonas* bacteria. The second groups of bacteria take the nitrite and oxidize it to nitrate (Metcalf and Eddy, 2003).

Nitrite concentration in a viable bacterial population is seldom above 0.1mg/l in surface water or 1mg/l in wastewater (Metcalf and Eddy, 2003). Nitrite is extremely toxic to most fishes and other aquatic species so usually present in low concentrations. Nitrite concentration in wastewater effluent is from 15 to 20 mg/l as N. Ammonia, nitrite, nitrate and organic nitrogen concentrations are determined by colorimetric method (Metcalf and Eddy, 2003).

### **2.7.13 Total Coliforms, Enterococci and Faecal Coliforms**

Wastewater usually contains bacteria. Bacteria are very small organisms which can be seen only under a microscope. Some bacteria are harmful and are called pathogenic bacteria whereas others are not and are referred to as non-pathogenic bacteria. Pathogenic bacteria cause typhoid, cholera, dysenteries, etc. Because it is difficult to



isolate pathogenic bacteria in the laboratory, simple test are carried out to determine the possible presence of intestinal organisms. These are termed as the coliforms groups of bacteria, some of which are non-pathogenic (Okoh, 2010).

The presence of intestinal bacteria indicates the presence of pathogenic bacteria also. Coliforms are good indicators of pollution. Hence, the presence of pathogenic bacteria is detected by testing for the coliforms group of bacteria. In the total count test, the sample of water with agar added is placed in an incubator at 37 °C for 24 hours. The bacteria in the water grow and form colonies which can be seen and counted (Okoh, 2010).

The most common risk of human health associated to wastewater comes from the presence of pathogenic microorganisms (Metcalf and Eddy, 2003). Tchobanoglous *et al.* (2003) reported that each person discharges from 100 to 400 billion bacteria per day, in addition to other kinds of bacteria. Coliforms bacteria in environmental samples, is an indication that pathogenic organism associated with fecal contamination may be present.

Poorly treated greywater, leachate from sanitary landfills and urban solid waste disposal sites, which contain human faecal matter are potential sources of pathogens. Detection of all possible pathogens is rather complex, costly and time consuming, hence *Escherichia coli* is used as indicator organism for detecting the presence of pathogens. Methods commonly used are multiple tube fermentation and membrane filtration techniques (Metcalf and Eddy, 2003).



## **2.8 TRACE METALS**

Heavy metals are important because they are often toxic and they impede or interfere with the biological treatment process when in excessive quantities. Depending upon the metal and the species, all the reactions are pH dependent (Russell, 2006).

### **2.8.1 Cadmium**

In Ghana cadmium is introduced into the aquatic environment through waste streams from mining activities, refuse and sewage sludge disposal in urban areas and manufacturing industries such as steel and iron. Cadmium is a contaminant in many chemical fertilizers (Moore *et al.*, 1995). Phosphate contains 5-100 mg Cd kg<sup>-1</sup>. Storm water runoffs carry these fertilizers in receiving water bodies. Concentration as low as 0.1 mg/l is potential for accumulation in plants and soils to concentrations that may be harmful to humans (Tchobanoglous *et al.*, 2003).

### **2.8.2 Copper**

Copper is an essential micro-nutrient, but at high doses has been shown to cause stomach and intestinal distress, liver and kidney damage, and anemia. Copper is a reddish-brown metal, often used in plumbing of residential and commercial structures that are connected to water distribution systems. Copper containing water occurs as the result of the corrosion of copper pipes that remain in contact with water for a prolonged period (Shelton *et al.*, 2005). Copper is toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solution. Recommended maximum concentration for irrigation is 0.2 mg/l (Tchobanoglous *et al.*,).



### **2.8.3 Lead**

Lead is one of the commonest metals that are used in industry for a wide variety of purposes, including pipes, paint pigment, alkyl compounds for gasoline, lead acid accumulators, brass and bronze fixtures and cable sheathing. Lead is a heavy metal that can cause a variety of adverse health effects in humans. At relatively low levels of exposure, these effects may include interferences in red blood cell chemistry, delays in normal physical and mental development in babies and young children, deficits in the attention span, hearing, and learning abilities of children and increases in blood pressure of some adults (Shelton *et al.*, 2005).

Plants growing near high ways often absorb this lead as do some grasses that grow near abandoned lead mines (Moore *et al.*, 1995). Concentration of water above 5 mg/l lead can inhibit plant growth. Materials that contain lead have frequently been used in the construction of water supply distribution system and plumbing systems in private homes other buildings. Lead in these materials contaminates water and natural water as a result of the corrosion that takes place when water comes into contact with that material (Metcalf and Eddy, 2003).

## **2.9 SAMPLING**

Sampling deals with the collection of a portion of a material that represents the actual sample composition. The quality of the analyzed data depends on activities such as formulating the particular objective for a sampling program, collecting representative samples, proper sample handling, sample preservation and proper analyses of the samples. Sampling techniques used in wastewater survey ensure that representative



samples are obtained, since the data from the analysis of the samples, ultimately serve as a basis for decision making and planning. Usually sampling programs are tailored to fit a particular scenario since there are no laid down universal procedures. The following types of samples have been listed (Okoh, 2010).

### **2.9.1 Grab Sample**

Grab sample is an individual sample, collected at a particular time and place. This type of sample represents conditions at the time it was collected. Very often, a grab sample is usually not used as a basis for decision making. However, in certain scenarios some sources are quite stable and may be represented well by a single grab sample (Okoh, 2010).

### **2.9.2 Composite Sample**

Composite sample refers to a mixture of grab samples collected at the same point at different times. Usually a series of smaller samples are collected in a single container and blended for analysis. The mixing process averages the variation in sample composition and minimizes analytical effort and expense. In scenarios where a time interval is being considered, grab samples are collected within suitable sampling intervals and chosen according to the expected changes. Also in scenarios where composition depends on location, grab samples are collected from appropriate source (Okoh, 2010).

Composite samples reflect the average characteristics during the sampling period and in most cases, a 24 hour period is standard. The volume of samples taken must be constant



(for example, 200 mls each time) in constant time intervals (for example every hour), and mixed well at the end of the composite period.

### 2.9.3 Split Sample

Split samples are taken for checking analytical performance. Usually the sample is taken into one container mixed thoroughly, and halved into another properly cleaned container. Both samples are preserved as needed and represent the same sampling point and are referred to as split samples (Okoh, 2010).



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## **CHAPTER THREE**

### **3.0 RESEARCH METHODOLOGY**

#### **3.1 DESCRIPTION OF STUDY SITE**

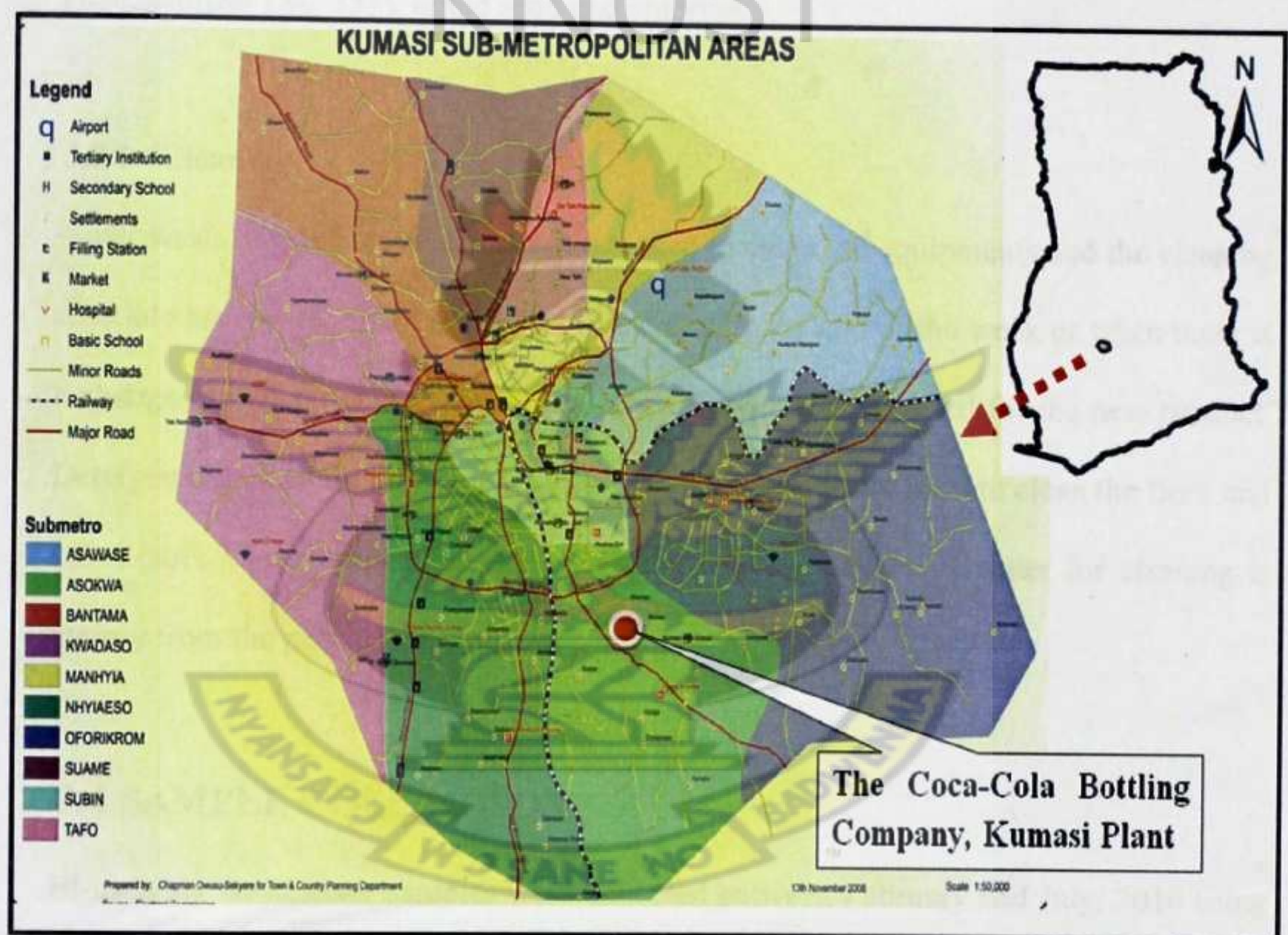
Kumasi, the capital city of the Ashanti Region of Ghana, is located in the south-central part of the country, about 270 km (by road) northwest of Accra and with an approximate size of 254 km<sup>2</sup>.

Kumasi is the second largest city in the country; the metropolis has many industries, ranging from small to large-scale enterprises. These industries are scattered in almost all the suburbs of the metropolis, with the majority concentrated at Ahensan, Kaase, Asokwa and Chirapatre areas. They are engaged in the manufacture of a variety of products including alcoholic beverages, soft drinks, nails, foam mattresses, lumber and plywood. There is also a slaughterhouse for animals (Sarfo-Afriyie, 1999). Pertinent amongst these industries is The Coca-Cola Bottling Company of Ghana, Kumasi Plant which is part of the multi-national beverage industry.

The Coca-Cola Bottling Company of Ghana Limited (TCCBCGL), Kumasi plant is located on plot No.2 Block 1 on the Lake Road at the Ahensan Industrial Area, Kumasi in the Ashanti Region. The site is bounded on the north-west by the Guinness Ghana Brewery Group –Ahensan (GGBG-Ahensan) and on the eastern and southern sides by the Ahensan Residential Area while the west is defined by the Lake Road and the Latex foam company.



The Coca Cola Bottling Company of Ghana (TCCBCGL), Kumasi has a work force of 234 out of which 225 are males and 9 females. The plant consists of the Production block, Administration block, Sales block, Warehouse, Wastewater Treatment plant, Canteen block and the Fleet Maintenance block. The plant has only one production line that produces a package size of 300 ml of its product including Coke, Sprite, Fanta Pineapple, Fanta Lemon, Fanta Orange, Fanta Cocktail, etc. (Sarfo-Afriyie, 1999).



**Figure 3.1: Study Site**

### **3.2 ACTIVITIES AT THE PRODUCTION DEPARTMENT**

It operates 168 hours a week and the following industrial processes do take place. There is a water treatment plant for the treatment of water from the municipal water supply for production of the beverage and the preparation of syrup which is used for the beverage.



Container preparation which involves washing of the bottles and the final stage being the production processes. There is also a quality assurance section that monitors and controls all quality indicators in the plant.

### **3.3 RAW MATERIALS USED**

The frequently used raw materials in the plant are bottles, concentrate, sugar and crown corks. Chemicals used in the production department are water, caustic soda (NaOH), Titan sanitizer (SU 357), liquid soap and chlorine.

#### **3.3.1 Cleaning**

Water wash, steam/hot water, caustic are used to clean the equipments and the cleaning schedule are mostly either at the end of the day, at the end of the week or when there is a change of one flavour to another and the machine is to be used for the new product. Detergents such as liquid soap, SU, calcium hypochlorite are used to clean the floor and some parts of the equipments for production and the source of water for cleaning is mainly from the public water supply.

### **3.4 SAMPLE COLLECTION**

Bi-monthly wastewater samples were collected between February and July, 2010 using Non-Pet Plastic bottles of 0.5 L and 1.5 L volumes which had been thoroughly washed, cleaned with a detergent and double distilled water and labelled. Each bottle was rinsed with the water to be sampled. The bottles were then filled with its water content and tightly closed with its cap. These were transported in an ice chest to the Laboratory. The samples were then analysed within six hours. In all, thirty six (36) samples were



collected from both the influent and effluent sampling site. Samples for bacteriological analysis were collected in sterilized plain glass bottles and transported to the laboratory on ice packs in an ice chest.

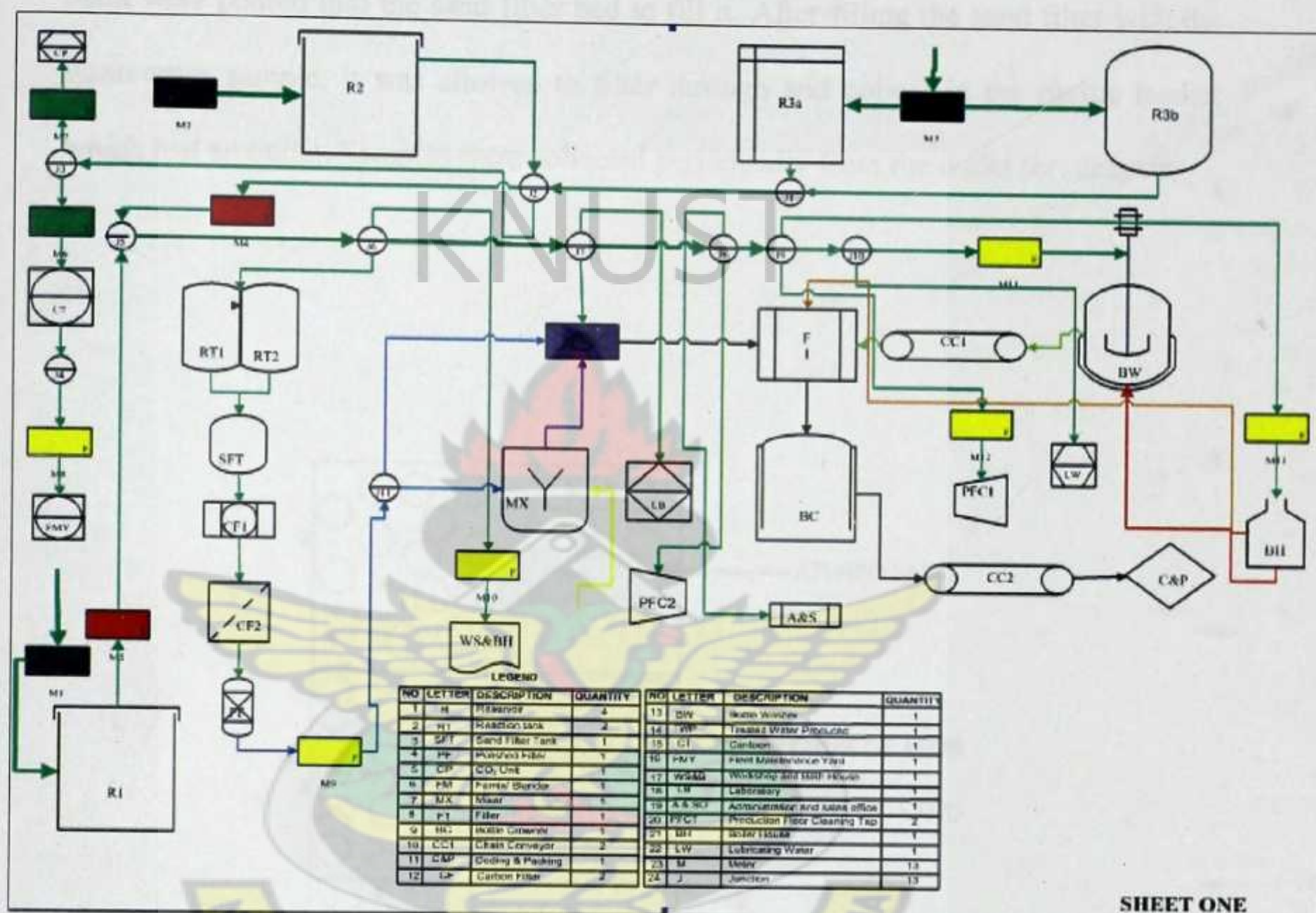


Figure 3.2: Process flow diagram for the production of beverage at the plant (Okoh, 2010).

### 3.5 SETTING-UP OF THE SAND FILTER BED SYSTEM

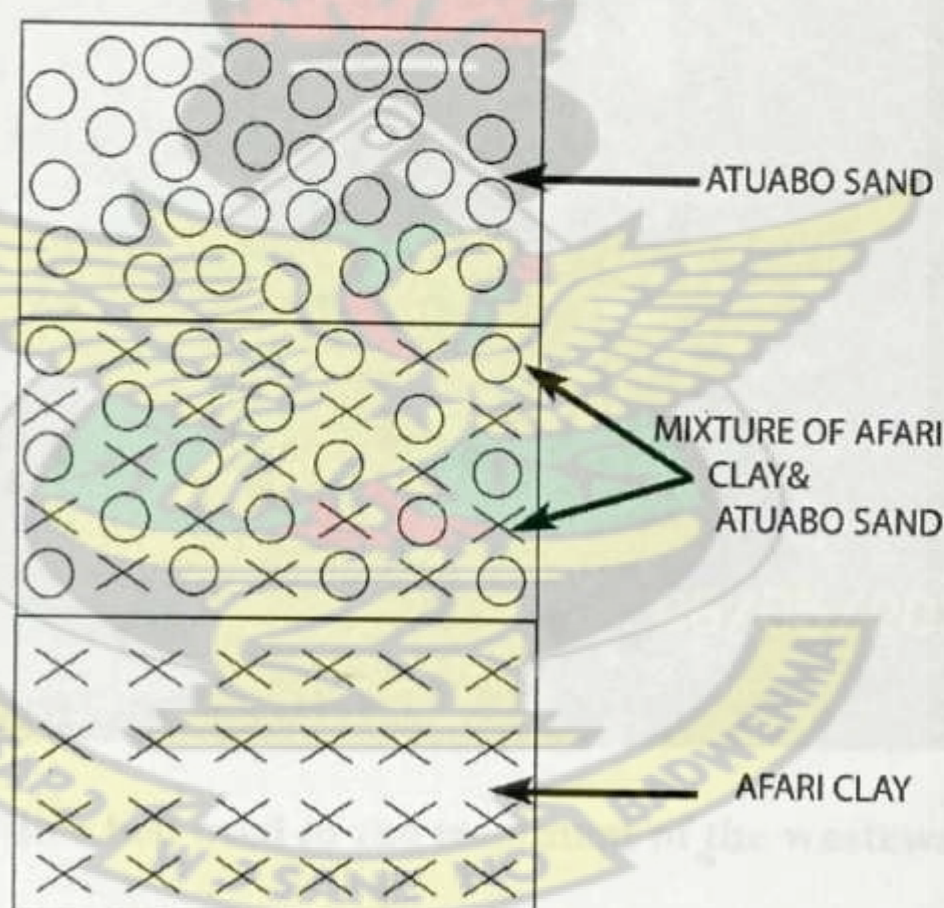
#### Experimental Procedure

A sand filter bed system was set up using fine soil which served as the filtration media. The fine sand particle sizes were 38.5 percent for sand, 25.0 percent for silt and 36.5 percent for clay. The soil used for the sand filter was obtained from Afari which is a



known clay quarry in Kumasi and Atuabo in the Western region. A two inch cylindrical PVC pipe was placed vertically into a ten litre plastic bucket as shown in figure 3.3.

