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DECLARATION

I Menitoyan Johnson Dolo, do hereby declare that with the exception of the references to other people's work which have been duly acknowledged, this M.Phil dissertation is entirely my own work and that no part of this publication or the whole has been presented for another degree elsewhere.

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DEDICATION

This work is dedicated to God Almighty for his countless blessings upon my life during this study. To my Uncle, Rev. David M. Tokpah and his family for their tireless effort in giving me all the financial supports to have reached this far in my education. Then to my beloved parents Mr. and Mrs. Johnson M. Dolo for their excellent parenthood and spiritual guidance. Also, to my beloved son Nutalee M. Dolo, the pillar of strength and ultimate source of inspiration. Finally, this study is dedicated to my brothers and sisters, Junior, Johnny, Mrs. Ela D. Harris, Miatta and Deborah.

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LIST OF ACRONYMS

AMA--------Accra Metropolitan Area

AOX--------Adsorbable Organic Compound

AOP---------Advance oxidation Process

ANOVA----Analysis of Variance

BOD--------Biochemical Oxygen Demand

COD-------Chemical Oxygen Demand

DO---------Dissolve Oxygen

EE2-------17α-ethinylestradiol

EPA------Environmental Protection Agency

LSD-- ----Least Significant Difference

MRI------Magnetic Resident Index

MOH-- ---Ministry of Health

NGO-----Non Governmental Organization

NAICS--North American Industry Classification System

PPCP-- --Pharmaceutical and Personal Care Products

pH-- -----Hydrogen Ion concentration

PhAC-- -Pharmaceuticals

PPMC-- Pearson's Product Moment Correlation Coefficient

UWW--Urban Wastewater

UNICEF-- United Nations Children's Emergency Fund

WWTP-- Wastewater Treatment Plant

GLOSSARY

Client: Patients and their caregivers or visitors to the health facilities.

Hazardous Waste: Waste that can have significant adverse effect on public health and/or the environment due to its infectiousness, toxicity, corrosiveness, carcinogenicity or other properties.

Health care Waste: All untreated solid and liquid waste (both hazardous and non-hazardous) generated during the administration of medical care, veterinary care or the performance of medical research involving human and animals. These include infectious, pathological, radioactive, pharmaceutical and other hazardous waste.

Infectious Waste: Waste containing pathogenic organism like bacteria, viruses, parasite and fungi in sufficient quantity to cause disease in susceptible hosts.

Pathogen: disease causing agents

Pathological Waste: Tissues, body parts, organs etc that have the potential to be infectious and are therefore sometimes classified as subcategory of infectious wastes.

Domestic Waste: wastes generated in homes and may consist primarily of Vegetables and other participle matters, such as papers, metals, textiles, plastics, glass, etc.

*Environmen*t: the physical surroundings including air, water, land, natural resources, flora, fauna, humans and their interrelationships.

Environmental Impacts: any change to the environment, whether adverse or beneficial, wholly or partially resulting from activities, products or services.

ABSTRACT

Hospitals effluent often contain chemical compounds which may have negative impact on the environment and human health if not properly treated. Investigations were conducted to determine the bacteriological and physico-chemical qualities of effluent discharged from University of Ghana hospital into the environment and its effects on agricultural soils and vegetables. Water and soil quality analyses of some physico-chemical and bacteriological variables were carried out on effluent samples using standard methods over a three month period (WHO, 2010). Human health risk assessment was conducted to determine the potential risk on the consumption of vegetables irrigated with the effluent water. The results showed the following variations in physico-chemical parameters; EC (1522-2220 µS/cm), pH (8.2-8.8), TDS (947-1410.7mg/l) BOD (34.8-66.8mg/l) DO (0.8-1.4mg/l) COD (548-775.2mg/l), NO_2^-–N (0.24-0.45mg/l), NO_3^-–N (34.5-101.1mg/l), NH_3-N,$^-$(15.9-28.8mg/l) PO_4^{3-}(6.3-9.8mg/l). The TC and *E. coli* also ranged from 3.120×10^3 - 4.582×10^3 cfu/100ml and 1.5×10^1- 2.9×10^1 cfu/100ml respectively. Lead and arsenic in water were below the recommended FAO guideline of 0.1 and 0.01mg/l respectively for water used for irrigation of vegetables. Cadmium, Cr, Ni and mercury however, exceeded the guideline. Mercury, nickel and chromium were above the FAO recommended guideline for Agricultural soils whilst Cd, Pb and As fell below the recommended limit. All the heavy metals in cabbage, lettuce and cauliflower in this study were all below recommended limit set by the FAO for vegetables wholesome for human consumption. The human health risk assessment of the vegetables revealed that the hazard index and Hazard quotient for cabbage, lettuce and cauliflower were all less than 1 which indicates that consumers are not at risk to the consumption of these vegetables in the short term. To prevent or reduce environmental effects and health risk associated with hospital effluent, adoption and utilization of decentralized wastewater technologies that are economically viable and efficient such as waste stabilization ponds are recommended to safeguard public health and prevent negative environmental effects.

CHAPTER ONE

INTRODUCTION

1.1 Background

Provision of health care, like any other human activities, generates waste which has to be managed and disposed of in a safe manner to minimize risks posed to the health of health workers, clients and the community at large. About 10 to 25% of waste generated in health institutions are hazardous and require special arrangements for management (WHO, 2010). Examples of hazardous health care waste include pathological waste such as tissues and body fluid, and pharmaceuticals waste, include expired or unused drugs, sharps syringes, disposable scalpels, blades and non-sharps such as swabs, bandages, disposal and medical devices (UNICEF, 2008). Others are chemicals solvents, disinfectants, wastewater including effluents from mortuaries and laboratories (WHO, 2010). These pose risks by being infectious, toxic, radioactive or causing injuries.