The two inch PVC pipe was then filled with 100 g of Afari clay, 100 g of both the Afari clay and Atuabo sand and 100 g of Atuabo sand. Wastewater samples from the beverage plant were poured into the sand filter bed to fill it. After filling the sand filter with the wastewater sample, it was allowed to filter through and collect in the plastic bucket which had an outlet. Samples were collected periodically from the outlet for analysis



**Figure 3.3 A flow diagram showing the various composition of the soil**



### **3.5.1 Determination of Particle Size Distribution of Soil**

The soil particle sizes were determined by first drying in air or in the sun. In wet weather, drying was done in an oven at 105 to 120 °C. The clod formed was broken with wooden mallet to hasten drying. Care was taken not to break the individual soil particles. Tree roots and pieces of bark were removed from the sample.



**Plate 1.1: A Sand Filter bed used in the treatment of the wastewater effluent.**

## **3.6 ANALYTICAL METHODS**

### **3.6.1 Particle Size Distribution of Soil**

Five hundred grams of the dried soil sample was mixed in water and either 2 g of sodium hexametaphosphate or 1 g of sodium hydroxide and 1 g of sodium carbonate per litre of water, added as a dispersive agent. The soil sample was allowed to soak in the water for 10 to 12 hrs.



The soil sample was then washed through 4.75 mm IS Sieve with water till clean water comes out. The retained soil sample on the 4.75 mm IS Sieve was oven-dried for 24 hrs. This dried soil sample was sieved through 20 mm and 10 mm IS Sieves.

### *3.6.2 Reporting of Results*

The oven-dried material was riffled and about 200 g taken. The 200 g sample was again washed through a 75  $\mu$ m IS Sieve with half a litre of distilled water, till clear water comes out.

The material retained on the 75  $\mu$ m IS Sieve was dried in an oven at a temperature of 105 to 120  $^{\circ}$ C for 24 hrs. The dried soil sample was again sieved through 2 mm, 600  $\mu$ m, 425  $\mu$ m and 212  $\mu$ m IS Sieves. Soil retained on each sieve was weighed.

If the soil passing through the 75  $\mu$ m sieve was 10% or more, hydrometer method was used in analysing the soil particle size.

### **3.6.2 Hydrometer Analysis**

Particles passed through the 75  $\mu$ m IS Sieve along with water was collected and placed in a 1000 ml jar for hydrometer analysis. More water, if required, was added to make the soil water suspension up to 1000 ml. The suspension in the jar was vigorously shaken and carefully placed on a flat top table.

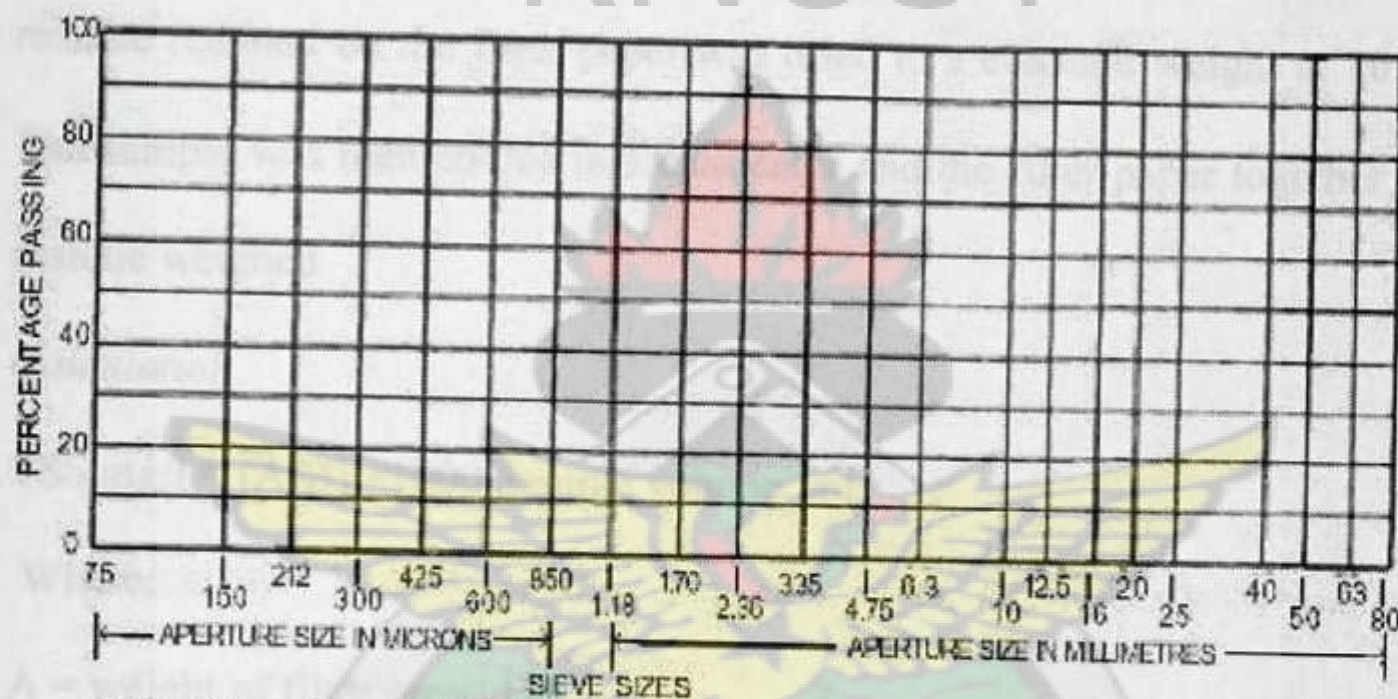
A graduated hydrometer was carefully inserted into the suspension with minimum disturbance. At different time intervals, the density of the suspension at the centre of gravity of the hydrometer and temperature was noted. Hydrometer readings were taken at 0.5, 1.0, 2.0, 4.0, 15.0, 45.0, 90.0 minutes, and at 3, 6, 24 and 48 hrs.



Using the nomogram given in IS: 2720 (Part 4) – 1985, the diameter of the particles for different hydrometer readings were determined.

### 3.6.3 Reporting of Results

After completing the mechanical and hydrometer analysis, the results were plotted on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate



Note - The vertical scale of this chart is an arithmetic scale and the horizontal scale is logarithmic.

**CHART FOR RECORDING SIEVE ANALYSIS RESULTS**

### 3.6.4 pH

Hundred millilitres of the wastewater sample was measured into a beaker and its pH and temperature were determined using a Hanna pH meter (model HI 83141). The procedure was then repeated for an average value to be determined.



### **3.6.5 Total Dissolved Solids (TDS).**

Hundred millilitres of the wastewater sample was measured into a beaker and its TDS determined using a conductivity meter after the value has been stabilized on the meter.

The procedure was again repeated to get an average value of the TDS.

### **3.6.6 Total Suspended Solids (TSS)**

A filter paper was weighed and placed in a filtration apparatus. About 100 ml of the wastewater sample was mixed thoroughly and filtered through the filter paper. The residue retained on the filter paper was dried to a constant weight at 103°C to 105°C.

The sample was then cooled in a dessicator and the filter paper together with the dried residue weighed

#### *Calculation*

$$\text{TSS mg/l} = (A-B) \times 1000 / \text{Sample volume, ml:}$$

Where;

A = weight of filter + residue

B = weight of filter

### **3.6.7 Conductivity**

The conductivity of each sample was measured using a Tetra Con 325 cond 330i conductivity meter. The probe was immersed in a well shaken wastewater sample and the conductivity value recorded. The procedure was again repeated for an average value to be determined.



### **3.6.8 Biochemical Oxygen Demand (BOD)**

#### *Dilution method*

About 25 ml of the wastewater sample was measured and made up to 1 liter with dilution water. This was well mixed with a mixing rod. The mixed dilution was siphoned into two BOD bottles making sure that there was no air bubble. The Initial DO of one of the bottled samples was determined and the other bottle stoppered and incubated in the dark for five days at 20°C. Incubation in the dark prevents photosynthesis action by any algae contained in the sample that might give oxygen to interfere with the BOD determination.

#### *Calculation:*

$$\text{BOD}_5 \text{ mg/l} = (D_0 - D_1)/S$$

Where:

D0 = initial DO

D1 = final DO

S = volume of sample used

### **3.6.9 Chemical Oxygen Demand (COD)**

#### *Open refluxed method*

Digestion tubes and caps were washed with 4M sulphuric acid to ensure that they were clean. Ten millilitres of wastewater sample was placed into the digestion tube and 6 ml digestion solution added. Fourteen millilitres of sulphuric acid was carefully run down inside the tube to form an acid layer under the sample-digestion solution layer.

The tubes were tightly capped and inverted several times to mix completely. The samples were then refluxed for two hours and then cooled to room temperature. The



samples were transferred into a larger container for titration. One to two millilitres of ferroin indicator was added and it was titrated with 0.1M FAS until the colour changed from blue-green to reddish brown. Again, the procedure was repeated for the blank sample.

*Calculation:*

$$\text{COD mg/l} = (A-B) \times M \times 8000 / V_s$$

Where:

A = volume of FAS used for blank

B = volume of FAS used for sample

M = molarity of FAS

V<sub>s</sub> = volume of sample used

#### **3.6.10 Total Hardness**

A one gram portion of ammonium chloride buffer solution was added to 100 ml of the wastewater and two drops of Eriochrome Black T indicator solution added. The resulting solution was titrated against EDTA solution with continuous swirling until the last reddish colour changes to blue. The procedure was again repeated to determine an average value.

*Calculation;*

$$\text{Total hardness in mg/L} = [A \times B \times M \times 1000] / \text{ml of sample}$$

Where;

A= Volume of EDTA consumed

B= Concentration of EDTA

M= Molar mass of CaCO<sub>3</sub> (100g/mol)



### **3.6.11 Alkalinity ( $\text{HCO}_3$ )**

Fifty millilitres of the wastewater sample was measured into a conical flask and two drops of methyl orange indicator added. This was titrated against 0.1M hydrochloric acid solution until a permanent pink colour develops.

*Calculation:*

$$\text{Alkalinity } (\text{HCO}_3) \text{ (mg/L)} = [C \times V_1 \times M \times 50000 / V_2]$$

Where, C= Molarity of Hydrochloric acid (0.1M)

V1= Volume of acid consumed

V2= Volume of sample taken

### **3.6.12 Total Alkalinity ( $\text{CaCO}_3$ )**

Fifty milliliters of the wastewater sample was placed in an erlenmeyer flask and five drops of phenolphthalein indicator added. On development of a pink colour ( $\text{pH} \geq 8.3$ ), it was titrated with 0.02N HCl until the pink colour disappeared and the volume of HCl used recorded.

Again 5 drops of methyl orange indicator was added to the solution or the mixed indicator and was titrated until a red colour appears, the volume used was first recorded. In case no colour appears, ( $\text{pH} \leq 8.3$ ): about 5 drops of methyl orange indicator was added to the solution or the mixed indicator and titrate until a red colour appears, the volume used was recorded.

*Calculation:*

$$\text{Alkalinity as mg/L } (\text{CaCO}_3) = (V \times N \times 1000 / \text{ml sample} \times 2) \times 100. \text{ Where;}$$

V = titration volume in mL,

N = normality of the acid solution,

100 = molecular mass of  $\text{CaCO}_3$



### **3.6.13 Chloride**

Fifty millilitres of the wastewater sample was measured into a 100 ml conical flask and the pH adjusted to between 7-10 with sulphuric acid or sodium hydroxide. Two drops of potassium chromate indicator was added to the sample and titrated against silver nitrate solution to a pinkish yellow end point. The procedure was again repeated to determine an average value.

#### *Calculation*

$$\text{Mg Cl/L} = (A - B) \times M \times 35.45 \times 1000/\text{mL sample}$$

Where

A = ml titration for sample

B = ml titration for blank

M = Molarity of  $\text{AgNO}_3$

### **3.6.14 Dissolved Oxygen (DO)**

Three hundred milliliters of the wastewater sample was measured and carefully transferred into a 250-300 ml bottle, 1.0 ml  $\text{MnSO}_4$  was added to the sample followed by 1.0 ml alkali-iodide-azide, making sure that the tip of the pipette was held just above the liquid. The sample was stoppered carefully to exclude air bubbles and mixed by inverting the bottle a few times.

The precipitate was allowed to settle and the supernatant discarded. One milliliter conc.  $\text{H}_2\text{SO}_4$  was added and swirled gently to dissolve the flocs formed. It was then titrated with 0.025M  $\text{Na}_2\text{S}_2\text{O}_3$  to pale straw colour, a few drops of starch was added and titrated until the blue colour disappeared.



### *Calculation*

$$\text{DO mg/l} = V \times M \times 8 \times 1000 / V_s - 2$$

Where

V = ml  $\text{Na}_2\text{S}_2\text{O}_3$  used

M = Molarity  $\text{Na}_2\text{S}_2\text{O}_3$

$V_s$  = Sample volume

### **3.6.15 Phosphate and phosphorus**

#### *Phos Ver (Ascorbic Acid) Method using Powder pillows*

The spectrophotometer was switched ON and the programme number 490 was entered. The wavelength was rotated until the display showed 890 nm and then mg/l  $\text{PO}_4^{3-}$  -PV. A 10 ml Cell Riser was inserted into the cell compartment. The wastewater sample to be analyzed was well shaken and a 1ml portion measured and diluted with distilled water to 250 ml.

Ten millilitres of the sample was poured into a 10 ml sample cell. The content on one Phos Ver 3 phosphate powder pillow was added to the sample in the cell and immediately well shaken to mix. A blue colour forms if phosphate was present. The Shift Timer button was then pressed and allowed to react for two minutes. A second 10 ml sample cell was filled with a portion of the diluted sample which served as a blank. When the two minute reaction time was over the timer beeped and the display showed mg/l  $\text{PO}_4^{3-}$  -PV. The blank was placed into the cell holder and the light shield closed. The Zero button was pressed to set the machine to zero for that particular sample. The blank was removed and the prepared sample was put into the cell holder and the light shield closed. The Read button was pressed and the display showed the concentration of the  $\text{PO}_4^{3-}$  in mg/l. Other concentrations of phosphorus, P and polyphosphate ( $\text{P}_2\text{O}_5$ )



were obtained by pressing arrow buttons in turn. The actual concentration was calculated by multiplying the read value by the dilution factor which in this case was 250.

### **3.6.16 Calcium**

Hundred milliliters of the wastewater sample was measured into a conical flask. 2.0 ml NaOH solution was measured and placed into the sample or a volume sufficient to produce pH 12-13. It was mixed and then 2 drops of murexide indicator was added and mixed again.

The sample was titrated with EDTA slowly, with continuous stirring to the proper end-point. The colour changes from red to violet. The end-point was checked by adding 1 to 2 drops of titrant in excess to make certain that no further colour change occurs. The end-point recognition was noted by preparing a colour comparison blank containing 2.0 ml NaOH solution, 2 drops of murexide indicator and sufficient EDTA titrant (0.05-0.10mL) to produce an unchanging colour.

#### *Calculation*

$$\text{Mg Ca/L} = (V \times M \times 40.08) \times 1000 / \text{mL sample}$$

Where

V = mL EDTA titrated

M = Molarity of EDTA

### **3.6.17 Colour**

A Nessler tube was filled to the 50 ml mark with the wastewater sample. The sample was filtered if it was turbid. The tube was then placed in the right-hand compartment



and the left-hand compartment left empty. The Disc NSA was placed in the disc compartment and the light of the Nessleriser switched on. The disc was then rotated to obtain a colour match. Then the colour was read in degree Hazen from the disc.

### **3.6.18 Turbidity**

Twenty five millilitres of the wastewater sample was measured using a measuring cylinder and put into a clean sample cell. The surface of the sample cell was carefully cleaned with tissue paper. The sample cell was placed into the instrument light cabinet and covered with the light shield. Reading for turbidity was obtained in NTU.

*Calculation in case of dilution*

$$\text{Turbidity (NTU)} = A \times (B+C)/C$$

Where

A = NTU found in diluted sample

B = Volume of dilution water

C = Sample volume taken for dilution

### **3.6.19 Determination of Total Coliforms and Faecal Coliforms**

Total and faecal Coliforms were determined using the three-tube Most Probable Number method (MPN) according to standard procedures. Dilutions of  $10^{-1}$ - $10^{-6}$  were prepared in 0.1% buffered peptone water (BPW) (Oxoid) and 1 ml of each dilution inoculated into 5 ml of Minerals Modified Glutamate medium (Oxoid). Tubes showing acid and gas production after incubation for 24 hours at 37 °C for total Coliforms and 44 °C also for faecal Coliforms were confirmed by plating on MacConkey no.3 agar (Oxoid) and typical colonies were examined. Counts were estimated from MPN tables.



### **3.6.20 Determination of Enterococci**

Membrane filtration technique was used in determining Enterococci. Ten millilitres of the wastewater samples were filtered through white, grid-marked, 47 mm diameter, Millipore HA-type, and cellulose filter with a pore size of 0.45  $\mu\text{m}$ . The samples were filtered using a vacuum pump at a pressure of 65 kPa (500mmHg) and a triple glass filtration unit. The filters were placed with the grid side upward on petri dishes of Slanetz and Bartley agar (oxoid) and incubated for 4 hours at 37 °C and for 44 hours at 44 °C. Red, maroon, or pink colonies were counted as presumptive Enterococci. Presumptive colonies were confirmed on MacConkey no. 3 agar (Oxoid). All counts will be expressed as cfu 100 ml.

### **3.6.21 Determination of Metals**

Fifty milliliters of wastewater samples were placed into a 100 ml beaker. Fifteen millilitres of concentrated nitric acid was added to the wastewater sample and the mixture heated until 50 ml of the mixture evaporates. The mixture was allowed to cool and an additional 5 ml of concentrated nitric acid was added and then heated again until 15 ml of the mixture was left. The sides of the beaker were washed with distilled water and the solution was transferred into a 100 ml volumetric flask.

### **3.6.22 Instrumental Analysis**

Metal samples were analysed using the Atomic Absorption Spectrophotometer (AAS). The device was first calibrated using recommended standard solutions and distilled water as blank. Filtrates were aspirated, sprayed into fine aerosol and converted into



atomic vapour in a chamber aligned to the optical path of a spectrophotometer designed with a Hollow Cathode Electrode made of the element to be determined.

### **3.7 ANALYSIS OF RESULTS / DATA**

A summary of the wastewater analytical results of the study are given in Table 4.6 to 4.14 for physicochemical, metals and microbiological parameters. The mean value of each parameter considered for the various sampling times have been computed and tabulated. Raw data for total Coliforms, faecal Coliforms, Enterococci and E-coli were transformed by adding a value of one to all scores in order to eliminate zero data points, and then each datum was converted to  $\log_{10}$ . Plots of the mean water quality data for the influent, effluent and sand filter wastewater as well as EPA Ghana guideline for the various parameters considered were also plotted. The percentage reduction for the effluent treatment plant and that of the sand filter are given in Table 4.3 and 4.4 respectively. Treatment of the influent wastewater using the sand filter is also given in Table 4.5 as well as its percentage reduction. Statistical analysis were performed using data analysis tool of Microsoft Excel and were, presented in terms of mean, percentage, standard deviations and standard errors

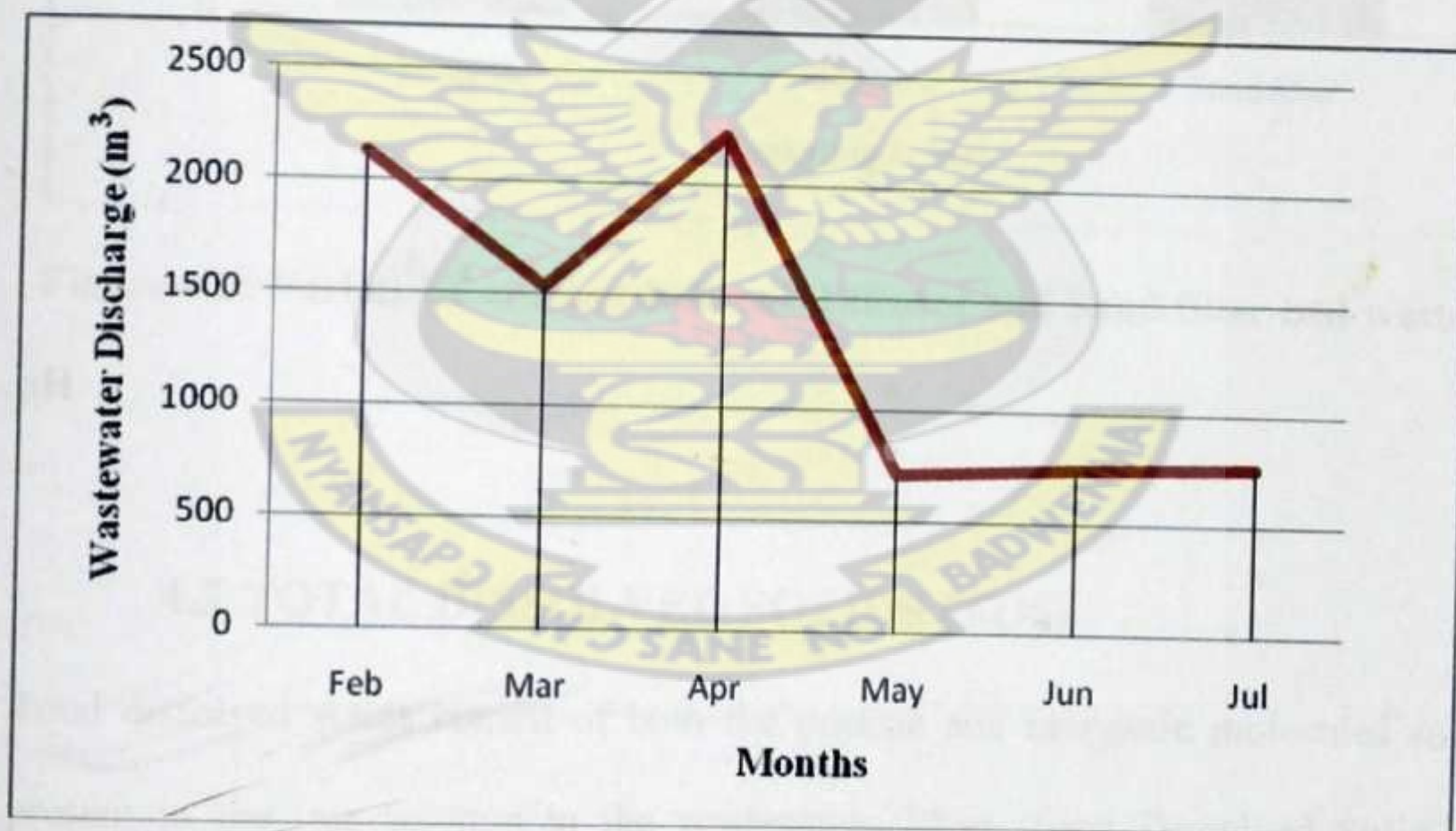


## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 VOLUME OF WASTE WATER DISCHARGE DURING THE SIX MONTH PERIOD

The highest average monthly wastewater discharge during the six month study occurred in April followed by February and March (Figure 4.1). The lowest volume of wastewater discharge occurred from May to July; but increased from March to April, which coincides with the Easter festive season when production peaks as a result of increased demand for the product (Table A.1 and Figure 4.1).



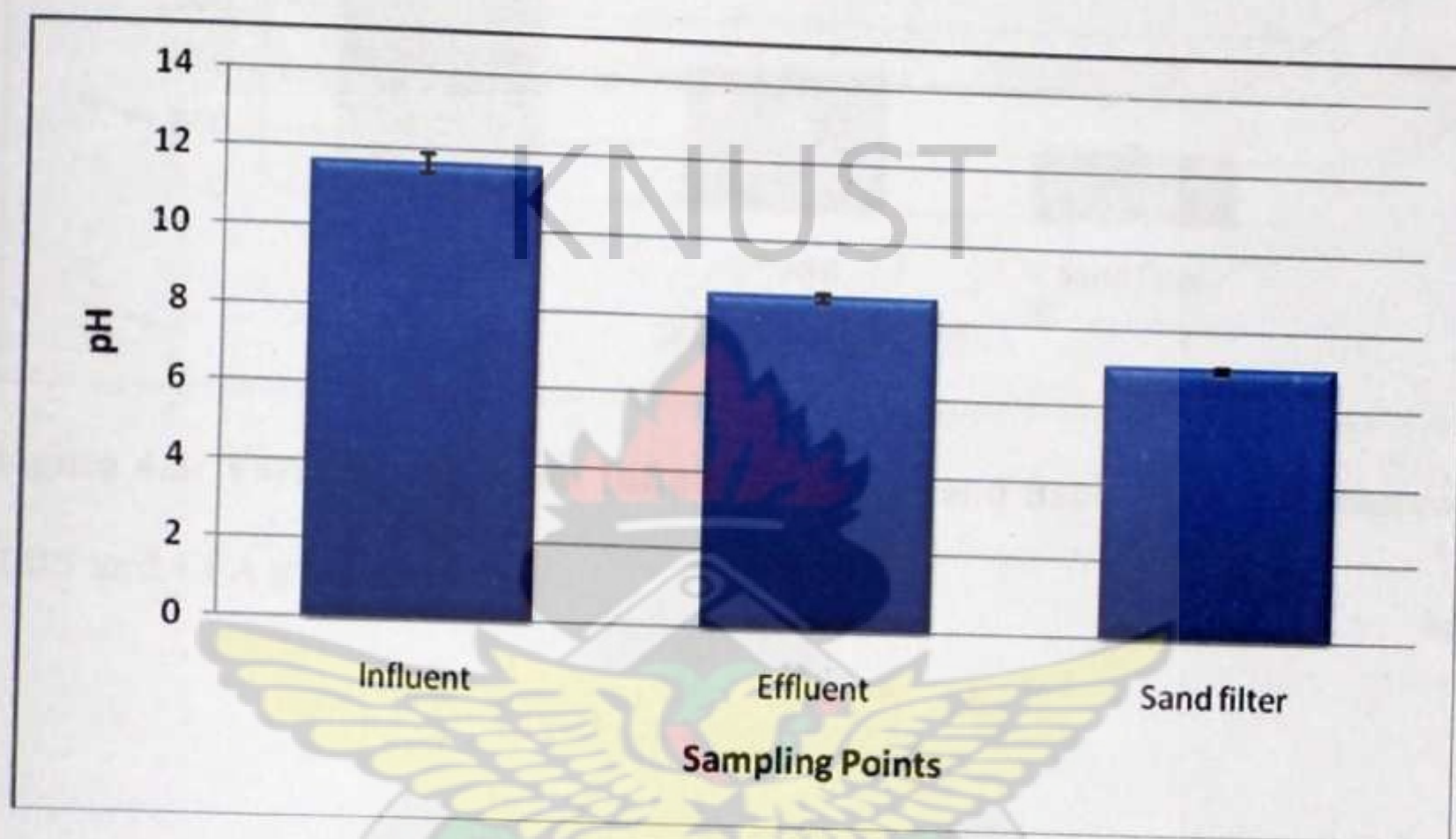
**Figure 4.1: Mean monthly Wastewater discharge during the six month period**

#### 4.2 pH

Over the six month study period, mean influent wastewater was alkaline.11.67 and ranged between 9.55 and 12.50 (Figure 4.2). Mean effluent wastewater pH was less



alkaline, 8.57 and ranged between 8.05 and 9.10. However, outflows from the sand filter bed recorded a mean pH of 7.00 and ranged from 6.60 to 7.30. Both the mean effluent wastewater and the outflows from the sand filter bed were all within EPA Ghana guideline range of 6 to 9.

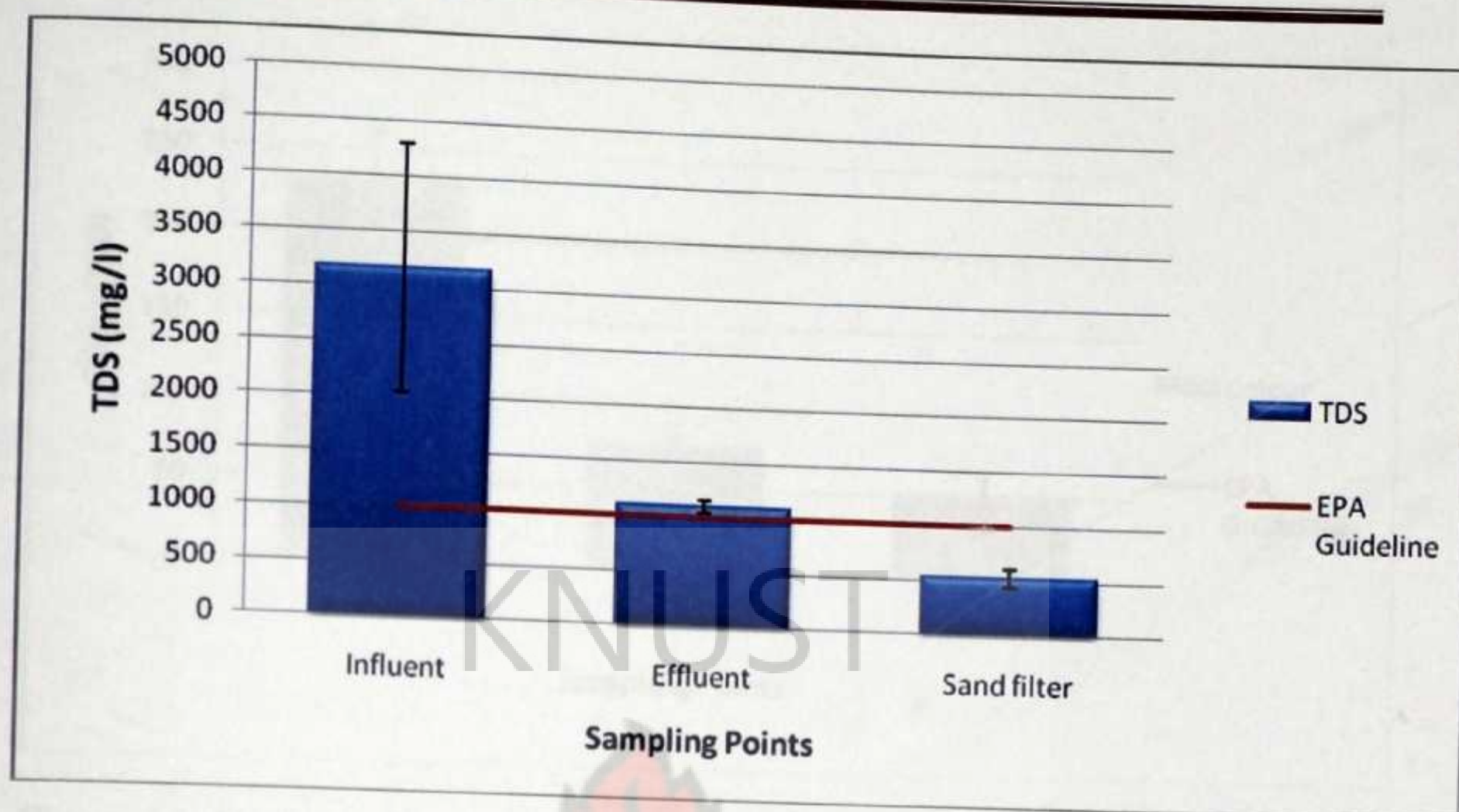


**Figure 4.2: Variations in mean Influent, Effluent and Sand filter bed wastewater pH**

### **4.3 TOTAL DISSOLVED SOLIDS (TDS)**

Total dissolved solids consist of both the organic and inorganic molecules and ions present in the true solution in the wastewater. Mean Total Dissolved Solid in the influent wastewater was 3170.0 mg/l. but decreased to 1105.5 mg/l in the effluent and further down to 529.9 mg/l in outflows from the sand filter bed (Figure 4.3). Both average influent and effluent TDS exceeded the EPA Ghana guideline of 1000 mg/l for beverage industrial effluent discharged into water bodies.



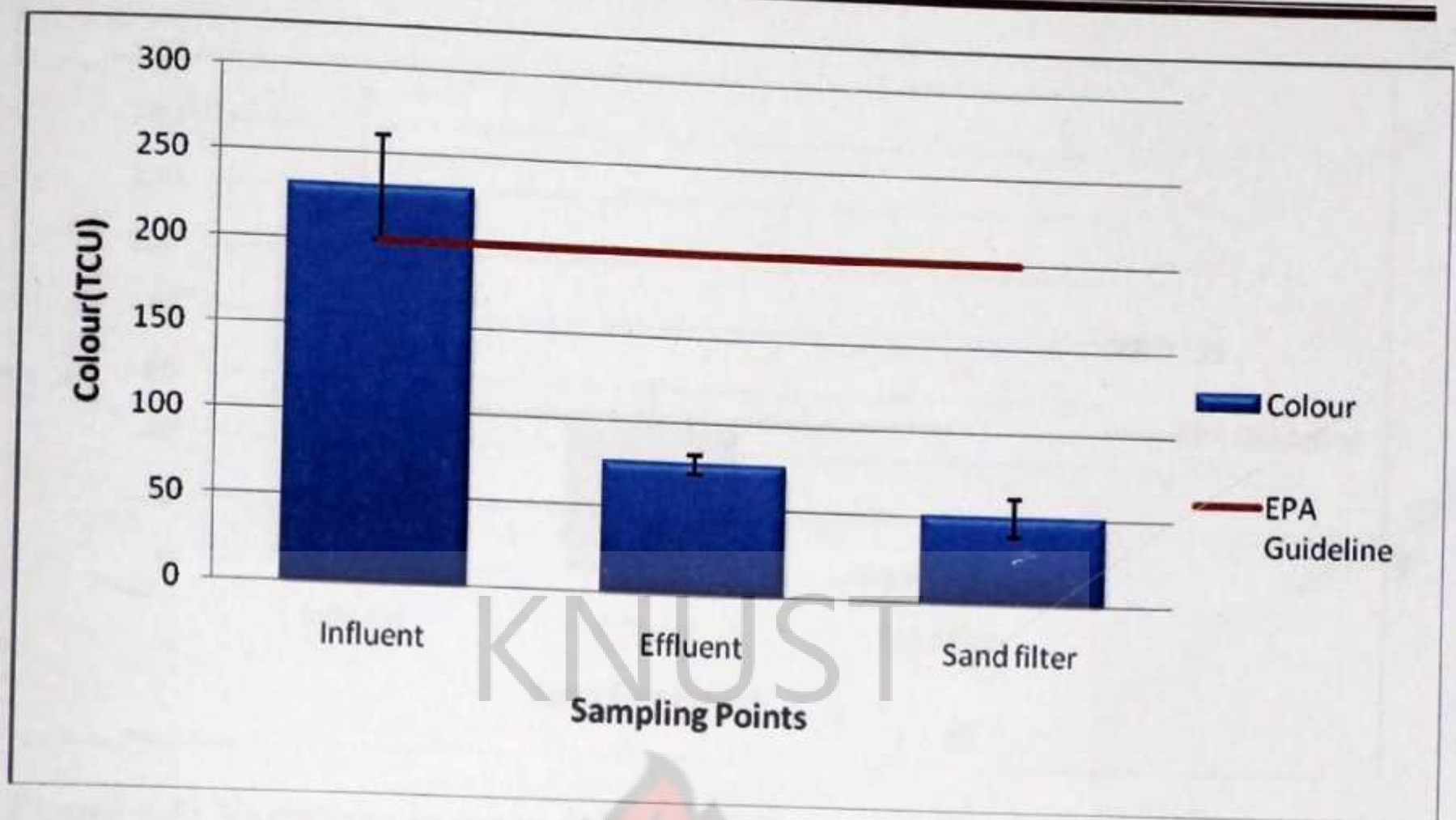


**Figure 4.3: Variations in mean Influent, Effluent and Sand filter bed wastewater TDS and EPA guideline**

#### **4.4 COLOUR**

Various industrial processing activities such as cleaning and bottle washing impact considerable amount of colour to water. Mean colour value for the influent, effluent and the sand filter bed wastewater were 230.75, 76.13 and 50.70 TCU, respectively (Figure 4.4). The effluents from the treatment plant were within the recommended limit of EPA Ghana guideline for discharges into receiving water bodies.



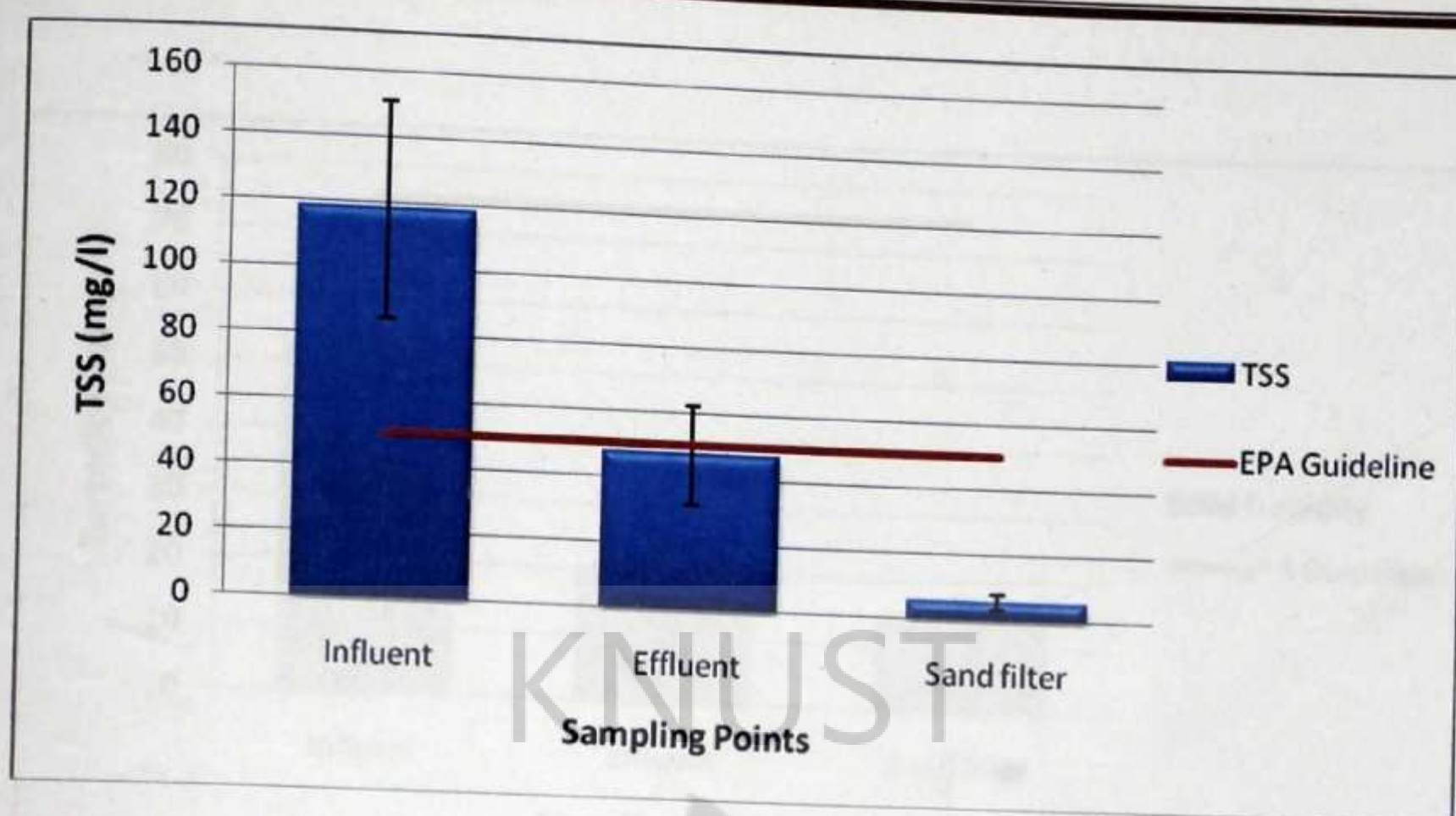


**Figure 4.4: Variations in mean Influent, Effluent and Sand filter bed wastewater Colour and EPA guideline**

#### **4.5 TOTAL SUSPENDED SOLIDS (TSS)**

From figure 4.5 the Mean influent and effluent TSS values were 118.0 and 47.3 mg/l (Figure 4.5). However, the mean TSS concentration for the sand filter bed was considerably low (5.49 mg/l). Total suspended solids concentration of the effluent and the sand filter bed recorded high values during the peak season of production. However further treatment of the effluent using the sand filter bed recorded the lowest average results due to the effective nature of the sand filter bed, thus making it compliant with the EPA Ghana Permissible guideline of <50 mg/l (Figure 4.5).