The Waste Management Department of the Accra Metropolitan Assembly (AMA) conducted a study in 6 major hospitals in Accra which show the unit generation of health care waste to be 1.2 kg/bed/day. The total number is likely to be increasing due to an increased number of hospital beds and improved standard of living. With a bed state of 4,372 in Accra in 2002 (does not include all private facilities) and an occupancy rate of 99%, it is estimated that waste generated is over 5.2 tons daily. This translates to over 1,850 tons of health care waste annually, of this, over 330 tons could be hazardous, with the assumption that 18% of waste generated is of hazardous nature (AMA, 2010).

Hospitals effluent may contain chemical compounds which could have an impact on the environment and human health. Indeed, substances found in the hospital wastewater are genotoxic and are suspected to be possible cause of cancer (Hutton & Haller, 2004).

Hospitals consume a significant amount of water in a day ranging from 400 to 1,200 liters per day per bed and generate significant amount of wastewater loaded with microorganisms, nutrients and radioactive elements (Wyasu et al., 2012).

Children, adults and animals all have the potential to come into contact with hospital waste effluent through irrigation or agricultural activities which may pose severe health risk to them.

Study conducted by Daughton (1999) indicates that farmers used hospital effluent to irrigate crops. Heavy load of nutrient pollution in agricultural soil and environment have the potential hazards to affect not only the crops but also human health (Daughton et al., 1999).

The disposal of wastewater has serious health impact on the environment with attendant social and economic costs (Ghana EPA, 2010). According to Daughton (1999), hospital wastewater may come into contact with human beings at several stages in the waste cycle. The group that are at risk include farmers who use wastewater for irrigation, people living close to waste disposal facilities, population whose water supplies have become polluted due to wastewater disposal. For example, groundwater used for drinking purposes can become chemically or microbiologically polluted if wastewaters are discharged in or near water sources. Handling of hospital effluent obviously entails health risks, potentially leading to infections and chronic diseases and accidents. Pollution of water resources increases the technical difficulty and cost of providing water supplies to citizens and thus results to limitation of water supply (Daughton, 1999).

Organic wastes from hospitals can also pose serious health risks because they ferment and create favorable conditions to the survival and growth of microbial pathogens if not managed properly. They are especially hazardous if they become intermixed with human excreta due to poor sanitation (Daughton, 1999). In addition, the unsightliness and foul smell of inadequately managed wastes from the University Hospital might constitute a major discomfort to the surrounding environment.

The purpose of this study therefore is to assess the effluent quality at the University of Ghana Hospital and to compare it to the EPA standard in order to inform policy decision at the hospital on apparent strategies for effluent discharge.

1.2 Problem Statement

In many developing countries, wastewater is considered a major problem especially in large hospital generated waste, solid waste and air pollution which are of growing concerning (WHO, 1996). In Ghana, hospitals in the Accra Metropolis alone produced about 1,850 tons of waste from hospital annually and these waste are increasing with the proliferation of other private hospitals with the high rate of population (EPA, 2010). Among these, wastewater disposal is of great environmental concern for hospitals in Accra and its surrounding (EPA, 2010).

Challenges in hospital waste management are a major concern in a developing country like Ghana. Both effluent generated from hospitals, and solid waste management seem to put hospital workers and authorities under pressure and the public gets more and more sensitive to the kind of danger these waste pose to them. Wastewater generated in a health care institution may present a serious health hazard but there is scarce information about the health hazard of hospital effluent at the University Hospital.

Wastewater from the University Hospital premises is discharged down the drainage without prior treatment and there is no proper method of disposal (Wyasu et al., 2012). Furthermore, there are no preliminary treatment options such as dilution, disinfection by oxidation or absorption onto solid materials, recycling or reuse to minimize the negative effect to the environment (Daughton, 1999). There are also farming activities in the surrounding environment, suggesting possibility of ground water contamination from the wastewater discharged into the land. The proximities of various communities within the same locality might pose a serious and long term health implications to the livelihood of the people.

1.3 Study Justification

Effluent discharge into the environment must meet EPA standards for wastewater discharged into the environment so that the final product released would not have adverse effect. This research work assessed and analyzed effluent quality from the University Ghana hospital and compare with EPA Ghana Standard for effluent. The study would help the University hospital to design appropriate wastewater treatment technologies to mitigate the possible effect that could potentially impact the ecosystem and subsequently protect human health. The findings will also add to the existing body of knowledge on waste management research.

1.4 General Objective

The general objective of the study is to determine effluent quality from the University of Ghana hospital and its effect on agricultural soils and vegetables as well as its potential impact on health of consumers of vegetables irrigated with effluent from the hospital and on the environment.

1.4.1 Specific Objectives:

The specific objectives are to:

- Determine the concentrations of some physico- chemical parameters (Temperature, pH, EC, TDS, TSS, DO, BOD, COD, PO_4^{3-} - P, NO_3-N) of effluent discharge from the University Hospital.
- To analyze the levels of bacteriological parameters (*E .coli* and TC) of effluent discharge from the University hospital.

- To determine the concentrations of some heavy metals (Cd, Cr, Pb, Ni, Hg and As) in hospital effluent, soil where vegetables are grown and the vegetables itself.
- To conduct human health risk assessment of heavy metals in vegetables irrigated with hospital effluent.

1.5 Organization of the Study

The dissertation is organized into six chapters. The first chapter is focused on the introduction and significance of the study, research problem, study justification, general and specific objectives; problem statement. The second chapter delved into the relevant literature review and outlined conceptual framework that guided the conducted of the study. The third chapter also outlined data collection and laboratory analysis. In chapter four, the results of the study is presented and chapter five explains and discuss the results generated from the study. Chapter six then provides a conclusion and recommendation to the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Hospital effluent mostly contain considerable amount of dissolved organic matter, pathogens and chemical contaminants and substances which if not properly handled, treated and disposed of may create extensive health hazards (Mesdaghinia et al., 2009). Hospital effluent and urban runoff contribute the bulk of the waste generated in Ghana (Obuobie et al., 2006).

The hospital effluent is mainly the liquid waste containing some solids which consists of washing water, faeces, urine and laundry waste, chemicals and other materials which goes down drains and toilets and finally discharged at a discharged point (Mesdaghinia et al., 2009).