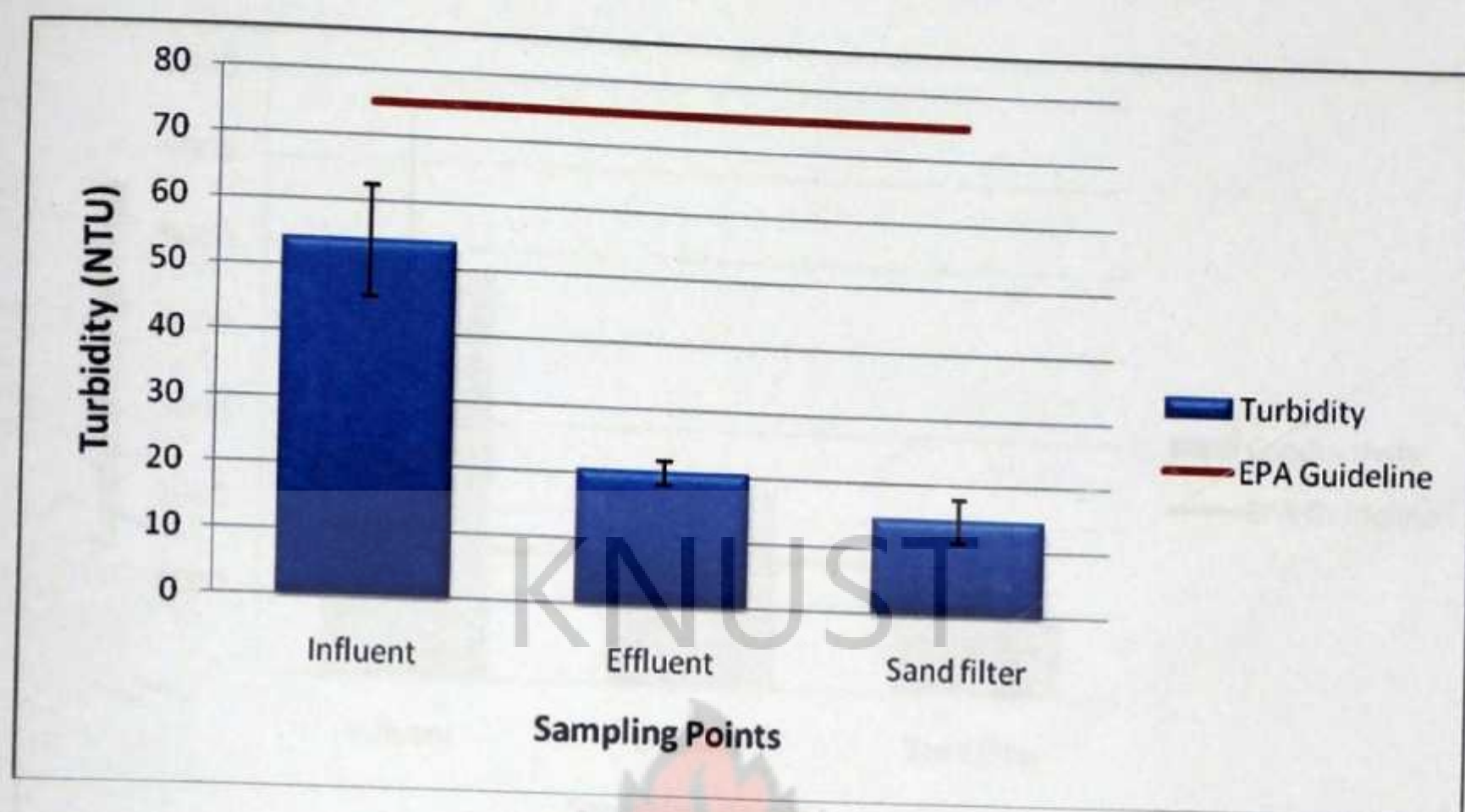
**Figure 4.5: Variations in mean Influent, Effluent and Sand filter bed wastewater TSS and EPA guideline**

#### **4.6 TURBIDITY**

Turbidity, a measure of the light transmitting properties of water, indicates the quality of wastewater discharges with respect to colloidal and residual suspended matter. High levels of turbidity in industrial effluents contribute large amounts of suspended solids to receiving water bodies.

The mean influent turbidity value recorded in this study was 53.95 NTU (Figure 4.6). The effluent turbidity was lower, ranging between 29.8 NTU to 19.00 NTU with an average of 20.35 NTU. The mean sand filter bed turbidity was even lower, 14.53 NTU and ranged from 38 NTU to 4.3 NTU. The sand filter and most effluents values were below the EPA Ghana guideline value of 75 NTU. High turbidity values were recorded for the effluent and sand filter during the fourth sampling period which coincided with the peak production season.



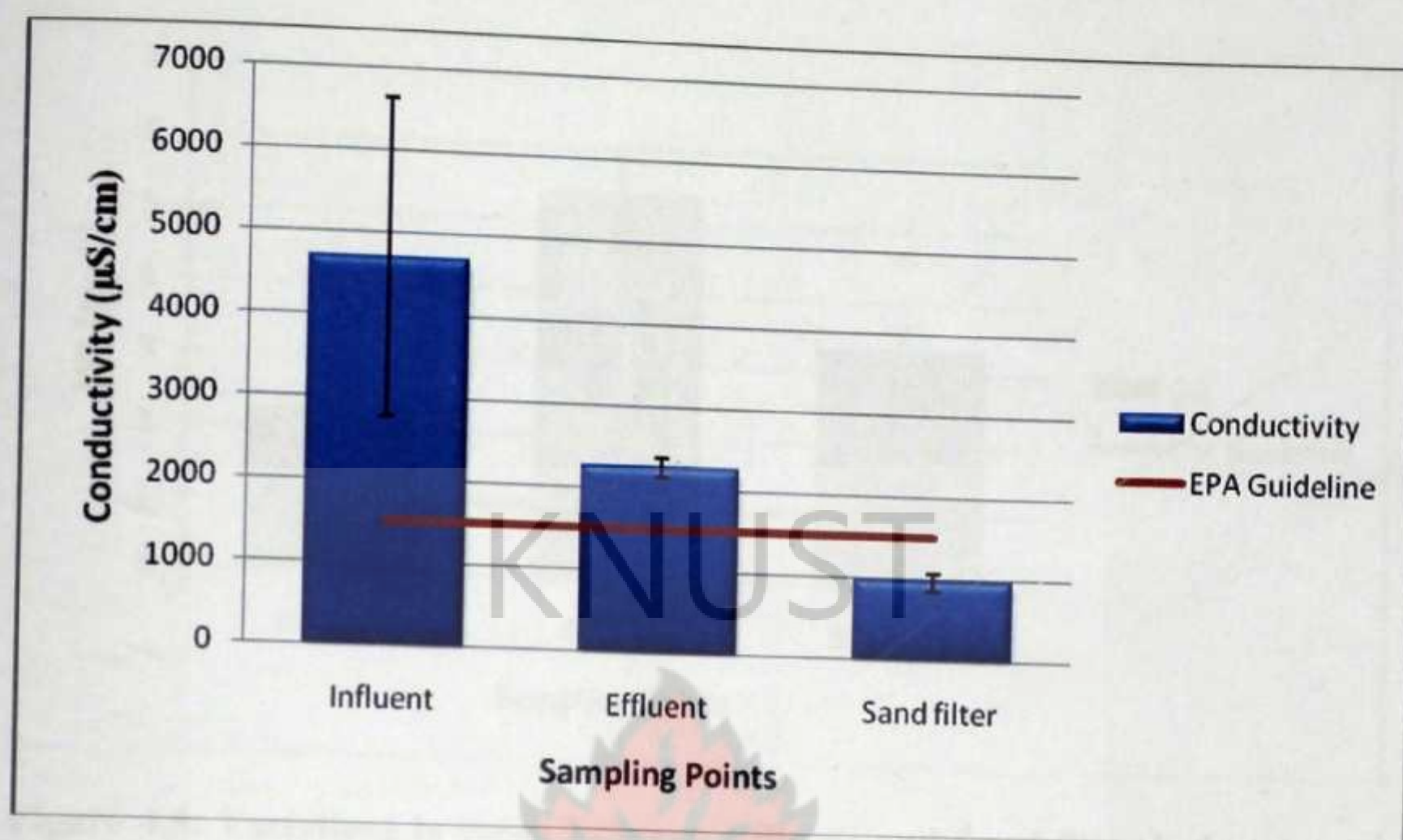


**Figure 4.6: Variations in mean Influent, Effluent and Sand filter bed wastewater Turbidity and EPA guideline**

#### **4.7 CONDUCTIVITY**

Generally, conductivity informs us of the ability of the waters to conduct electrical current. The mean influent conductivity value was 4690.5  $\mu\text{S}/\text{cm}$  and ranged from 22000  $\mu\text{S}/\text{cm}$  to 2440  $\mu\text{S}/\text{cm}$ . Similarly, the mean effluent conductivity was 2267.2  $\mu\text{S}/\text{cm}$  and ranged from 2650  $\mu\text{S}/\text{cm}$  to 1585  $\mu\text{S}/\text{cm}$ . However, the final mean sand filter bed was lower, 963.2  $\mu\text{S}/\text{cm}$  and ranged from 1702  $\mu\text{S}/\text{cm}$  to 650  $\mu\text{S}/\text{cm}$ . Further treatment of the effluent using the sand filter recorded a 57.52% removal (Figure 4.7).



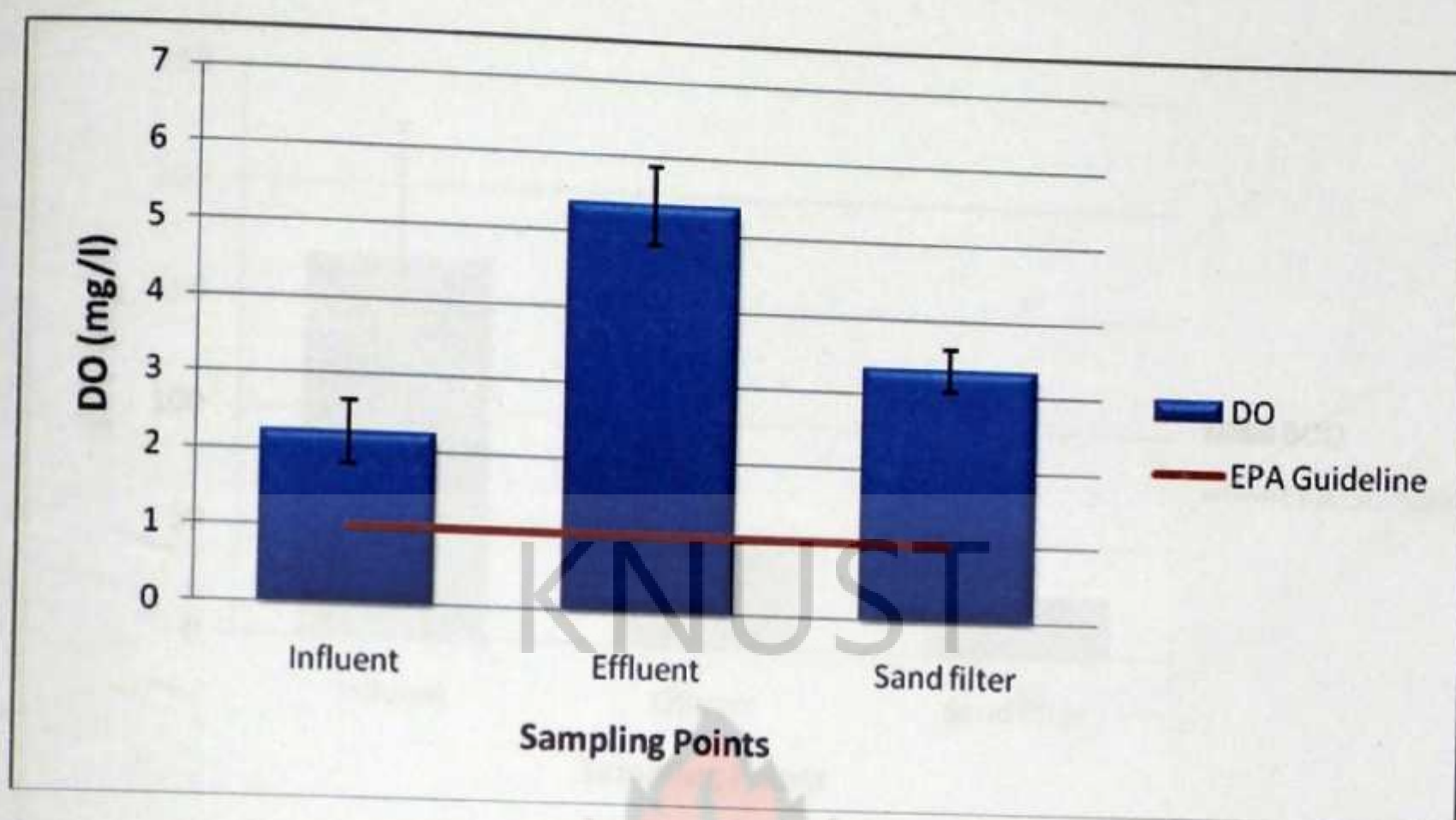


**Figure 4.7: Variations in mean Influent, Effluent and Sand filter bed wastewater Conductivity and EPA guideline**

#### **4.8 DISSOLVED OXYGEN (DO)**

Dissolved oxygen is required for the respiration of aerobic microorganism as well as all other aerobic life forms. Mean influent DO was 2.24 mg/l and ranged from 5.29 mg/l to 0.82 mg/l. Mean effluent DO were higher, 5.37 mg/l, and ranged from 8.1 mg/l to 2.62 mg/l. However, this reduced in the sand filter bed to a mean of 3.33 mg/l (Figure 4.8).



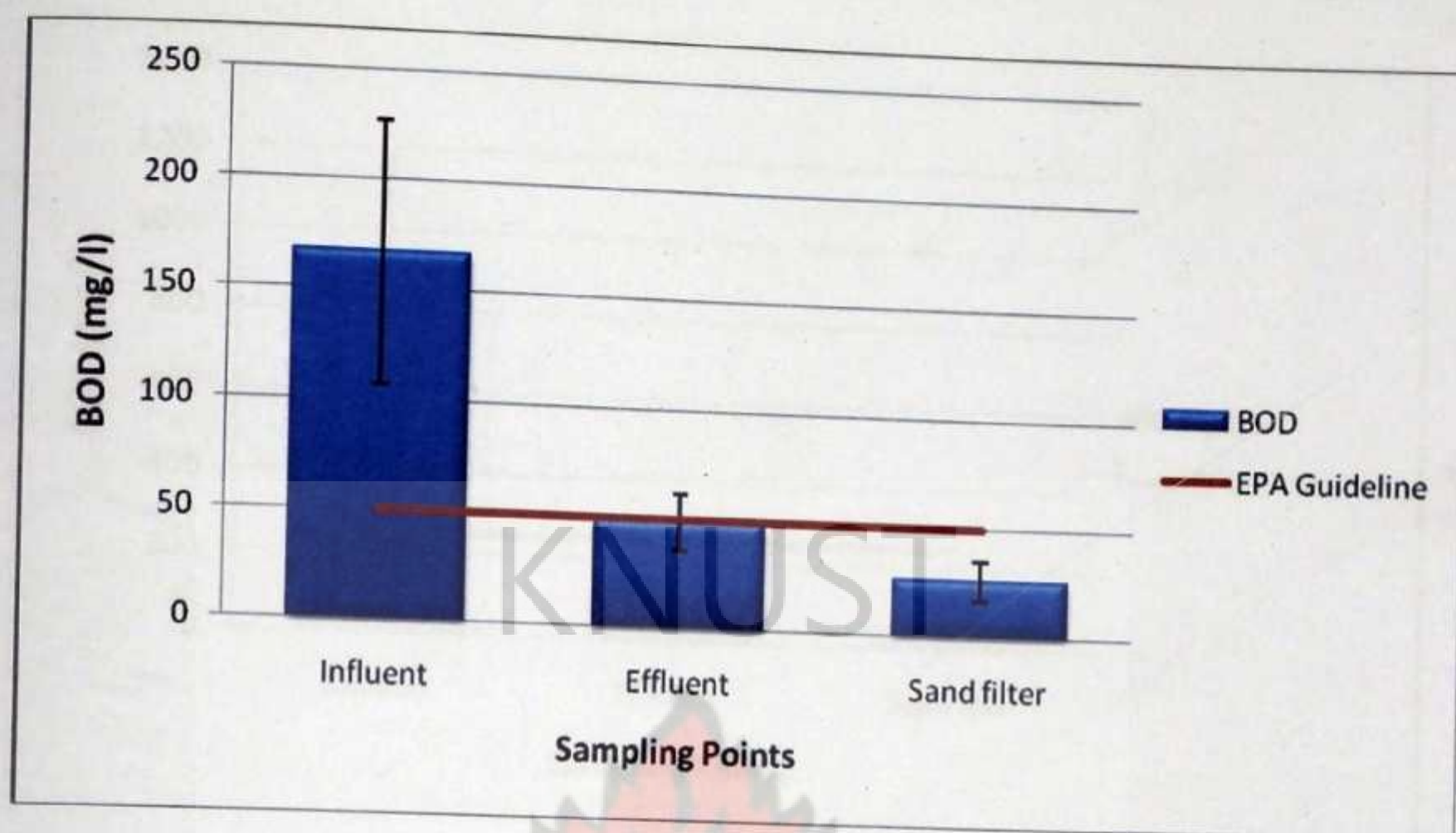


**Figure 4.8: Variations in mean Influent, Effluent and Sand filter bed wastewater DO and EPA guideline**

#### **4.9 BIOCHEMICAL OXYGEN DEMAND (BOD<sub>5</sub>)**

The influent BOD concentration of the treatment plant ranged from 690 mg/l to 27 mg/l, with a mean of 167.2 mg/l. However, mean effluent BOD concentration was 48.7 mg/l and ranged from 130 mg/l to 12 mg/l. The sand filter bed BOD concentration was low, 26.4 mg/l and ranged from 90 mg/l to 6.2 mg/l (Figure 4.9).



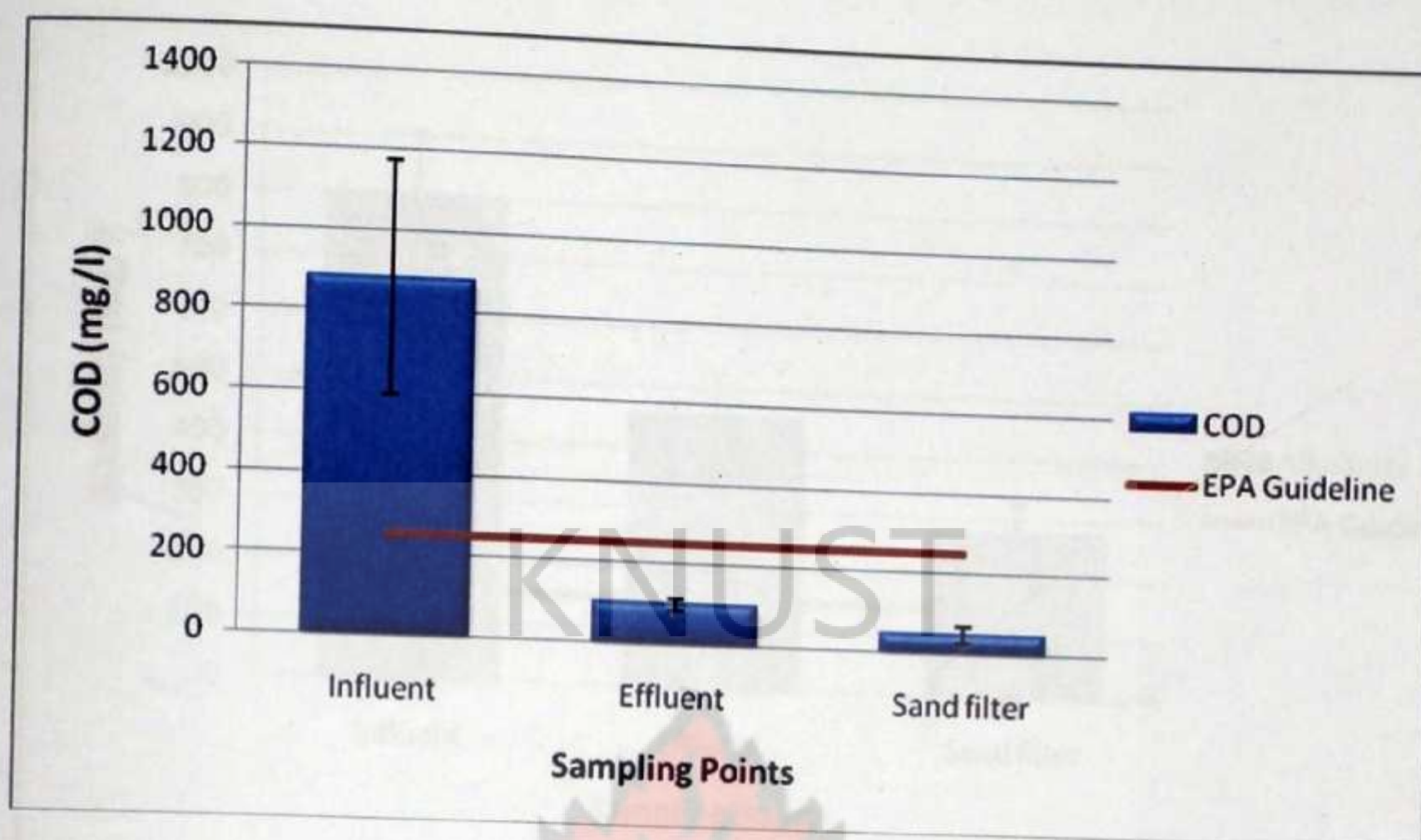


**Figure 4.9: Variations in mean Influent, Effluent and Sand filter bed wastewater BOD and EPA guideline**

#### **4.10 CHEMICAL OXYGEN DEMAND (COD)**

The mean influent, effluent and that from the sand filter bed COD were 883.2 mg/l, 98.3 mg/l and 46 mg/l respectively. The mean COD value for both effluent and sand filter values meet the EPA Ghana guideline value of 250 mg/l; the sand filter was able to reduce the treated effluent further (Figure 4.10).





**Figure 4.10: Variations in mean Influent, Effluent and Sand filter bed wastewater COD and EPA guideline**

#### **4.11 ALKALINITY**

Alkalinity in wastewater results from the presence of the hydroxides, carbonates and bicarbonates of elements such as calcium, magnesium, sodium and potassium. The mean influent Alkalinity value was 801.2 mg/l but halved to 456.1 mg/l in the effluent and further reduced to 276.3 mg/l in the sand filter bed (Figure 4.11).



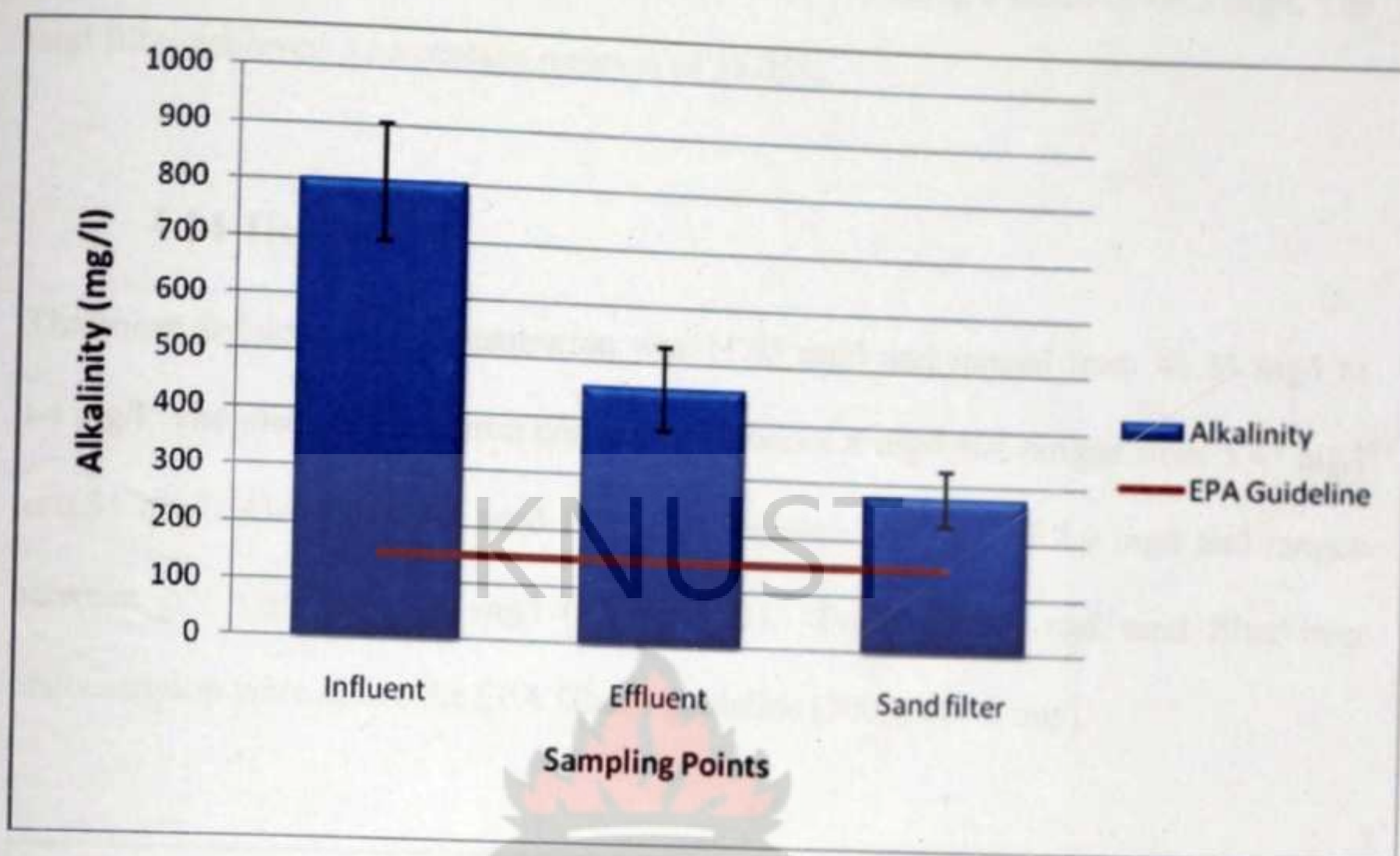


Figure 4.11: Variations in mean Influent, Effluent and Sand filter bed wastewater Alkalinity and EPA guideline

#### 4.12 PHOSPHORUS

Phosphorus concentrations were generally low varying from 0.88 mg/l. in the influent to 1.9 mg/l in the effluent and 1.30 mg/l in the sand filter bed. The concentration of both effluent and sand filter phosphorus did not change much and were all within the EPA Ghana guideline value of  $< 2$  mg/l, however The sand filter achieved a percentage removal of 31.58%.

#### 4.13 SULPHATES

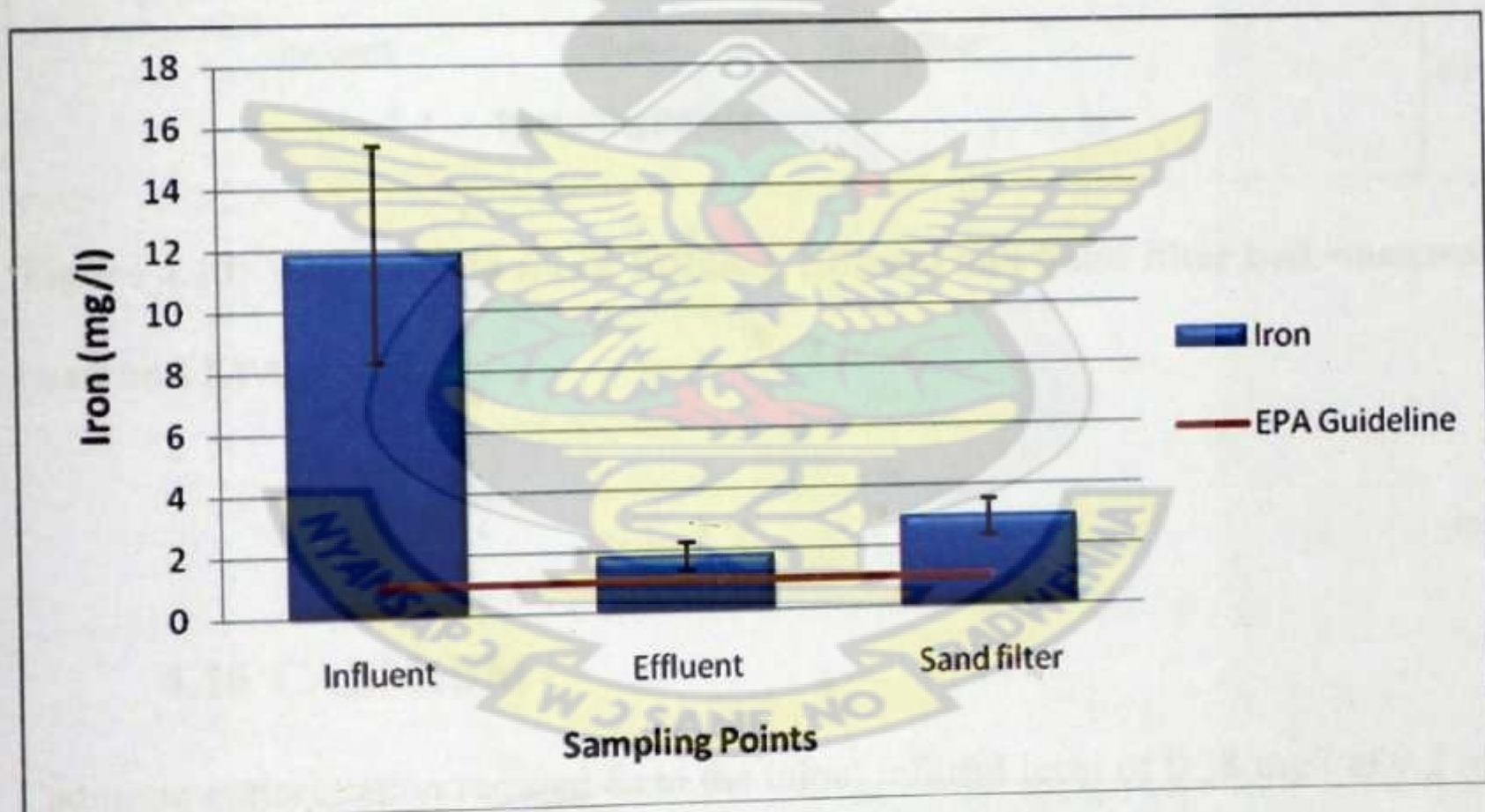
Sulphate concentration in both the effluent and sand filter bed were within the EPA Ghana guideline of 250 mg/l as it varied from 54.7 mg/l in the influent, 61.6 mg/l in the



effluent. They were slightly lower in the sand filter recording a mean of 46.3 mg/l. The sand filter achieved a percentage removal of 33.05%.

#### 4.14 IRON

The mean influent iron concentration was 11.85 mg/l and ranged from 41.53 mg/l to 0.4 mg/l. The mean effluent iron concentration was 1.8 mg/l and ranged from 5.43 mg/l to 0.31 mg/l. Also the mean sand filter iron registered a mean of 2.9 mg/l and ranges between 6.9 mg/l to 0.008 mg/l (Figure 4.12). Both effluent and sand filter iron concentration were above the EPA Ghana guideline (2000) of <1 mg/l.



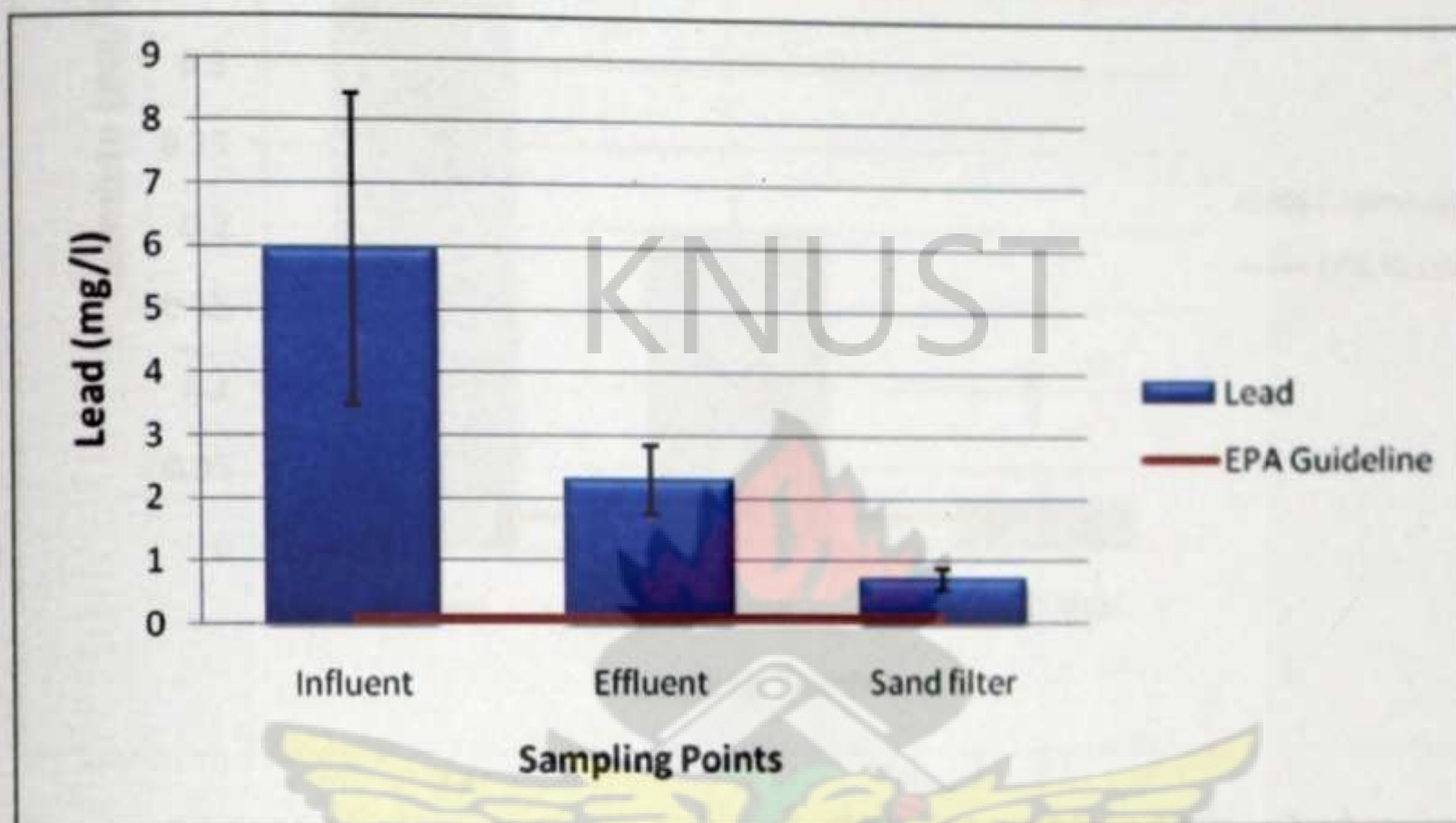
**Figure 4.12: Variations in mean Influent, Effluent and Sand filter bed wastewater Iron and EPA guideline**

#### 4.15 LEAD

The mean influent, effluent, and sand filter bed lead concentrations of 5.95 mg/l, 2.29 mg/l and 0.71 mg/l, respectively obtained during the sampling period were outside the



EPA Ghana set guideline (2000) of 0.1mg/l (Figure 4.13). The percentage removal of lead by the sand filter bed was 69 percent.

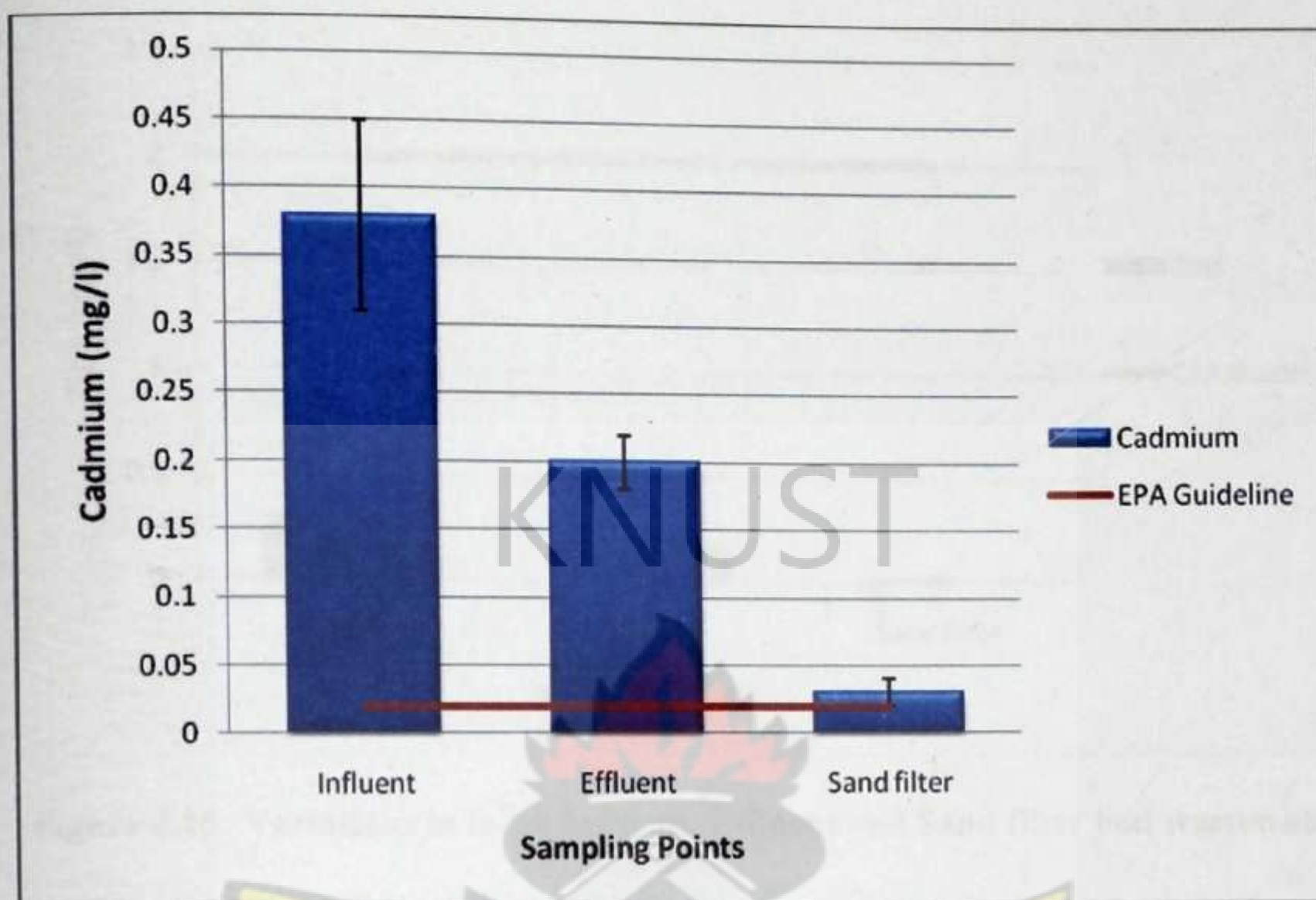


**Figure 4.13: Variations in mean Influent, Effluent and Sand filter bed wastewater Lead and EPA guideline**

#### **4.16 CADMIUM**

Cadmium concentration reduced from the initial influent level of 0.38 mg/l to 0.2 mg/l in the effluent and further down to 0.03 mg/l in the sand filter bed (Figure 4.14). The quality is unacceptable according to the EPA Ghana guideline (2000).





**Figure 4.14: Variations in mean Influent, Effluent and Sand filter bed wastewater Cadmium and EPA guideline**

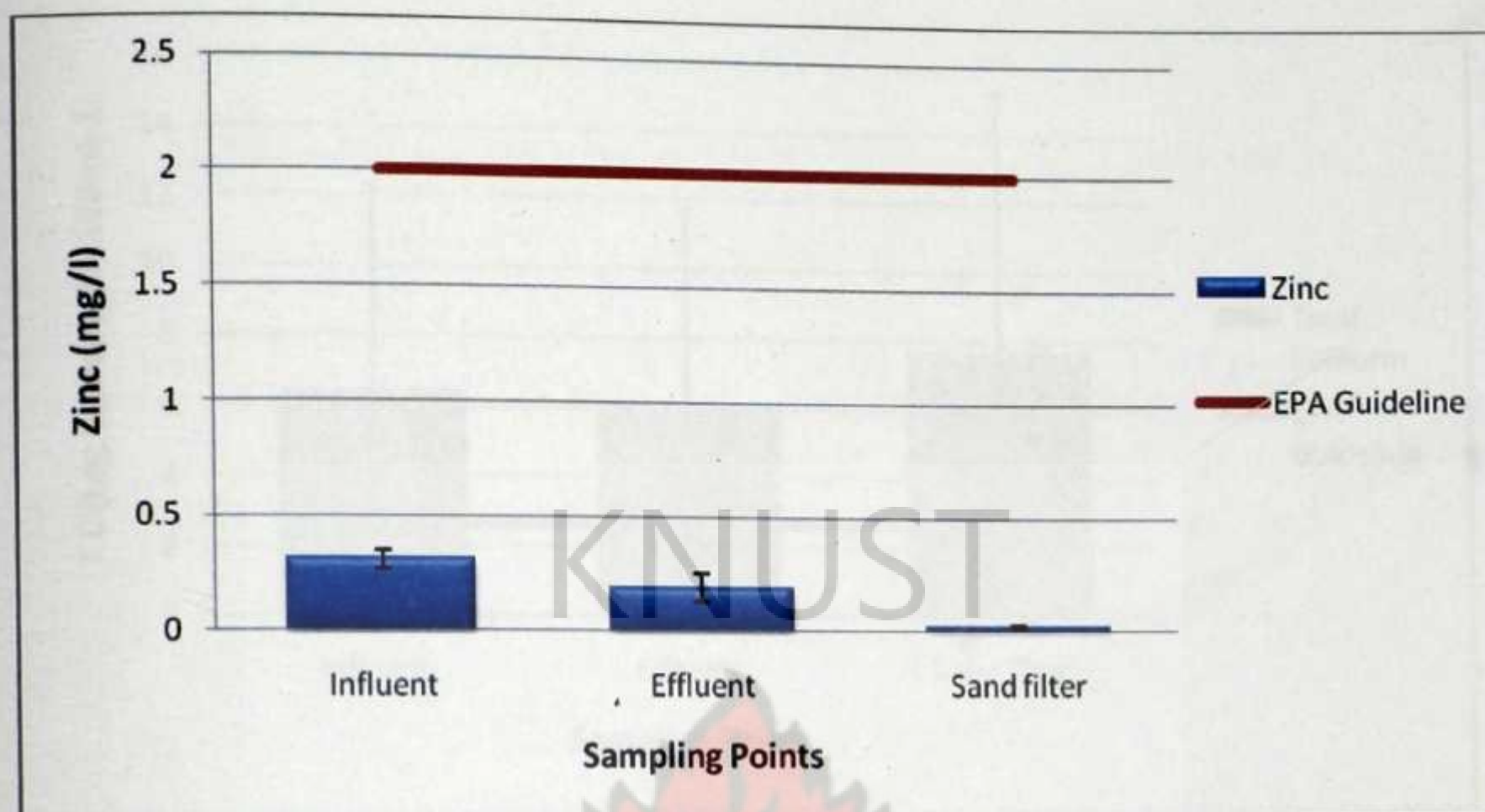
#### **4.17 COPPER**

The mean influent copper concentration ranged from 0.55 mg/l to 0.07 mg/l with an average of 0.56 mg/l. However, mean effluent copper concentration was slightly lower, 0.39 mg/l and ranged from 1.9 mg/l to 0.03 mg/l. Similarly mean sand filter copper concentration ranged from 0.62 mg/l to 0.01 mg/l and registered an average of 0.33 mg/l.