In Ghana, most health facilities have adopted treatment technologies for hospital waste due to its hazardous nature but few others discharge into other channels without adequate treatment to remove contaminants that would meet the wastewater standards meant to be disposed into the environment (Obuobie et al, 2006).

2.2 Overview of hospital waste management in Ghana

Medications are consumed in thousands of homes and healthcare institution in Ghana on daily basis. There is a growing concern in the medical and the environmental protection communities concerning the current handling and disposal methods for pharmaceutical waste and other waste materials from hospitals (Hackett, 1989; Prüss et al., 2002). In the recent years waste management and other sanitation related programs in hospitals have received some attention in Ghana (Haruvy, 1997; Letterman et al., 1999).

At present there are no specific regulations, legislation or by laws for the management of health care waste in Ghana. According to the ministry of health document on policy and guidelines for institution on health care waste management in Ghana, solid waste materials from hospital, which also include pharmaceutical waste, require different handling and disposal technologies. The World Health Organization (1996) states that, “health care waste is considered the second most hazardous waste after radioactive waste. It is the responsibility of the health care establishment to treat and dispose waste material generated by them in such a manner to ensure that there would be no adverse health or environmental effect.

2.3 Management of wastewater effluent discharge into the environment

Increasing urban population, changing lifestyles and industrialization has led to generation of high volumes of wastewater of many categories into receiving water bodies and natural environment (Hida et al., 2008; Sasu et al., 2011). The quality of effluent discharge has deteriorated over the years hence, there is the need for treatment before it can be recycled for any purpose. Since effluent treatment is an expensive process, many of the underdeveloped and developing nations of Africa and Asia have not been able to treat their effluent to appropriate levels and continue to use it in agriculture with deleterious long-term effects on soil, groundwater and human health (Sasu et al., 2011).

There is the need for effluent treatment for the fact that untreated wastewater discharged into a natural water bodies constitute a great hazard in the environment and a health risk for human and animal life. The environmental risk is mainly due to overloading of physical and chemical components associated with human activity into an aquifer (Hutton, 2004).

The use of on-site treatment systems is quite extensive in Ghanaian communities. Individual and community/residential based septic tanks are the most preferred. Septic tanks only partially treat sewage, and the effluent is still rich in organic material. The septic tank has to be emptied from time to time and the disposal of the septic sludge causes severe public health and environmental concern particularly in urban areas in Ghana (Spellman and Drinan, 2012). Major wastewater treatment methods found in Ghana includes stabilization ponds, trickling filters and activated sludge plants. More than half of all treatment plants in Ghana are in the Greater Accra region, mainly in the capital city of Accra and Tema. The stabilization pond method is the most extensively used method with almost all faecal sludge well treated before discharge (Obuobie et al, 2006).

2.4 Environmental Impacts of Hospital Effluent

Interest in the environmental impacts for natural waters has emerged in the past decade, particularly in developed countries where large quantities of pharmaceuticals are consumed by humans and are used in agriculture. Concerns about environmental contamination by pharmaceuticals were first raised in the 1970s (Heberer, 2002). In the 1980s, some preliminary analyses and estimates of pharmaceuticals concentration in surface water and potable water were performed. From the 1990s, technologies have become sufficiently advanced for researchers to quantify pharmaceuticals concentration in aquatic samples at µg/L and ng/L levels (Verlicchi et al., 2010). There has been a lot of gradual increase in revealing of Pharmaceuticals in aquatic environments. By 1998, 25 pharmaceuticals had been identified in Asia in the aquatic environment, but the number increased to 68 by 1999, and more than 80 by 2002 (Hartmann et al., 1998). Increasing detection of pharmaceuticals in the environment was largely due to improvement in analytical methodology and technology for measuring low concentration of Pharmaceuticals in water. Greater urban density and the increasing use of pharmaceuticals may also have contributed to the trend (Heberer, 2002).

2.4.1 Impacts of Pharmaceuticals in drinking water and its effect on human health

Pharmaceuticals have been detected in drinking water in Canada and other countries at ng/L concentration or lower (Joss et al., 2006). However there is currently no evidence that these levels of pharmaceuticals have detrimental effects on human health. Environmental risk assessment considering endpoint in terms of human health demonstrates that the levels of Pharmaceuticals in drinking water are unlikely to harm healthy adults. However, a lack of evidence of effects does not constitute a lack of effects, and the possibility of chronic effect of long term consumption cannot be eliminated (Joss et al., 2006, Isikwue et al., 2011).

2.4.2 Impacts of pharmaceuticals in surface water on aquatic organism

Certain pharmaceuticals have been found to affect organisms at ug/L to ng/L concentrations. A well-known example is the feminization of fish in surface water contaminated by 17α-ethinylestradiol (EE2), the active ingredient in oral contraceptive from wastewater treatment plant effluent (Jobling et al., 1998). Environmental risk assessment for Pharmaceuticals and other microorganism found in hospital effluents, such as ibuprofen, paracetamol, carbamazepine, germfibrozil, mefenaminacid, and disinfectants are likely present in some aquatic environments at levels sufficiently high to harm aquatic organisms (Daughton & Terns, 1999). Pharmaceuticals can be expected to have effect on aquatic organism, as they are often highly bioactive. Even at low concentrations, they are designed to resist degradation, have several target receptors and follow complex biological pathway (Daughton & Ternes, 1999). Not only can it affect vertebrate such as fish but they have also been found to affect invertebrates in laboratory studies (Spellman, 2013). In fact, some invertebrates seem more sensitive to Pharmaceuticals than many vertebrates. Effects on algae and bacterial have been documented as well (Daughton & Ternes 1999). It is known that vulture in Asia have been dying from eating cattle containing relatively low concentration of the drug diclofenac (Nasr et al., 2008). Acute effects of the result of exposure to relatively low concentration are possible. It is difficult to predict how pharmaceuticals might affect non target organism (Rushbrook et al., 1999). Therefore standard acute toxicity test are of limited use in assessing the environmental impacts of Pharmaceuticals. More sophisticated environmental assessment methods are needed, potentially microcosm and mesocosm studies and methodologies designed to test for endocrine disrupting effects (Nasr et al., 2008; Johnson et al., 1997; Wollenberger et al., 2000).