#### **4.18 ZINC**

Mean concentration of zinc in the influent was 0.31 mg/l, 0.19 mg/l in the effluent and 0.02 mg/l in the sand filter bed.





**Figure 4.15: Variations in mean Influent, Effluent and Sand filter bed wastewater Zinc and EPA guideline**

#### **4.19 TOTAL COLIFORMS AND FAECAL COLIFORMS**

Reduction in total coliform numbers along the treatment line was gradual; reducing from a mean of  $2.4 \times 10^6$  counts/100 ml for the influent wastewater and  $9.7 \times 10^5$  counts/100 ml in the effluent. However, numbers went up again in the sand filter bed to  $5.2 \times 10^7$  counts/100 ml (Figure 4.16). Faecal Coliform numbers were lower ranging from  $9.9 \times 10^5$  counts/100 ml in the influent to  $5.1 \times 10^5$  counts/100 ml in the effluent and down to  $9.6 \times 10^4$  counts/100 ml for the sand filter bed. The effluent treatment registered a percentage reduction of 48.48% whilst the sand filter bed further reduced the faecal coliforms by 81.18 %.( Figure 4.17).



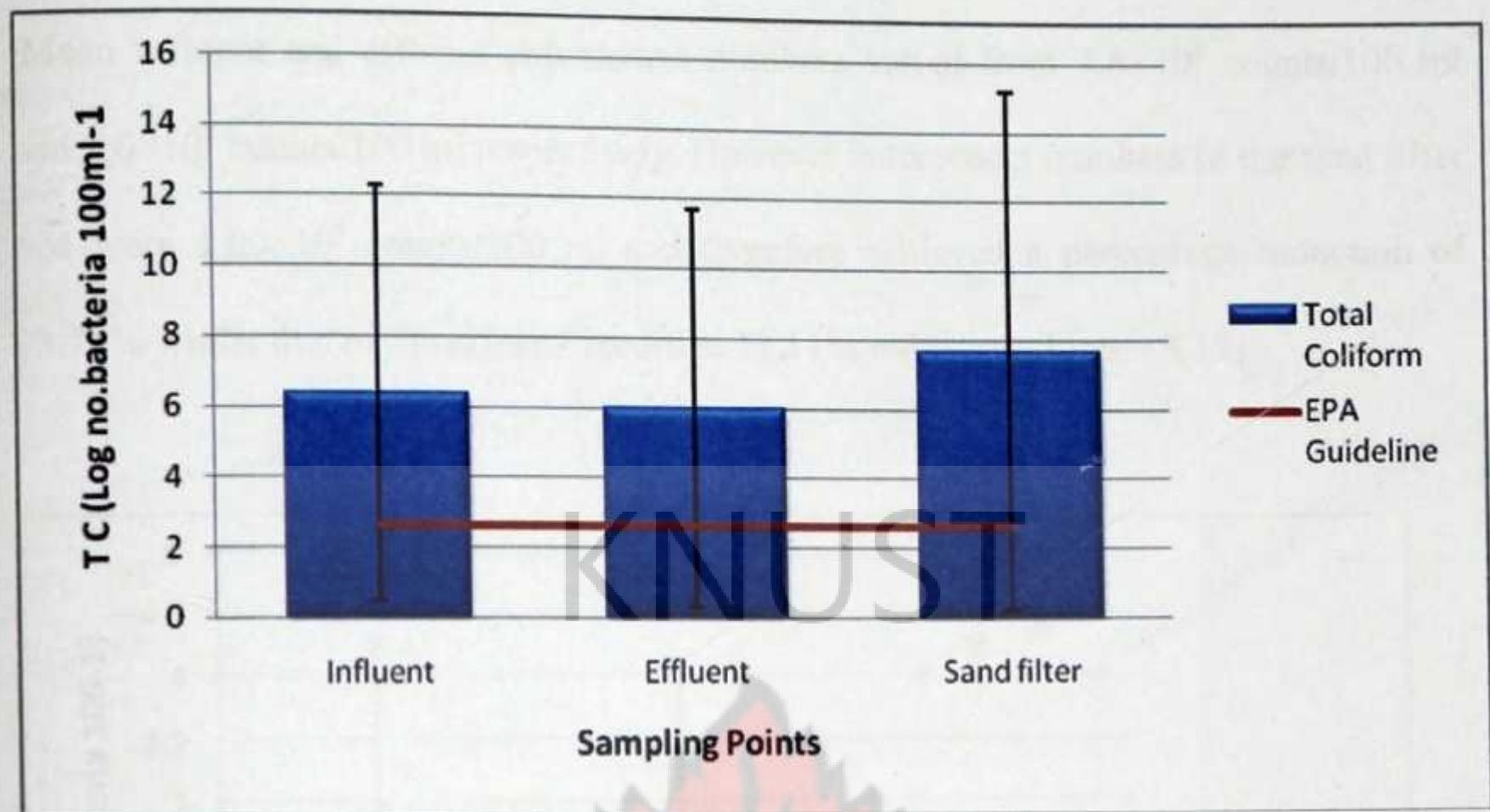


Figure 4.16: Variations in mean Influent, Effluent and Sand filter bed wastewater Total Coliform and EPA guideline

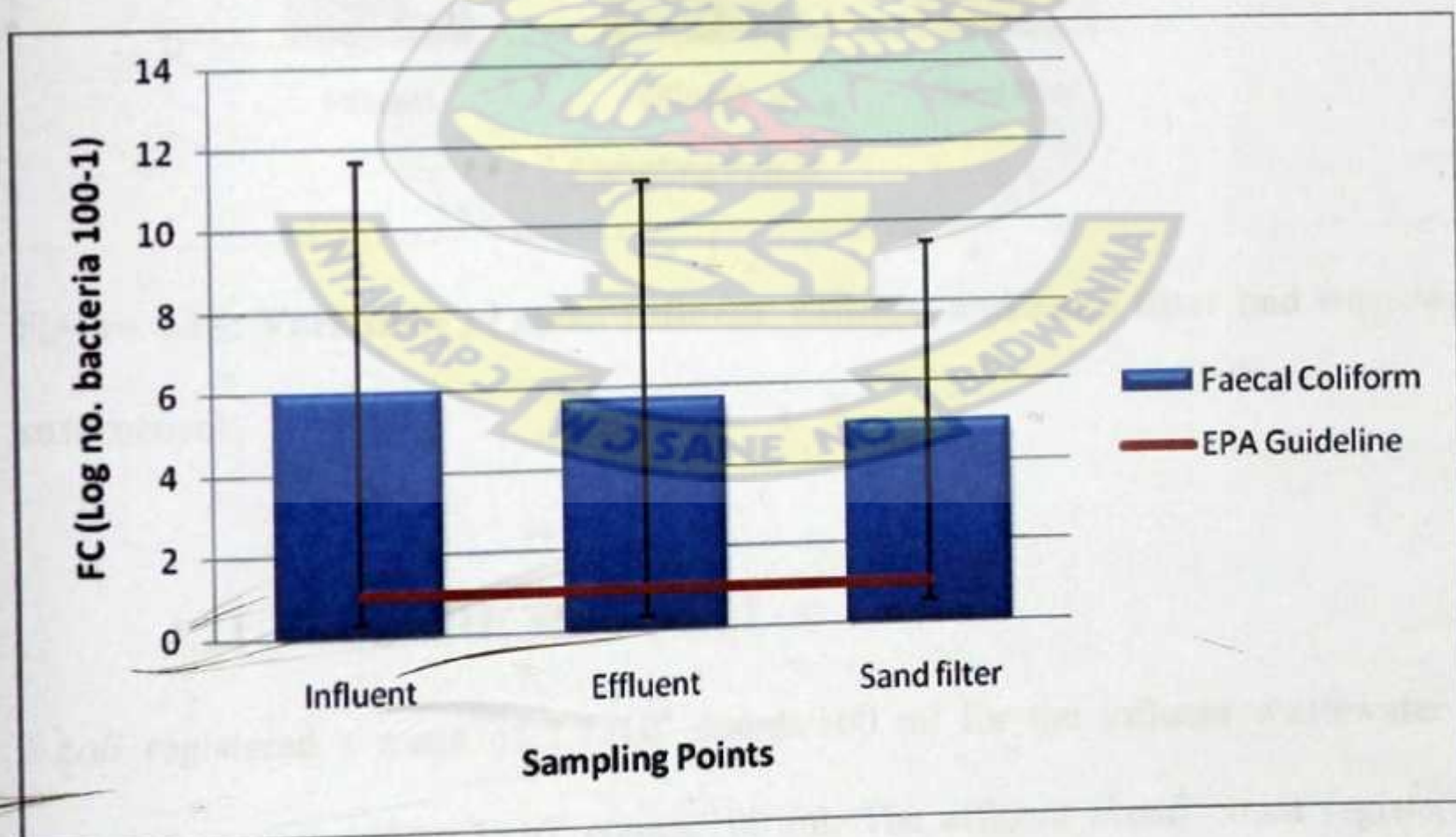


Figure 4.17: Variations in mean Influent, Effluent and Sand filter bed wastewater Faecal Coliform and EPA guideline



## 4.20 ENTEROCOCCI

Mean influent and effluent enterococci numbers varied from  $1.8 \times 10^2$  counts/100 ml and  $1.6 \times 10^2$  counts/100 ml respectively. However enterococci numbers in the sand filter bed were  $1.00 \times 10^1$  counts/100 ml and therefore achieved a percentage reduction of 93.75% whilst that of the effluent recorded 11.11% reduction (Figure 4.18).

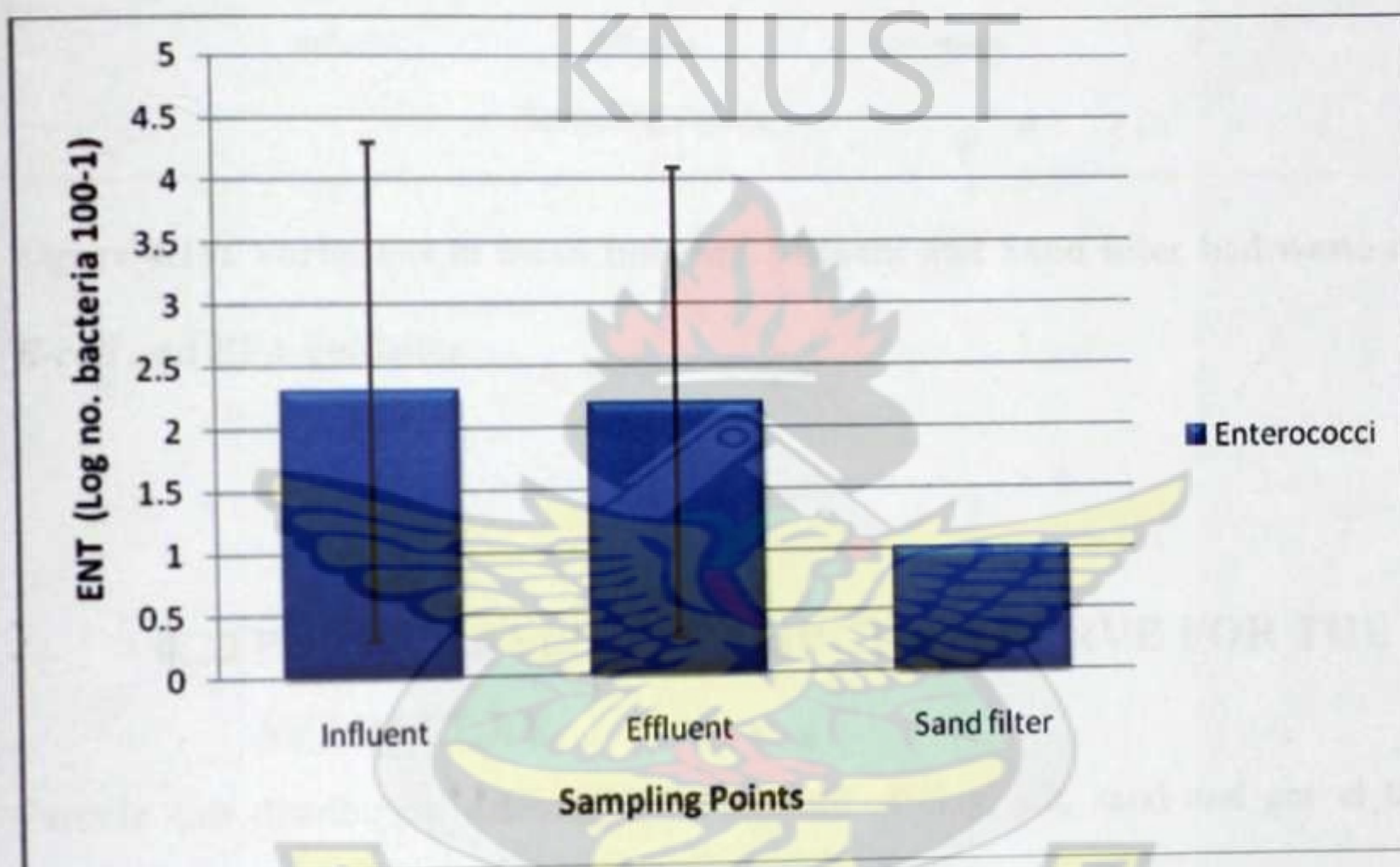
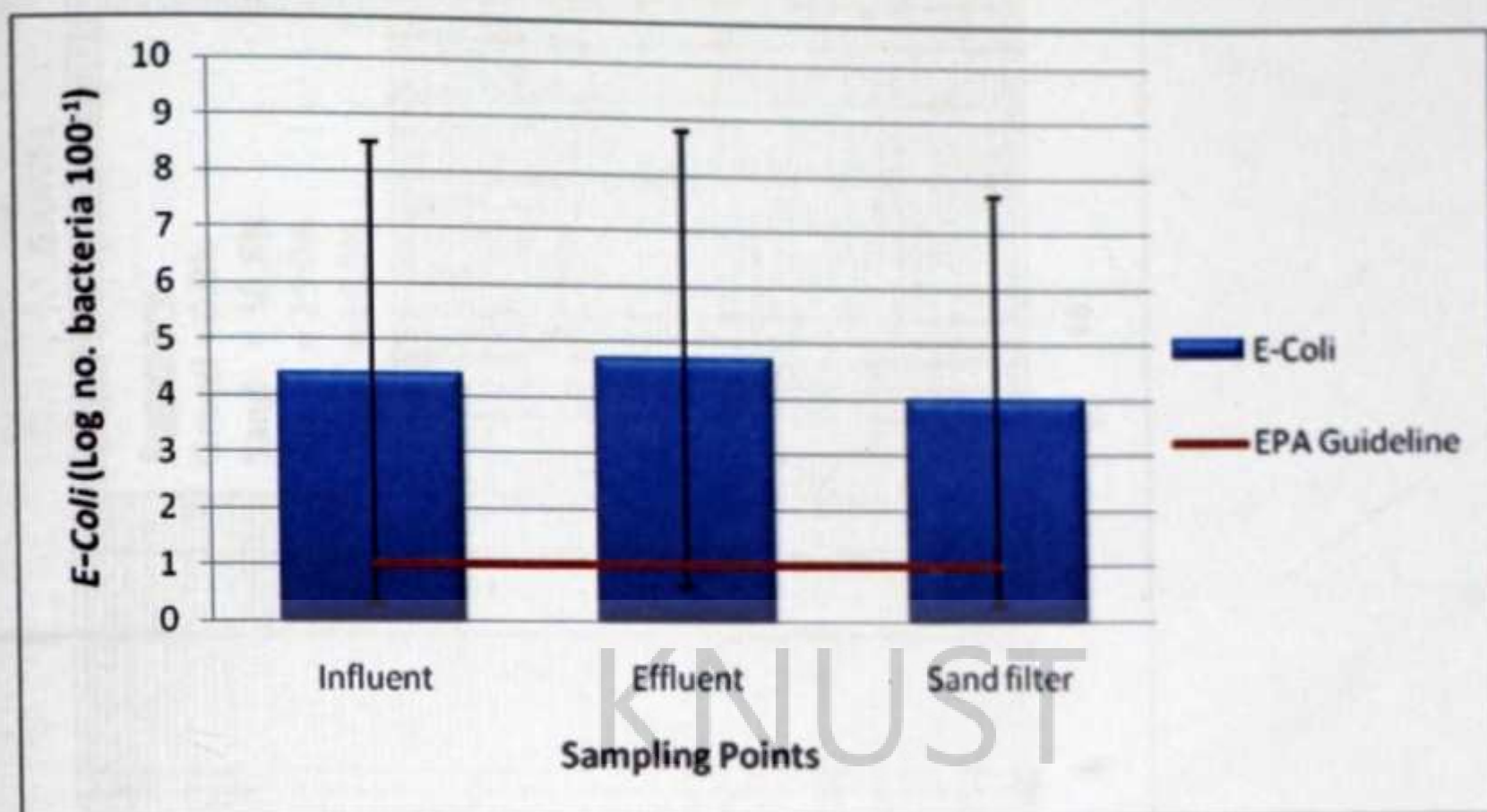


Figure 4.18: Variations in mean Influent, Effluent and Sand filter bed wastewater enterococci

## 4.21 ESCHERICHIA COLI

*E.coli* registered a mean of  $2.7 \times 10^4$  counts/100 ml for the influent wastewater and ranged from  $9.8 \times 10^4$  to  $1 \times 10^1$  counts/100 ml. The effluent *E.coli* count registered a mean of  $5.5 \times 10^4$  counts/100 ml and ranged from  $9.8 \times 10^4$  to  $0.4 \times 10^3$  counts/100 ml. The sand filter also registered a mean of  $1.1 \times 10^4$  counts/100ml and ranged from  $3.35 \times 10^4$  to  $1 \times 10^1$  counts/100 ml (Figure 4.19).





**Figure 4.19: Variations in mean Influent, Effluent and Sand filter bed wastewater *E-coli* and EPA guideline**

#### 4.22 PARTICLE SIZE DISTRIBUTION CURVE FOR THE AFARI CLAY

Particle size distribution determines the amount of clay, silt, sand and gravel that a particular soil sample contains. The particle size distribution curve of the Afari clay used for the sand filter bed was found to contain some amount of sand, silt and clay and recorded a percentage of 38.5, 25.0 and 36.5 respectively with sand being the dominant. The clay passes through a sieve size of 0.002 mm, 0.002- 006 for silt and 0.06 - 0.2 mm for sand which is the finest soil particle.