2.5 Some physico-chemical parameters which serve as indicators of hospital effluent quality

Physico- chemical characteristic offer a way to assess the state of a water body at any given period. In a number of industrialized countries as well as countries in transition, it has become a common practice to base water quality criteria for discharge of hazardous substance on the best available technology (Clara et al., 2005). Physical measurements include temperature, conductivity, total suspended solid, total dissolved solid, odor, turbidity and color whereas chemical measurement parameter include pH, alkalinity, hardness, biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate, nitrate, nitrite, and dissolved oxygen.

2.5.1 Nitrates and Nitrites

Nitrate and nitrite have been identified as major pollutants in groundwater worldwide (Horne, 1995). Nitrate has been the most widely investigated chemical contaminant derived from hospital effluent and this is as a result of the high concentrations of nitrogen in human excreta and its adverse impacts on human health (APHA, 2010). Sources of Nitrates (NO_3) and nitrite (NO_2) include the application of Nitrogen fertilizer as well as the disposal of human or animal waste. Both Nitrate (NO_3-) and nitrite (NO_2-) are very mobile in water, and groundwater typically contains higher levels than surface water (UNICEF, 2008).

Ghana’s EPA requires that the maximum contaminant limit of nitrate in wastewater discharged into a receiving environment should not exceed 50mg/l. Drinking water with concentrations between 11mg/l and 40 mg/l of nitrate causes methemoglobinemia according to Baird (1999).

2.5.2 Total Dissolved Solid (TDS) and Total Suspended solid (TSS)

One of the common parameters used in defining a wastewater is TSS and TDS. Total dissolved solids and total suspended solid comprised of organic matter and inorganic salts, and non-filterable substances which may originate from sources such as sewage, effluent discharge, and urban run-off or from natural bicarbonates, chlorides, sulphate, nitrate, sodium, potassium, calcium and magnesium (). Color, taste and odour are aesthetic properties of water that are judged subjectively and are caused by dissolved and suspended impurities either from the natural sources or from the discharges from domestic and industrial waste into the water caused by man. Turbidity in water is caused by suspended and colloided matter such as clay, silt, finely divided organic and inorganic matters and plankton and other microscopic organism. (APHA, 2010). Suspended solid and turbidity have been found to influence the diversity of fish and phytoplankton (Sasu et al., 2011). TDS concentration beyond 500 mg/l, decreases palatability and may cause gastrointestinal irritation and constipation effects. However, no health based guideline values exist for total dissolved solid. The Ghana Environmental protection Agency (EPA) requires that wastewater discharged into the receiving environment should not have a TDS and TSS values exceeding 1000mg/l and 50mg/l respectively (EPA, 2010). A higher level of dissolved solids increase the density of water, influences osmo- regulation of fresh water organism, reduces solubility of gases like oxygen and reduces utility of water for drinking, irrigation and industrial purposes (Sasu et al., 2011). TDS is the summed ion concentration of minerals dissolved in water. Coote et al. (2005) reported TDS value as high as 1166.89 mg/l in a hospital waste effluent. Ekhaise and Omavwoya (2008), in a similar research reported TSS values of a hospital wastewater to be in the range 61mg/l to 147mg/l.

2.5.3 pH

pH measures the concentration of hydrogen ions. It is measured by using either an electrode, which gives a digital reading, or an acid-base indicator dye, which changes color as the pH increases or decreases. The significance of pH lies in the fact that it influences the taste and odour of a substance significantly (Coote et al., 2005). Also, Coote et al., (2000) asserts that low pH values can lead to health concerns associated with corrosion of metal containers. pH of more than 5 is found to increase the survival time of bacteria in soils whiles low pH enhances the retention of bacteria (Maiti, 2013). According to Maiti (20130) a pH range of 5.0-8.5 is suitable for the growth of *Legionella*. Water with low pH increases the solubility of nutrients like phosphates and nitrates, thereby corroding pipes in drinking water distribution systems and releases lead, cadmium, copper, zinc and ions into drinking water. However, the pH levels of water samples are influenced by the presence of dissolved carbonates and bicarbonates (Brown et al., 2006). Furthermore, the ability of the concentration of pH to corrode metals possibly could influence water disinfection. The Ghana EPA guideline requires that the pH in wastewater should be in the range 6-9 before it can be effectively discharged into a receiving environment (EPA, 2010). Mahvi et al., (2009) reported pH values in a wastewater sampled from a hospital and it varied from 6.13 to 6.78.Mesdaghinia et al. (2004), also reported a pH range between 6.2 and 8 in a hospital waste effluent. In Indonesia, the range of pH in the hospital wastewater was obtained to be 5.9-12.5.

2.5.4 Temperature

Temperature is one of the important factors in an aquatic environment for its effects on the Chemistry and biological reactions in the organisms. Temperature affects physical, chemical and bacteriological process in water bodies, and therefore the concentration of many variables. As water temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilization of substances from the water. Increase temperature also increases the solubility of gases in water such as oxygen (O_2), carbondioxide (CO_2), Nitrogen gas (N_2) and Methane (CH_4) (Brown et al., 2006). In general the temperature of domestic and municipal sewage is slightly higher than the water supply because heat is added during the utilization of the water (Brown et al., 2006).

Microorganism's growth is influenced by temperature some of which produce bad tasting metabolites and odour (Ahmed & Sorenson, 1995) Ahmed & Sorenson (1995) also established that water temperature is an important factor in reducing the survival of total coliform and *E. coli*. It has also been noted by Paluszak et al., (2003) that a fecal bacterium in environmental waters generally increases as temperature decreases. Low water temperatures aid in longer survival of bacteria (WHO, 2010). *Legionella* has been found to survive in varied water temperatures of 0-63 °C (WHO, 2010). A study revealed higher occurrence of coliform bacteria when water temperatures were above 15 °C. This shows temperature as a factor influencing bacterial growth. Thus warm climatic zones support rapid bacterial growth than cold climatic zones. The concentration of dissolve gases and their solubility in water is also influenced by temperature (Chanda, 1999). Increased temperatures also increases the concentration of total dissolved solids through the evaporation of water leading to decrease in water volumes. The mean temperature values varies with the local air temperatures. For lower temperatures the microbial reactions will appear more slowly, and at very high temperatures, aerobic digestion and nitrification stop. Effluent water with higher temperatures than naturally found in the recipient could also affect the conditions regarding aquatic life, as it can cause a change in the species of fish that can live there (Tchobanoglous et al., 2011). Wastewater temperatures, as high as 30 to 35°C have been reported for countries in Africa and Middle East (Tchobanoglous et al., 2011).

2.5.5 Electrical Conductivity (EC)

The conductivity of water is an expression of its ability to conduct electric current hence relate to the ionic content of the sample which is in turn a function of the dissolved solids concentration. It is a physical parameter of water which reflects the mineral salt content of water. The electrical conductivity of water is used as an indirect measure of the concentration of dissolved solids, which can affect the taste and salinity of the water (mostly from the dissociation of mineral salts). The conductivity of water may range from 10 to 1,000µScm^{-1} but may exceed 1,000 µScm^{-1}, especially in polluted water (APHA, 2010). Conductivity provides an indication that the composition of the water particularly the mineral concentration has changed (Chanda, 1999).

2.5.6 Phosphate phosphorus

Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates) and organically bound phosphates. They occur in solution, in particles or detritus, or in the bodies of aquatic organisms. Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm runoff. They are major constituents of many commercial cleaning preparations (APHA, 2010).

Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contains phosphates (Reed et al., 1995). They exist in solution as particles, loose fragments or in the bodies of aquatic organisms. Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate stimulates the growth of plankton and aquatic plants which provides food for fishes. Phosphate also leaches into groundwater. It may not be toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates (APHA, 2010). Mahvi et al., (2009) reported the lowest value of phosphate of 0.54 mg/L and highest value of phosphate 51.5mg/L in a research work conducted in wastewater effluent collected from Rafsanjan Ali Ebn Abi Taleb Hospital in Iran. The Ghana EPA guidelines requires that total phosphorous in wastewater that is to be discharged into a receiving environment should not exceed 2mg/l as this may lead to cultural eutrophication (a biological effect in which there is an increase in plant nutrients causing excessive algae growth and bloom in water bodies).

2.5.7 Dissolved Oxygen (DO)

Dissolved oxygen represents the amount of oxygen in dissolved state in sewage. According to Reed and Brown (1995), sewage has generally no dissolved oxygen (DO) which is contentious. Thus DO presence in raw sewage indicates the sewage is fresh and its presence in the effluent treatment indicates that considerable oxidation has been accomplished by the sewage treatment methods. DO parameter has been regarded as indicator of the performance of aeration systems. Mahvi et al., (2009) reported an average DO value in hospital wastewater sampled from Kerman Province Hospitals to be 2.3mg/L. Ekhaise and Omavwoya (2008) reported low dissolved oxygen values in the ranges of 2.4 mg/l to 5.4 mg/l in a hospital waste effluent.

2.5.8 Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

BOD_5 gives a quantitative index of the degradable organic substances in water and is used as a measure of waste strength. Microorganism use the atmospheric oxygen dissolved in the water for biochemical oxidation of organic matter, which is their source of carbon (Mesdaghinia et al., 2004).The biochemical oxygen demand is used as an approximate measure of the amount of biochemically degradable organic matter present in a sample

(Reed et al., 2009). The chemical oxygen demand on the other hand provide the measure of the oxygen equivalent of that portion of the organic matter in a water sample that is susceptible to oxidation (Mahvi et al., 2009). The COD is often measured as a rapid indicator of organic pollutant in water. The COD measures biodegradable and non-biodegradable organic matter of wastewaters. It is a test used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution. Some research work has been conducted on hospital waste effluent and their findings reported to have various BOD_5 and COD ranges; Giesy et al., 1999; Mahvi et al, (2009) in a research work conducted at Kerman Province Hospital, Iran reported an average BOD_5 and COD values to be 73 mg/l and 162mg/l respectively; Ekhaise et al. (2008) reported an average value of 374 mg/l and 60.5 mg/l for COD and BOD_5 in a hospital waste effluent respectively; Ekhaise et al., (2008) reported that BOD_5 and COD in hospital waste effluent were 113mg/l and 188 mg/l respectively; Sarafraz (2006) also reported BOD_5 and COD in hospital effluent were 12.53 mg/l and 51.7 mg/l respectively. The minimum and maximum concentrations of BOD_5 and COD were obtained in Valiasr Hospital and Bahrami Hospital, Iran to be 228 mg/l and 435 mg/l respectively. A similar research conducted also reported the average concentrations of BOD_5 and COD in Bahrami Hospital waste effluent to be 768 mg/l and 1362 mg/l respectively (Mesdaghinia et al., 2004). In Bangkok, the BOD_5 and COD concentrations of a hospital wastewater were 300 mg/l and 430 mg/l respectively (Mesdaghinia et al., 2004; Geldreich, 1996). The Ghana EPA has set the maximum contaminant level of BOD_5 and COD for wastewater discharged into a receiving environment to be 50 mg/l and 250 mg/l respectively (EPA, 2010).