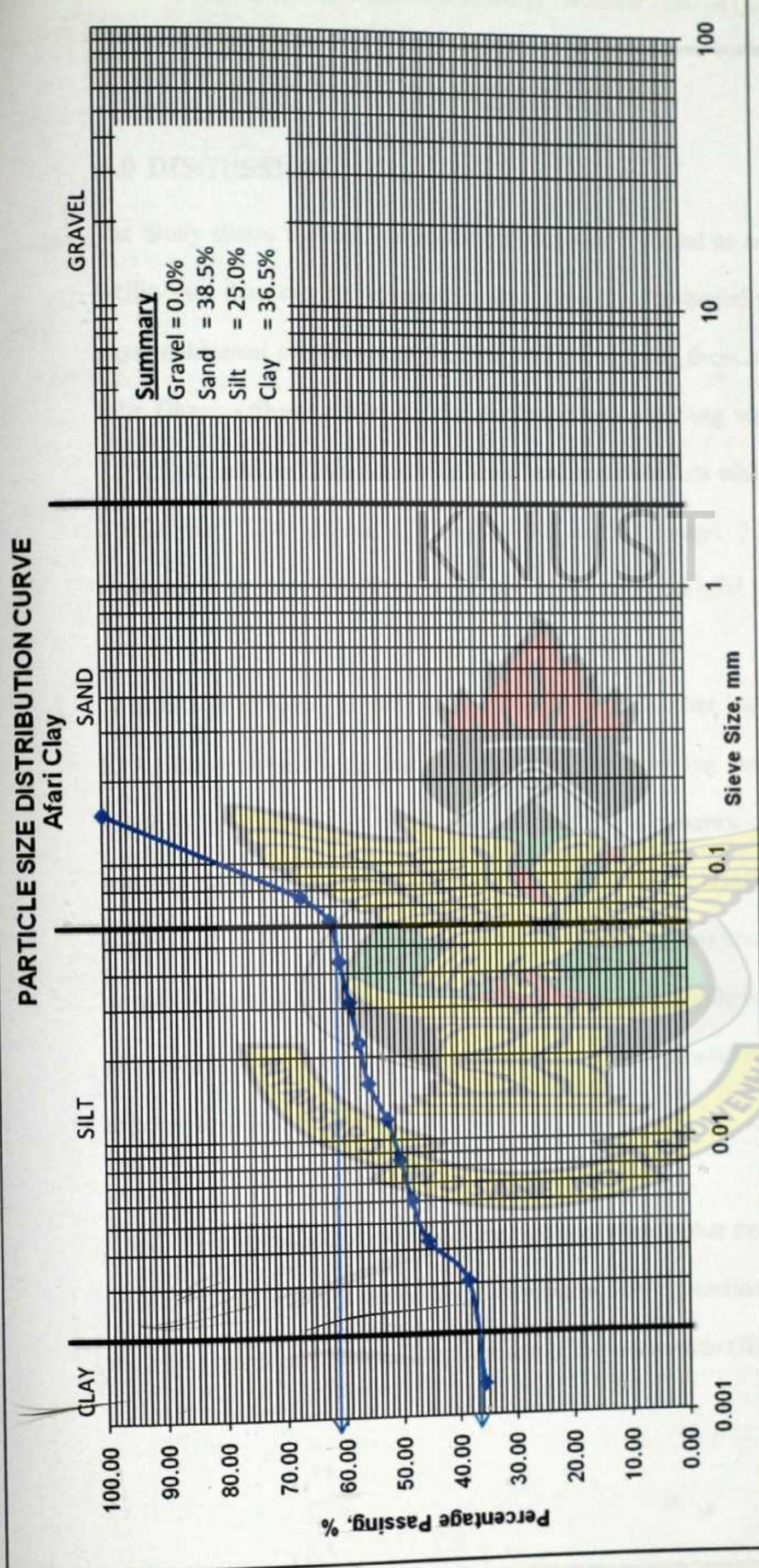


Figure 4.20: Particle size distribution curve of the Afari Clay



## CHAPTER FIVE

### 5.0 DISCUSSION

The Study shows that the sand filter bed that was installed as an additional treatment facility to that of the company's was able to substantially improve measured physicochemical parameters of the final effluent to bring them in compliance with the EPA Ghana effluent guidelines for discharge into receiving water bodies. However, TDS, Conductivity, DO, Alkalinity, iron, lead and cadmium which recorded a mean of 1105.5 mg/l, 2267  $\mu$ S/cm, 5.37 mg/l, 456.1 mg/l, 1.8 mg/l, 2.29 mg/l and 0.2 mg/l respectively for the final effluent were not improved by the sand filter bed.

Wastewater effluent pH after going through the sand filter bed brought it within the EPA Ghana effluent guidelines for discharge into receiving water bodies (Table H.1) although they were basic which could be due to the presence of caustic soda used in washing the glass bottles and the treatment plant which is alkaline. It is also observed that the pH levels of the wastewater fell after filtration. This could be due to the nature of the sand-bed; it is likely that it contains some slightly acidic constituents. The drop in pH could also have resulted from the products of biodegradation as a result of it being exposed to air (Akporhonor *et al.*, 2007).

Total dissolved solids of the wastewater effluent were higher than the outflow from the sand filter bed which is below the recommended EPA guideline. This is attributable to the high organic and inorganic ions present in the wastewater (Baah, 2007).



Various industrial processing activities such as general plant cleaning and bottle washing are known to impact considerable amount of colour to water. Colour standard is set for reasons of appearance and requires that water be virtually colourless. According to EPA Ghana effluent guidelines for discharge into receiving water bodies, the colour limit should be 100 TCU. Both the wastewater effluent and the sand filter bed colour analysed were within the EPA guideline and will therefore not pose any health threat to those that use the water.

Total suspended solids (TSS) is an important parameter in designing wastewater treatment plants (WWTP) (Baah, 2007). The decrease in TSS for both the effluent treatment plant and the sand filter bed indicates that the wastewater discharged had less suspended solids. Murphy (2005) showed that, high TSS of discharged wastewater can block light from reaching submerged vegetation in the water body which eventually slows down photosynthesis and affects the amount of DO released into the water by plants. High TSS also causes an increase in surface water temperatures as the suspended particles absorb heat from sunlight.

Turbidity levels of effluent from both the treatment plant and the sand filter beds were high and could probably be due to the large amount of wastewater being released for treatment during production. High turbidity levels in industrial effluents contribute large amounts of suspended solids to receiving water bodies (Okoh, 2010).

The wastewater treatment plant did not have any impact on conductivity levels since the conductivity is directly related to total dissolved salts. The high TDS of the wastewater could be the reason for the high conductivity value in the treated effluent. Anions such



as chloride, nitrate, phosphate and sulphate and cations such as sodium, calcium, magnesium and iron are known to contribute to the overall conductivity of water (Goosselink and Mitsch., 2000). The improved conductivity by the sand filter bed shows a better option in the treatment of industrial effluent.

The influent and effluent and sand filter DO values were above the EPA Ghana guideline value of  $>1$  mg/l. However a decrease in the sand filter DO relative to the influent and effluent indicates that some form of treatment has being achieved. Metcalf and Eddy (1995) reported that DO is important to aquatic life because of the detrimental effects that can occur when DO levels drop below 4 to 5 mg/L depending on the aquatic species involved. Dewedar *et al.* (2006) revealed that treatment process can occur in the presence or absence of oxygen. However, in the absence of oxygen, decomposition of organic waste occurs at a much slower rate and can create severe odour problems. As such, oxygen is an essential ingredient in efficient treatment.

Generally, there was no significant reduction in biological oxygen demand by the wastewater treatment plant. Much higher values of BOD were recorded during the fourth and fifth months of sampling which could be due to the peak production season where large amount of wastewater are being channelled for treatment.

The results for the BOD and COD support studies by Metcalf and Eddy (1995) that the values obtained for ~~BOD~~ are always lower than that for COD because the activated sludge bacteria cannot degrade some of the compounds oxidized chemically in COD test and that some of the carbon removal during the BOD test is not oxidised but end up in bacteria biomass. Foster (2000) stated that COD and BOD are the two most important



parameters in determining the extent of pollution of wastewater and knowing the two values at the inlet and outlet of the wastewater treatment plant makes it easy to judge the efficiency of the plant.

The wastewater treatment plant and the outflow from the sand filter bed recorded high levels of alkalinity in the effluent wastewater and this could be attributed to the fact that the treatment of the wastewater takes place in an alkaline medium (Okoh, 2010). The high values recorded for the influent was as a result of the addition of acid which is usually used to resist changes in pH in the wastewater and the caustic soda used in washing the bottles.

All the heavy metals analysed over the six month study period recorded a relatively higher concentration with the exception of copper and zinc which were below the maximum permissible effluent quality guidelines. The higher value of iron recorded for the sand filter bed over that of the effluent could be due to the high levels of iron in the Afari clay. However, subsequent analysis was able to reduce the amount of iron present in the wastewater. The concentrations of lead and cadmium were higher in the effluent wastewater treatment compared to the sand filter bed which may be attributed to the wearing of lead pipes and some component parts of the washer equipment employed in washing the bottles. Presence of excessive amounts of cadmium in treated effluent may interfere with many beneficial uses of the water because of its toxicity (Tchobanoglous *et al.*, 2003).

Indicator bacterial numbers recorded during the six month study period were generally high and above the Ghana Environmental Protection Agency (GEPA) recommended



guidelines values. This could be due to the high organic matter content in the treatment tanks which served as food for the bacteria to grow. Dewedar *et al.*, (2006) had suggested that the environmental conditions, together with the availability of nutrients and the nature of the organic matter are major factors controlling the activity of different bacterial groups. The present study indicated that, changes in temperature during the sampling period may have affected the counts of different microbial groups during the course of analysis.

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## CHAPTER SIX

### 6.0 CONCLUSION AND RECOMMENDATION

#### 6.1 CONCLUSION

The physicochemical parameters; TDS, Conductivity, DO and Alkalinity were higher than the Ghana Environmental Protection Agency (GEPA) recommended guidelines.

Microbial indicator numbers were still high after going through the treatment plant (ETP) but were further reduced in the sand filter bed.

The concentrations of heavy metals in the effluent treatment plant (ETP) were high compared to the Ghana Environmental Protection Agency (GEPA) recommended guidelines and thus not satisfactory.

Further treatment of the wastewater by the sand filter bed system is a better option than using the effluent treatment plant (ETP) alone, but the greatest challenge was its inability to reduce Alkalinity, iron, lead and cadmium to acceptable levels.

Sand filter bed has showed very high adsorption capacities and can successfully be used as an additional low cost treatment facility in industrial wastewater treatment. Since this method involves less capital cost coupled with its efficiency it is recommended for developing countries.



## **6.2 RECOMMENDATIONS**

- Considering the high microbial numbers in the treated effluent which is eventually discharged into the Sisa River that serves as irrigation water for vegetable farmers, there is the need to further reduce these levels before discharge.
- The pollution levels of the wastewater treatment plant has been found to be very high, measures to ensure the smooth and continues operation of the treatment plant must therefore be given priority attention.
- Personnel with the requisite knowledge in environmental and waste management may be recruited and trained to oversee the day to day operation of the plant.
- High-quality treated wastewater can be a reliable water source in many beverage industries; this effluent if further treated can be reused for other minor purposes to reduce production cost.
- The provision of an additional treatment plant such as a sand filter bed system should be incorporated in the plant to take care of parameters that will be found to be above the GEPA guidelines.
- Disinfection of the effluent wastewater may be carried out before final discharge into the environment.



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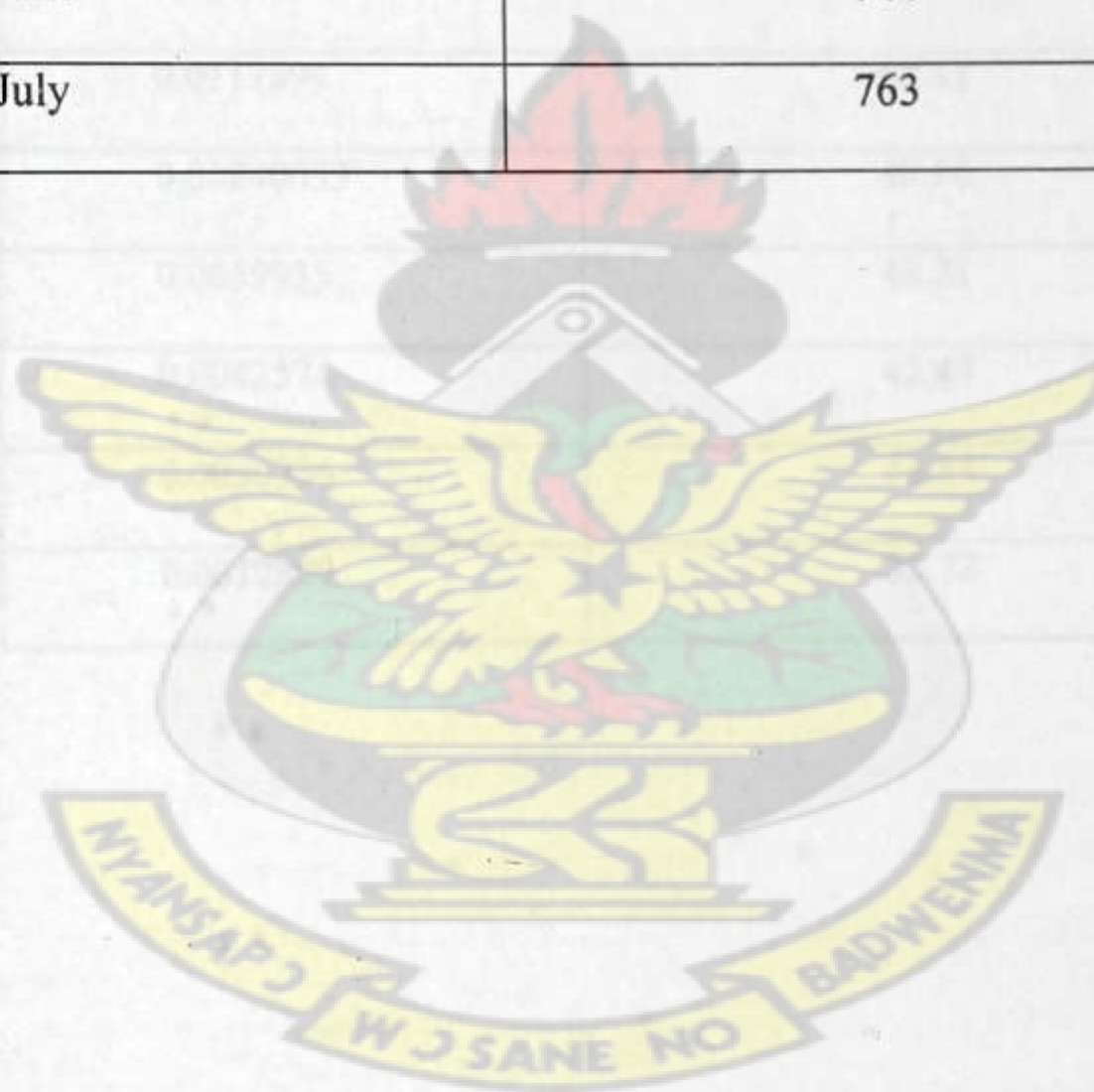


APPENDIX

APPENDIX A

Table A.1: Volume of Wastewater Discharge for the Six Months Period

MONTH	WASTEWATER DISCHARGE (m <sup>3</sup> )
February	2151
March	1528
April	2219
May	708
June	744
July	763





## APPENDIX B

Table B.1: Particle size distribution of the Afari Clay

Sieve Size (mm)	% Passing
0.15	100.00
0.075	67.00
0.0615745	62.10
0.0439098	60.47
0.0313085	58.85
0.0223204	57.22
0.0159106	55.60
0.0117899	52.43
0.00840033	50.16
0.0059935	48.21
0.0042574	45.47
0.0030336	38.44
0.0012809	35.72



# APPENDIX C

**Table C.1: Removal Efficiency of the Wastewater Treatment Plants**

PARAMETERS	MEAN INFLUENT	MEAN EFFLUENT	% REDUCTION
pH	11.67	8.57	26.56
T.D.S (mg/L)	3170	1105.5	65.13
COLOUR (TCU)	230.75	76.13	67.01
T.S.S (mg/L)	118	47.30	59.92
TURBIDITY (NTU)	53.95	20.35	62.28
ELECTRICAL COND( $\mu$ S/cm)	4690.5	2267.2	51.66
D.O( mg/L)	2.24	5.37	-139.73
B.O.D <sub>5</sub> (mg/L)	167.2	48.70	70.87
C.O.D (mg/L)	883.2	98.30	88.87
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	61.44	39.60	35.55
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	801.2	456.10	43.07
ALKALINITY ( HCO <sub>3</sub> ) mg/L	298.33	294.30	1.35
PHOSPHATE(mg/L)	2.87	6.90	-140.42
PHOSPHORUS(mg/L)	0.88	1.90	-115.91
SULPHIDE (mg/L)	0.03	0.02	33.33
SULPHATE (mg/L)	54.7	61.60	-12.61
AMMONIUM NITROGEN(mg/L)	1.90	0.88	53.68
FLUORIDE (mg/L)	3.12	1.81	41.99
CHLORIDE (mg/L)	83.9	48.40	42.31
MAGNESIUM (mg/L)	2.91	3.91	-34.36
CALCIUM (mg/L)	18.60	12.74	31.51
IRON (mg/L)	11.85	1.80	84.81
LEAD (mg/L)	5.95	2.29	61.51
CADMIUM(mg/L)	0.38	0.20	47.37
COPPER (mg/L)	0.56	0.39	30.36
ZINC (mg/L)	0.31	0.19	38.71
TOTAL COLIFORMS (MPN/100ml)	$2.4 \times 10^6$	$9.7 \times 10^5$	59.58
FAECAL COLIFORMS(MPN/100ml)	$9.9 \times 10^5$	$5.1 \times 10^5$	48.48
ENTEROCOCCI (MPN/100ml)	$1.8 \times 10^2$	$1.6 \times 10^2$	11.11
E-COLI (MPN/100ml)	$2.7 \times 10^4$	$5.5 \times 10^4$	-103.7

**Note: Negative value implies an increment in the effluent value over that of the influent.**



**Table C.2 Removal Efficiency of the Sand Filter Bed**

PARAMETERS	MEAN EFFLUENT	MEAN SAND FILTER	% REDUCTION
pH	8.57	7.00	18.32
T.D.S (mg/L)	1105.5	529.9	52.07
COLOUR (TCU)	76.13	50.70	33.40
T.S.S (mg/L)	47.30	5.49	88.39
TURBIDITY (NTU)	20.35	14.53	28.6
ELECTRICAL COND( $\mu$ S/cm)	2267.2	963.2	57.52
D.O( mg/L)	5.37	3.33	37.99
B.O.D <sub>5</sub> (mg/L)	48.70	26.42	45.75
C.O.D (mg/L)	98.30	46	53.20
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	39.60	34.15	13.76
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	456.10	276.3	39.42
ALKALINITY ( HCO <sub>3</sub> ) mg/L	294.30	190.81	35.16
PHOSPHATE(mg/L)	6.90	3.96	42.61
PHOSPHORUS(mg/L)	1.90	1.30	31.58
SULPHIDE (mg/L)	0.02	0.01	50.00
SULPHATE (mg/L)	61.60	46.30	24.84
AMMONIUM NITROGEN(mg/L)	0.88	0.39	55.68
FLUORIDE (mg/L)	1.81	0.75	58.56
CHLORIDE (mg/L)	48.40	40.45	16.43
MAGNESIUM (mg/L)	3.91	3.39	13.30
CALCIUM (mg/L)	12.74	11.59	9.03
IRON (mg/L)	1.80	2.90	61.11
LEAD (mg/L)	2.29	0.71	69.00
CADMIUM(mg/L)	0.20	0.03	85.00
COPPER (mg/L)	0.39	0.33	15.38
ZINC (mg/L)	0.19	0.02	89.47
TOTAL COLIFORMS (MPN/100ml)	$9.7 \times 10^5$	$5.2 \times 10^7$	-
FAECAL COLIFORMS(MPN/100ml)	$5.1 \times 10^5$	$9.6 \times 10^4$	81.18
ENTEROCOCCI (MPN/100ml)	$1.6 \times 10^2$	$1.0 \times 10^1$	93.75
E-COLI (MPN/100ml)	$5.5 \times 10^4$	$1.1 \times 10^4$	80



## APPENDIX D

**Table D.1 Treatment of the wastewater Influent using the Sand Filter Bed Alone**

PARAMETERS	INFLUENT	SAND FILTER	% REDUCTION
pH	11.65	7.65	34.33
T.D.S (mg/L)	1280	392	69.38
COLOUR (TCU)	100	75	25.00
T.S.S (mg/L)	7.0	0.0	100
TURBIDITY (NTU)	23	10	56.52
ELECTRICAL COND( $\mu$ S/cm)	2600	783	69.88
D.O( mg/L)	2.18	2.78	27.52
B.O.D <sub>5</sub> (mg/L)	136	40	70.59
C.O.D (mg/L)	800	440	45.00
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	52	22	57.69
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	1156	112	90.31
ALKALINITY ( HCO <sub>3</sub> ) mg/L	0.0	136.64	-
PHOSPHATE(mg/L)	1.64	4.64	-182.93
PHOSPHORUS(mg/L)	0.53	1.52	-186.79
SULPHIDE (mg/L)	0.047	0.034	27.66
SULPHATE (mg/L)	8.0	70	-755.00
AMMONIUM NITROGEN(mg/L)	1.04	0.38	63.46
FLUORIDE (mg/L)	2.05	1.03	49.76
CHLORIDE (mg/L)	72	15.0	79.17
MAGNESIUM (mg/L)	5.35	3.0	43.93
CALCIUM (mg/L)	12.02	4.01	66.64
IRON (mg/L)	9.34	3.602	61.43
LEAD (mg/L)	2.68	0.59	77.99
CADMIUM(mg/L)	0.19	0.06	68.42
COPPER (mg/L)	0.89	0.76	14.61
ZINC (mg/L)	0.74	0.41	44.59
TOTAL COLIFORMS (MPN/100)	$1.9 \times 10^5$	$0.4 \times 10^4$	97.89
FAECAL COLIFORMS(MPN/100)	$8.9 \times 10^4$	$2.8 \times 10^3$	96.85
ENTEROCOCCI (MPN/100ml)	0	0	-
E-COLI (MPN/100)	$0.4 \times 10^3$	$0.4 \times 10^3$	-