2.6 Bacteriological indicators of Hospital Effluent

Attempting to assess the occurrence of microbial pathogens in aquatic environment of polluted wastewater from hospital is very difficult due to multiplicity of factors. Low levels of pathogen may be present, it is quite necessary to monitor the supplies or the flow of indicator organisms (Spelman, 2013). Indicator organisms are easier to identify than pathogen because they occur in higher numbers. The basic assumption of this approach is that the presence of indicator organism is associated with the presence of pathogens (Brown et al., 2006). Brown et al., (2006) described these criteria as an ideal indicator as follows: An indicator should be applicable of all types of waters subject to investigation; the indicator must be present in the same or higher numbers than pathogen in all cases where the latter is found; Number of any indicator microorganism should not increase significantly in the absence of health hazard; Indicator microorganism should be more resistance to the physico chemical stress within aquatic environment, hence exhibit greater survival than pathogens; Indicator reaction or test data should be unique and characteristic of that microorganism or determination; Detectable by sample rapid and inexpensive methods; The presence of high coliforms densities in wastewater samples during sampling periods may be an indication of pollution of the environment due to human activities. Aluyi et al. (2006) reported high faecal load with high concentration of *E. coli* in wastewater discharged from university of Benin Teaching hospital and this was attributed to human activities. Ekhaise and Omavwoya (2008) reported total coliform counts ranging from $1.9x10^{7}$cfu/ml to $8.3x10^{18}$ cfu/ml in hospital wastewater. Mesdaghinia et al., (2009) reported that the minimum and maximum numbers of total coliforms obtained in the wastewater of Razi Hospital and Bahrami Hospital ranged from 2.2×10^{7} and 3.8×10^{8} MPN/100 mL respectively. The primary concern in bacteriological wastewater quality assessment is from diseases that are transmitted to human and through water contamination with human or animal wastes. Coliforms including *Escherichia coli* which are members of the family *Enterobacteriaceae* make up approximately 10% of the intestinal microorganism of human and other animals and have found widespread use as indicator organism (Sasu et al., 2011). Faecal coliform (FC) sometime called thermo tolerant coliform organisms including *E. coli*, are the most appropriate indicators of faecal pollution. According to Sasu et al., (2011), it is less useful to test for total coliform (TC) because they are not directly related to the presence of faecal coliform contamination and consequently to the risk of disease. This is also because the coliforms group include a wide range of bacteria whose primary source may not be the intestinal track of human and animals (Paluszak, 2003).

2.7 Pre-treatment of Hospital Effluent as a risk management approach

Due to the anticipated occurrence of pathogens, microbial organisms and pharmaceuticals in hospital effluent, it is important to consider the available options that exist for implementation of pretreatment technologies as identified sources. Pretreatment options of interest include physical, chemical, and microbial based treatment processes. However, due to the risk of developing antibiotic resistance bacteria, microbial base treatment technologies should be considered as a last resort option (Spellman et al., 2012).

Physical- chemical treatment processes such as Nano-filtration, reverse osmosis, oxidation and advanced oxidation demonstrated proven potential to separate or oxidize organic contaminants in aqueous system (Spellman et al., 2012). For pretreatment on site, however, advanced oxidation has greater promise due to its smaller space requirement and lower initial cost. From the growing literature, only one study to date reports on the effectiveness of an advance oxidation technology to degrade a pharmaceutical and personal care product (PPCP) like ciprofloxacin using real hospital effluent samples as the test matrix. Ciprofloxacin with an initial concentration of 200 µg/l was completely destroyed within 1 hr using a heterogeneous photocatalytic process (Spellman et al., 2012). The rest of related literature is full of reports of Advance Oxidation Processes (AOPs) which was evaluated base on spiking pharmaceuticals into distilled water or drinking water. In order to understand the actual effectiveness of existing oxidation technologies, evaluation should be done with real Hospital samples to evaluate matrix competition for the oxidants (Halling-Sørensen et al., 2000).

2.8 Health care facilities as potential sources of Pharmaceutical and Personal care Products (PPCPs) to municipal wastewater

Environmental waters contamination with PPCPs is wide spread and our understanding of associated exposure risk is limited. As a precautionary measure, risk management effects to characterize sources of PPCPs to environmental systems and promote removal of PPCPs from known release point are needed. Source characterization data is lacking for PPCPs and the use of data for PPCPs is also difficult to obtain across sectors of society or on an individual community. However the health care sector control the flow of pharmaceuticals to patient and administered doses at much higher levels than are usually prescribed to the general public. Health care facilities also administer hormones therapy using natural and synthetic hormone. These facilities also are consumer of detergents use in house to launder linens. Therefore healthcare facilities are a logical starting point when attempting to characterize important sources of PPCPs release to municipal wastewater (WHO, 2010).

In the United States there are approximately 9,178 general medical and surgical hospitals (North American Industry Classification System (NAICS Code: 622110), 21,459 nursing care facilities (NAICS Code: 6233110) 6,843 containing care retirement communities (NAICS Code: 623311) and 3,491 homes for elderly (NAICS Code: 623312) providing health care services for millions of patients. The importance of these health care facilities is potential point source contributor of PPCPs to municipal wastewater system is widely anticipated, but there is a lack of information in literature regarding the concentration and magnitude of PPCPs in the wastewater from these facilities (WHO, 1996)

Beginning the mid-1980s, researchers begun developing methods to determine the concentration of individual pharmaceutical classes in hospital effluents that were release either due to patient excretions or disposal practices of expired pharmaceuticals. Heberer (2002), investigated chemotherapeutic platinum- based compounds, which was the first class of pharmaceuticals compounds investigated.

While determining the concentration of pharmaceuticals in hospital effluent is timely, concentration data alone does not allow for the characterization of hospital effluent as sources of pharmaceuticals in the environment. In order to characterize hospitals as a source, flow data need to be integrated to determine a mass loading of pharmaceuticals from the facilities (Heberer, 2002).

From the limited data available in the literature, it is apparent that hospitals do release some pharmaceuticals to municipal sewer system and the environment. However, hospital effluents have not been evaluated for the presence of many of the commonly prescribes pharmaceutical or for other personal care products.

2.9 Water Consumption/usage in hospitals

Hospitals require a significant amount of water per day for different purposes and services depending on the activities which take place within the structure. The quantity of wastewaters (WWs) produced in a hospital depends on so many factors: bed numbers, hospital age, accessibility to water, general services present inside the structure (kitchen, laundry and air conditioning), numbers and type of wards and units, institution management policies and awareness in managing the structure in safe guarding the environment, climate, culture and geographical factors (Joss et al., 2005).

In addition literature data for specific water consumption for commercial, institutional and recreational sources show that the rate for hospital is much greater than other specific consumption and that it ranges over a wider interval (Tchobanoglous et al., 2011).

2.10 Chemical and Microbiological Characteristic of Hospital Effluent

Many chemicals and pharmaceutical waste used in health care establishment are hazardous toxic, genotoxic, corrosive, flammable, reactive, explosive, shock sensitive, carcinogenic, and pathogenic. These substances are usually in small quantities in health care waste; larger quantity may be found when unwanted or outdated chemicals are disposed. They may cause intoxication, either by acute, or by chronic exposure, and injuries including burns (WHO, 2010).

2.10.1 Common macropollutant

An in depth literature has been conducted on conventional pollutants of wastewater from hospital of different sizes (60-900 beds), different wards and of the following countries: France Turkey, India, Iran, Thailand, Canada and Greece (Nasr et al., 2008).

2.10.2 Micropollutants

A great variety of chemical substances commonly used in hospitals for laboratory and research activities in surgery. These do not only including pharmaceuticals but also diagnostic agents and disinfectants. The main class of compound used in hospitals is reported in Table 2.1 (Joss et al., 2006).

Table 2.1 Main Class of Compound used in hospitals

Class	Examples
Antibiotics	Cefazolin, chlortetracycline, ciprofloxacin, ciprofloxacin, Doxycycline, erythromycin, lincomycin, norfloxacin, ofloxacin, Oxytetracycline, penicillin, sulfamethoxazole, tetracyclin, Trimetoprime
Analgesics &Anti inflammatorie	codeine, diclofenac, dipyrone, ibuprofen, indomethacin, Mefenamic acid, naproxen, paracetamol, propyphenazone salycilic acid
Cytostatics	5-fluorouracil, ifosfamide
Anaesthetics	Propofol
Disinfectants	Triclosan, glutaradehyde
Heavy metals	Platinum, mercury
Iodized contrast	Iopromide, iopamidol

The type and amount of pharmaceuticals in hospital wastewater reflect the substances and quantities of the particular drugs being administered there. In the case of outpatient at the Razi Hospital, unmetabolized drugs excretion partially occur inside the hospital with the remainder elsewhere. This will depend on the specific therapy and the time spent at the hospital. For instance, cytostatics are administered at high percentages in out patients' treatment wards, but relevant amount of them were found in the wastewater of inpatient treatments wards (Joss et al., 2006).

2.10.3 Disinfectants

These are used in large quantities for the disinfection of surfaces, instrument and skins, in glue and size production and use, and in food processing. They are often highly complex product or mixtures of active substances: alcohol and aldehydes as well as chlorine containing compound such as recalcitrant chlorophenols which are used as active compounds. The main heavy metals found in HWWs are platinum. They are excreted by patients treated with cis-platinum and carboplatinum or other cytostatic agents; mercury usually found in diagnostic agents, active ingredients of disinfectants as well as diuretic agents, which is uses in magnetic Resident Images (MRI) due to its high magnetic moment.

Finally, adsorbable organic compounds (AOX) are the most persistent in the environment. They also tend to accumulate in the food chain; often they are toxic to humans and aquatic organisms. In clinical wastewater the main contributors to the burden of total AOX are iopromide (ICM) (Joss et al., 2006). Concentrations of pharmaceuticals in hospital wastewater as well as in urban wastewater are the results of the combination of characteristic (mainly stability and biodegradability) of the specific compounds (Abi Saleh et al., 1996).

2.10.4 Antimicrobials

Antimicrobials can disrupt wastewater treatment process and have a high potential for ecosystem impact because they are designed specifically to be toxic to bacteria (Hartmann et al., 1998). They can be hydrophobic or hydrophilic and some bio-accumulate. Some such as erythromycin also appears to accumulate in soils. It is possible that low concentration of antimicrobials in natural waters may exert selective pressure leading to the development of antimicrobiotic resistance in bacteria. Other sources of antimicrobials of special concern include: Agriculture which account for 50% of antibiotic used in Europe, and manure used as fertilizer represent a potential source of antibiotic contaminations of surface water and ground water (Kolpin et al., 2006). Concentrations of antibiotics of most pathogen have been found in hospital effluent indicating the possible excretion of selective pressure on pathogenic bacteria. In particular, ciprofloxacin, a fluoroquinolone antimicrobial, is known to be highly toxic to bacteria (Hatmann et al., 1998), and is therefore of special concern with regard to ecosystem impacts.

2.10.5 Synthetic Hormones

These have the potential to affect the endrocrine system of humans and wild life at low levels. The main synthetic hormones found in environmental sample is 17α-ethinylestradiol (EE2), used in oral contraceptives for humans. Other synthetic hormones exist, such as mestranol also used as human oral contraceptive but has only been found occasionally in environmental samples (Heberer, 2002). A study of aquifer storage recovery by Charry et al., (2008) determined that EE2 did not degrade significantly in aquifer material over the period of 70 days.

EE2 is a major concern because it is extremely potent at very low concentrations. A concentration of 0.1 ng/L EE2 in surface water is sufficient to induce productions of the female egg protein vitellogen in male rainbow trout (Purdom et al., 1994). In U.K, concentrations of EE2 of up to 10 ng/L are commonly found in wastewater treatment plant and hospital effluents (Purdom et al., 1994). Studies have shown over the years that effluent discharge from a hospital in the receiving environment if left untreated is capable of causing potential health hazard to the environment and human.

2.10.6 Lipid regulators

Lipid regulators are among the most ubiquitous chemicals in environmental samples. Clofibric acid, a metabolite of the lipid regulator clofibrate was the first pharmaceuticals chemicals to be found in tap water at concentration of 10 -165ng/L in Berlin. Clofibric acid is extremely persistent due to it its chemical properties. It has a reported half-life of up to 21 years and continue to be found in environmental samples, including drinking water even in location where it has been removed from the market, trace sample of clofibric acid are still been found (Joss et al., 2006).