APPENDIX E

Table E.1: Physicochemical Results of Influent Wastewater sampling

PARAMETERS	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	MEAN	STD	STD ER.
	1	2	3	4	5	6	7	8	9	10				
pH	11.57	9.55	11.70	12.28	11.96	11.84	11.43	12.50	11.90	11.98	11.67	0.81	0.26	
T.D.S (mg/L)	2030	1230	1330	10900	8850	1930	1350	1355	1410	1315	3170	3576.88	1131.10	
COLOUR (TCU)	150	300	311.54	375	326	265	185	175	115	105	230.75	96.21	30.42	
T.S.S (mg/L)	320	270	30	120	165	96	58	78	19	24	118	104.45	33.05	
TURBIDITY (NTU)	15.5	36	35	99	72	55	88	65	31	43	53.95	26.76	8.46	
ELECTRICAL COND(μS/cm)	4170	2460	2650	22000	2490	2560	2710	2440	2665	2760	4690.5	6103.06	1929.94	
D.O( mg/L)	1.09	5.29	1.49	3.01	2.87	1.65	0.82	1.48	2.46	2.20	2.24	1.30	0.41	
B.O.D <sub>5</sub> (mg/L)	50	690	27	170	96	86	140	96	155	162	167.2	189.84	60.03	
C.O.D (mg/L)	1048	3400	254	592	384	244	780	653	685	792	883.2	919.61	290.80	
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	-	51	18	0.0	102	86	80	88	63	65	61.44	33.70	10.66	
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	442	700	279	1358	856	725	642	776	1086	1148	801.2	326.28	103.18	



ALKALINITY ( HCO <sub>3</sub> ) mg/L	-	894	1058	284	179	155	0.0	115	0.0	0.0	298.33	398.05	125.87
PHOSPHATE(mg/L)	5.85	5.75	3.2	4.5	3.1	0.85	0.64	1.20	1.48	2.10	2.87	1.95	0.62
PHOSPHORUS(mg/L)	1.92	1.9	0.4	1.16	1.20	0.19	0.14	0.97	0.50	0.44	0.88	0.66	0.21
SULPHIDE (mg/L)	-	0.052	0.008	0.050	0.008	0.008	0.008	0.009	0.052	0.056	0.03	0.02	0.01
SULPHATE (mg/L)	150	82	61	48	44	39	35	46	19	23	54.7	38.03	12.03
AMMONIUM NITROGEN(mg/L)	0.56	0.49	1.12	8.4	2.32	1.15	0.84	1.68	1.17	1.23	1.90	2.35	0.74
FLUORIDE (mg/L)	6.13	9.24	2.67	1.85	1.79	1.84	1.67	1.95	2.22	1.88	3.12	2.53	0.80
CHLORIDE (mg/L)	86	88	92	102	78	58	73	93	81	88	83.9	12.23	3.87
MAGNESIUM (mg/L)	2.4	3.1	2.94	0.0	2.62	1.44	3.65	4.51	4.91	3.48	2.91	1.43	0.45
CALCIUM (mg/L)	18.0	26.6	21.52	0.0	19.81	20.20	18.0	23	18.20	20.64	18.60	7.05	2.23



Table E.2: Physicochemical Results of Effluent Wastewater Analysis

PARAMETERS	EFF	2	3	4	5	6	7	8	9	10	MEAN	STD	STD. EFF
Ph	8.61	8.49	8.52	8.05	8.30	8.8	8.49	8.34	9.10	8.98	8.57	0.32	0.10
T.D.S (mg/L)	991	795	1230	889	1330	1280	1270	1115	1020	1135	1105.5	178.91	56.58
COLOUR (TCU)	60	50	71.32	50	81	69	100	98	94	88	76.13	18.95	5.99
T.S.S (mg/L)	170	63.0	12	48	65	42	25	23	11.5	13.5	47.30	47.61	15.06
TURBIDITY (mg/L)	12.5	17.2	12	29.8	20	26	25	21	19	21	20.35	5.65	1.79
ELECTRICAL COND( $\mu$ S/cm)	1987	1585	2490	1778	2650	2610	2520	2150	2420	2482	2267.2	371.79	117.57
D.O( mg/L)	5.51	6.53	2.62	4.80	3.85	3.7	5.8	6.8	8.1	6.0	5.37	1.65	0.52
B.O.D <sub>5</sub> (mg/L)	26	30	12	130	65	16	22	18	93	75	48.70	40.09	12.68
C.O.D (mg/L)	221	112.0	73	88	76	64	80	70	105	94	98.30	45.78	14.48
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	50	44	9	0.0	56	49	60	65	49	14	39.60	23.08	7.30
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	328	289	173	234	283	434	526	551	955	788	456.10	235.25	74.39
ALKALINITY ( HCO <sub>3</sub> ) mg/L	622	659	793	285	279	173	0.0	132	0.0	0.0	294.30	296.33	93.71



PHOSPHATE(mg/L)	7.02	8.1	6.11	5.14	6.55	7.13	7.26	8.3	6.55	6.82	6.90	0.92	0.29
PHOSPHORUS(mg/L)	2.28	2.13	0.52	1.68	2.30	2.19	2.49	1.82	1.80	1.75	1.90	0.56	0.56
SULPHIDE (mg/L)	0.04	0.030	0.005	0.015	0.019	0.018	0.016	0.018	0.020	0.016	0.02	0.01	0.00
SULPHATE (mg/L)	97	55	48	44	72	64	71	74	39	52	61.60	17.48	5.53
AMMONIUM NITROGEN (mg/L)	0.84	0.29	0.56	1.96	0.86	0.62	0.56	1.12	1.10	0.93	0.88	0.46	0.15
FLUORIDE (mg/L)	1.05	3.0	1.67	1.38	2.06	2.02	1.57	1.60	1.75	2.00	1.81	0.52	0.16
CHLORIDE (mg/L)	49	38	46	26	92	52	45	49	41	46	48.40	17.00	5.38
MAGNESIUM (mg/L)	1.97	0.97	1.18	0.0	8.61	7.91	7.29	3.40	4.15	3.64	3.91	3.07	0.97
CALCIUM (mg/L)	14.42	18.42	13.60	0.0	12.65	12.48	12.0	17.2	14.5	12.11	12.74	4.97	1.57



Table E.3: Physicochemical Results of Sand Filter Wastewater Analysis

PARAMETERS	SF 1	SF 2	SF 3	SF 4	SF 5	SF 6	SF 7	SF 8	SF 9	SF 10	MEAN	STD DEV.	STD. ER MEAN
pH	7.30	6.70	6.60	7.13	6.80	6.94	7.19	6.94	7.10	7.25	7.00	0.24	0.08
T.D.S (mg/L)	851	676	1044	528	465	360	340	220	400	365	529.9	257.71	81.49
COLOUR (TCU)	100	85	85	75	70	25	15	15	19	18	50.70	35.01	11.07
T.S.S (mg/L)	8.0	6.4	3.2	24	8.5	4.8	0.0	0.0	0.0	0.0	5.49	7.34	2.32
TURBIDITY (mg/L)	19.4	12.2	16	38	22	19	5.0	4.8	4.6	4.3	14.53	10.78	3.41
ELECTRICAL COND( $\mu$ S/cm)	1702	1342	1112	1055	880	805	681	650	715	690	963.2	344.13	108.82
D.O( mg/L)	3.83	2.54	1.72	5.04	3.75	3.98	3.15	3.18	2.85	3.25	3.33	0.90	0.28
B.O.D <sub>5</sub> (mg/L)	14	11	8	90	65	12	7.0	6.2	37	14	26.42	28.91	9.14
C.O.D (mg/L)	200	103.0	19	24	20	19	16	11	28	20	46	60.28	19.06
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	75	46	10.5	45	38	18	12	17	59	21	34.15	21.95	6.94
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	202	146	112	131	175	205	458	398	550	386	276.3	156.6	49.52
ALKALINITY ( HCO <sub>3</sub> mg/L)	246.4	264.7	287	160	136	128	159	154	205	168	190.81	56.56	17.89
PHOSPHATE(mg/L)	0.79	0.96	0.35	3.64	4.86	6.57	6.27	6.45	4.95	4.75	3.96	2.43	0.74



PHOSPHORUS(mg/L)	0.26	1.4	0.76	1.18	1.65	1.54	2.04	0.52	2.05	1.55	1.30	0.61	0.19
SULPHIDE (mg/L)	0.021	0.014	0.001	0.008	0.011	0.009	0.003	0.003	0.004	0.006	0.01	0.01	0.00
SULPHATE (mg/L)	55	46	37	42	56	49	63	59	22	34	46.30	12.75	4.03
AMMONIUM-NITROGEN( mg/L)	1.12	0.27	0.12	0.84	0.64	0.41	0.28	0.09	0.07	0.10	0.39	0.36	0.11
FLUORIDE (mg/L)	0.40	1.14	1.00	0.95	1.12	1.08	0.68	0.15	0.70	0.32	0.75	0.36	0.11
CHLORIDE (mg/L)	34.5	32	21	16	88	47	43	44	38	41	40.45	19.47	6.16
MAGNESIUM (mg/L)	1.97	1.7	1.31	2.43	7.32	5.15	5.83	2.3	3.25	2.60	3.39	2.01	0.64
CALCIUM (mg/L)	14.42	11.2	8.4	4.81	12.20	12.39	12.0	13.4	14.5	12.6	11.59	2.95	0.93



APPENDIX F

Table F.1: Determination of Metals in a Beverage Wastewater Influent

PARAMETERS	INF	2	3	4	5	6	7	8	9	10	MEAN	STD	STD. ER.
IRON (mg/L)	41.53	5.17	0.40	3.65	11.8	10.9	11.4	11.7	10.75	11.20	11.85	11.19	3.54
LEAD (mg/L)	14.18	0.49	0.11	25.33	4.20	3.80	2.70	2.69	3.12	2.83	5.95	7.84	2.48
CADMIUM(mg/L)	0.32	0.56	0.74	0.62	0.52	0.45	0.16	0.14	0.17	0.16	0.38	0.22	0.07
COPPER (mg/L)	0.45	2.4	0.07	0.37	0.40	0.34	0.30	0.28	0.43	0.55	0.56	0.66	0.21
ZINC (mg/L)	0.28	0.41	0.22	0.015	0.31	0.34	0.25	0.25	0.47	0.52	0.31	0.14	0.04



Table F.2: Determination of Metals in a Beverage Wastewater Treatment Plant (Effluent)

PARAMETERS	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	EFF	MEAN	STD DEV	STD. ER
	1	2	3	4	5	6	7	8	9	10										
IRON (mg/L)	5.43	0.57	0.31	1.05	2.42	2.65	1.34	1.42	1.38	1.44								1.80	1.46	0.46
LEAD (mg/L)	0.37	0.29	0.10	0.577	3.80	3.20	3.84	3.71	3.64	3.36								2.29	1.70	0.54
CADMIUM(mg/L)	0.15	0.14	0.05	0.24	0.18	0.22	0.24	0.25	0.28	0.20								0.20	0.07	0.02
COPPER (mg/L)	0.57	1.9	0.03	0.162	0.18	0.16	0.19	0.20	0.25	0.28								0.39	0.55	0.17
ZINC (mg/L)	0.44	0.60	0.34	0.010	0.25	0.09	0.07	0.06	0.018	0.022								0.19	0.20	0.06



Table F.3: Determination of Metals in a Beverage Wastewater using Sand Filter.

PARAMETERS	SF 1	SF 2	SF 3	SF 4	SF 5	SF 6	SF 7	SF 8	SF 9	SF 10	MEAN	STD DEV	STD. ER MEAN
IRON (mg/L)	6.90	3.1	0.10	0.008	2.8	3.2	3.8	3.5	2.65	2.92	2.90	1.93	0.61
LEAD (mg/L)	0.35	0.19	0.004	0.004	1.54	1.26	0.74	0.58	1.15	1.24	0.71	0.57	0.18
CADMIUM(mg/)	0.06	0.008	0.004	0.006	0.008	0.020	0.064	0.050	0.022	0.034	0.03	0.02	0.01
COPPER (mg/L)	0.34	0.34	0.01	0.193	0.26	0.21	0.62	0.53	0.50	0.31	0.33	0.18	0.06
ZINC (mg/L)	0.09	0.03	0.06	0.004	0.031	0.003	0.001	0.001	0.003	0.004	0.02	0.03	0.01



APPENDIX G

Table G.1: Bacterial numbers in Beverage Wastewater Influent

PARAMETERS	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	INF	MEAN	Log <sub>10</sub> Mean	STD DEV	STD. ER. MEAN
	1	2	3	4	5	6	7	8	9	10					
TOTAL COLIFORMS (MPN/100)	6×10 <sup>6</sup>	5.3×10 <sup>4</sup>	4.3×10 <sup>6</sup>	4.3×10 <sup>6</sup>	3.8×10 <sup>6</sup>	4.3×10 <sup>6</sup>	2.9×10 <sup>3</sup>	2.9×10 <sup>3</sup>	2.9×10 <sup>3</sup>	2.9×10 <sup>3</sup>	2.4×10 <sup>6</sup>	2.4×10 <sup>6</sup>	6.4	2.3×10 <sup>6</sup>	7.3×10 <sup>3</sup>
FAECAL COLIFORMS(MPN/100)	9.9×10 <sup>4</sup>	9.9×10 <sup>4</sup>	3.7×10 <sup>6</sup>	9.9×10 <sup>4</sup>	9.9×10 <sup>4</sup>	10.2×10 <sup>3</sup>	2.9×10 <sup>6</sup>	2.9×10 <sup>6</sup>	1×10 <sup>1</sup>	9.2×10 <sup>3</sup>	9.9×10 <sup>3</sup>	9.9×10 <sup>3</sup>	6.0	1.5×10 <sup>6</sup>	4.7×10 <sup>3</sup>
ENTEROCOCCI (MPN/10ml)	8×10 <sup>1</sup>	8×10 <sup>1</sup>	1×10 <sup>1</sup>	8×10 <sup>2</sup>	8×10 <sup>2</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1.8×10 <sup>2</sup>	1.8×10 <sup>2</sup>	2.3	3.3×10 <sup>2</sup>	1.0×10 <sup>2</sup>
E-COLI (MPN/100)	1×10 <sup>1</sup>	1×10 <sup>1</sup>	9.3×10 <sup>4</sup>	9.8×10 <sup>4</sup>	4.6×10 <sup>4</sup>	2.3×10 <sup>3</sup>	2.4×10 <sup>4</sup>	2.3×10 <sup>3</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	2.7×10 <sup>4</sup>	2.7×10 <sup>4</sup>	4.4	3.9×10 <sup>4</sup>	1.2×10 <sup>4</sup>



Table G.2: Bacterial numbers in Beverage Wastewater Treatment Plant (Effluent)

PARAMETERS	EFF 1	EFF 2	EFF 3	EFF 4	EFF 5	EFF 6	EFF 7	EFF 8	EFF 9	EFF 10	MEAN	Log <sub>10</sub> Mean	STD DEV	STD. ER. MEAN
TOTAL COLIFORMS (MPN/100)	$3.35 \times 10^4$	$3.35 \times 10^5$	$3.3 \times 10^3$	$3.35 \times 10^4$	$3.35 \times 10^5$	$4.3 \times 10^6$	$4.3 \times 10^6$	$3.4 \times 10^4$	$2.9 \times 10^5$	$3.4 \times 10^4$	$9.7 \times 10^5$	6.0	$1.7 \times 10^6$	$5.4 \times 10^5$
FAECAL COLIFORMS(MPN/100)	$5.15 \times 10^3$	$5.15 \times 10^3$	$4.3 \times 10^5$	$2.1 \times 10^6$	$10.8 \times 10^4$	$2.1 \times 10^6$	$2.9 \times 10^5$	$5.3 \times 10^4$	$5.2 \times 10^3$	$3.3 \times 10^3$	$5.1 \times 10^5$	5.7	$8.1 \times 10^5$	$2.6 \times 10^5$
ENTEROCOCCI (MPN/100ml)	$7 \times 10^1$	$7 \times 10^1$	$2 \times 10^2$	$7 \times 10^2$	$7 \times 10^2$	$1 \times 10^1$	$1 \times 10^1$	$1 \times 10^1$	$1 \times 10^1$	$1 \times 10^1$	$1.6 \times 10^2$	2.2	$2.3 \times 10^2$	$7.3 \times 10^1$
E-COLI (MPN/100)	$3.3 \times 10^3$	$10.8 \times 10^4$	$9.9 \times 10^4$	$10.8 \times 10^4$	$10.8 \times 10^4$	$5.3 \times 10^4$	$3.4 \times 10^4$	$3.3 \times 10^4$	$1.9 \times 10^3$	$1.4 \times 10^3$	$5.5 \times 10^4$	4.7	$4.4 \times 10^4$	$1.4 \times 10^4$



Table G.3: Bacterial numbers in Beverage Wastewater using Sand Filter Bed

PARAMETERS	SF 1	SF 2	SF 3	SF 4	SF 5	SF 6	SF 7	SF 8	SF 9	SF 10	MEAN	Log <sub>10</sub> Mean	STD DEV	STD. E
TOTAL COLIFORMS (MPN/100)	32.7×10 <sup>7</sup>	32.7×10 <sup>6</sup>	3.3×10 <sup>3</sup>	8.1×10 <sup>7</sup>	8.1×10 <sup>7</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	5.2×10 <sup>7</sup>	7.7	9.7×10 <sup>7</sup>	3.1×10 <sup>7</sup>
FAECAL COLIFORMS(MPN/100)	3.35×10 <sup>5</sup>	1.98×10 <sup>5</sup>	1.35×10 <sup>5</sup>	8.7×10 <sup>4</sup>	9.3×10 <sup>4</sup>	1.1×10 <sup>5</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	9.6×10 <sup>4</sup>	5.0	1×10 <sup>5</sup>	3.2×10 <sup>4</sup>
ENTEROCOCCI (MPN/100ml)	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1.0	0.0	0.0
E-COLI (MPN/100)	3.3×10 <sup>3</sup>	3.3×10 <sup>3</sup>	3.35×10 <sup>4</sup>	3.3×10 <sup>4</sup>	3.4×10 <sup>4</sup>	5.2×10 <sup>3</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1×10 <sup>1</sup>	1.1×10 <sup>4</sup>	4.0	1.5×10 <sup>4</sup>	4.7×10 <sup>3</sup>



## APPENDIX H

**Table H.1: Wastewater Quality Guidelines for Discharges into Water Bodies.**

PARAMETERS	EPA GHANA STANDARDS FOR EFFLUENT DISCHARGE FOR BEVERAGE INDUSTRY
pH	6 -9
T.D.S (mg/L)	<1000
COLOUR (TCU)	100
T.S.S (mg/L)	<50
TURB (NTU)	75
E.COND( $\mu$ S/cm)	1500
D.O( mg/L)	>1
B.O.D <sub>5</sub> (mg/L)	<50
C.O.D (mg/L)	<250
T. HARDNESS ( mg CaCO <sub>3</sub> /L)	
T. ALKALINITY ( mg CaCO <sub>3</sub> /L)	150
ALKALINITY ( HCO <sub>3</sub> ) mg/L	-
PHOSPHATE(mg/L)	
PHOSPHORUS(mg/L)	2
SULPHIDE (mg/L)	1.5
SULPHATE (mg/L)	250
AMMONIUM NITROGEN(mg/L)	
FLUORIDE (mg/L)	10
CHLORIDE (mg/L)	250
MAGNESIUM (mg/L)	
CALCIUM (mg/L)	
IRON (mg/L)	<1
LEAD (mg/L)	0.1
CADMIUM(mg/L)	<0.02
COPPER (mg/L)	1
ZINC (mg/L)	2
TOTAL COLIFORMS (MPN/100)	400
FAECAL COLIFORMS(MPN/100)	10
ENTEROCOCCI	
E-COLI (MPN/100)	10

Adapted from EPA (2000)