2.10.7 Anti-inflammatories and analgesics

Anti inflammatories and analgesics include some of the most widely used pharmaceuticals such as the over-the –counter pain killers acetaminophen, ibuprofen and acetylsalicylic acid (ASA). They are ubiquitous in surface water and are occasionally detected in ground water. Oaks et al., (2004) detected 6ng/L diclofenac, 3ng/L ibuprofen, and 50 ng/L phenazone in German tap water. Diclofenac has received increased attention recently as it has been found to be responsible for the death of more than 95% of the oriental white back vultures (Oaks et al., 2004). Although it is photodegradable diclofenac has been found in ground water samples.

2.10.8 Anti-epileptics

The anti convulsant drug carbamazepine is frequently found in environmental samples. It has been detected in surface water up to 1.1 µg/L and in ground water at 900 µg/L, and has been found in Canadian drinking water as well as 30 µg/L in German drinking water (Clara et al., 2005). The anti-epileptics carbamazepine and primidone were found to persist and were readily transported to ground water during bank filtration experiments (Clara et al., 2005). Carbamazepine is so persistent that some researchers have suggested it be used as a tracer to indicate water contamination by sewage effluent (Amoatey & bani, 2010).

2.10.9 Selective Serotonin Reuptake Inhibitors (SSRIs)

Selective serotonin reuptake inhibitors (SSRI) such as fluxetine are usually prescribed as anti-depressants. They can exert a wide range of effects on aquatic organisms, especially on invertebrates, inducing reactions such as the spawning of mussels (Coote et al., 2005). Fluoxetine has been detected at low level in Canadian surface water and in wastewater treatment plant effluents.

2.11 Heavy metals and irrigation water

It is believed that an estimated twenty million hectares in 50 countries worldwide are irrigated with raw or partially treated wastewater and this is even more likely to increase in the next few decades as water stress intensifies (Bempah et al., 2011). Wastewaters effluent depending on its source could contain high levels of heavy metals. Heavy metals are transported through wastewaters either as dissolved and/ or as adsorbed substances to suspended solids. The mobility of the metal levels in water is a function of the pH of the water, and increases with a decrease in pH (Bempah et al., 2011). Therefore free metal ions become released into the water column and subsequently enter into the food chain.

Inadequate water supply in Accra, makes it difficult for vegetable farmers to get suitable water for urban agriculture. It is a common practice that majority of vegetable growers use wastewater for irrigation (Anim-Gyampo et al., 2014). The effluent from hospitals and other industrial companies containing toxic chemicals and pathogens are channeled through closed gutters untreated. A survey conducted in Accra Metropolis revealed that only few vegetable growers used tap water and bore-hole waters, but the majority relied on rainfall, streams, rivers and wastewater from gutters to irrigate their crops (Obuobie et al., 2006).

As a remedy to reduce heavy metal pollution in irrigation water, recent studies have employed the use of microalgae in irrigation waters to remove free metals ions from the water due to their high affinity to sequester the metals (Kumar et al., 2015). Some farmers are aware of the risks involved in using wastewater for crop production and the application of this microalgae technology could promote safer vegetable production as wastewater treatment is cost effective.

2.12 Heavy metals in soil

Soil has the ability to immobilise introduced chemicals like heavy metal ions. The natural processes of weathering and/ or mining release heavy metals in the soil. The transport of these metals depend on their physicochemical properties such as density, conductivity, reactivity and also on the physicochemical properties of the soil including; pH, organic matter content, clay fraction content, mineralogical composition all of which collectively determine the binding ability of soil (Hamilton et al., 2007).

The metals introduced exist in soil solutions as either free (uncomplexed) metal ions in various soluble complexes with inorganic or organic ligands or associated with mobile inorganic and organic colloidal material (Kumar et al., 2015). The metals become readily mobile based on their solubility and exchangeable forms or they could be bound within the crystalline lattice structure of clay minerals. The heavy metals are mobile at lower pH but tend to be immobilized at higher pH rates (Wright et al., 2012). The heavy metal levels generally decrease from clay to coarse slit and to rich organic matter soils due to the high surface area of clay minerals and weak pH dependence of cation exchange capacity (Hamilton et al., 2007).

Moreover, agriculture lands have witnessed several residue depositions from the atmosphere and industries especially the mining companies either directly or indirectly. These depositions have caused the elevation of contaminants like heavy metals to increase in the soils. And as much as agricultural organic soils accumulate these heavy metals, a significant correlation is produced in the transfer of these metals from soils to vegetables. Numerous remedies to produce safer and quality vegetables have involved the use of greenhouse vegetable production houses, and even now on soilless greenhouse vegetable productions. This management mode is to limit the excessive application of chemicals like fertilizer and pesticides that would increase plant growth. However, this mode of production systems is not found in Ghana, where most vegetables farms are sited near gutters, refuse and other dumping areas owing to the huge cost involved in setting up the greenhouse farms. As such, many vegetables produced have been reported to contain some metals at high concentrations which pose a health threat to humans (Anim-Gyampo et al., 2012). In a study conducted in the northwest of Thessaloniki, North Greece, Kasassi et al. (2008) found low concentrations of Cr, Cu, Ni, Pb and Zn in soils samples.

2.13 Heavy metals in vegetables and Human health risk Assessment

Naturally, plants are able to take up metals which are essential to them like Fe and Zn and some few others (Hg, Cd, Ni and Pb) which are also toxic to them (Anim-Gyampo et al., 2012). Many different paths account for the deposit of heavy metals in vegetables. Potentially harmful heavy metals in soils may not come solely from the soil (bedrock), but also from human activities such as solid or liquid waste deposits and agricultural inputs (Hamilton et al., 2007). To an extent, the farmer's practices also contribute a great percentage of heavy metal uptakes by vegetables when polluted water is used for irrigation. The main routes of heavy metal entry in vegetables are through soil, water and atmospheric depositions. In a study conducted by Kasassi et al. (2008) it was found out that there was a substantial build-up of heavy metals among vegetables (Cabbage, lettuce) irrigated with water from different sources. Results of their study showed that both adults and children consuming vegetables grown in wastewater-irrigated soils ingest significant amount and poses potential human health risk to the consuming population although the metal values analyzed were below the tolerable levels. Angelova et al. (2004) also reported that the heavy metal concentrations in the leaves of cabbages grown in heavily polluted soils were found lower than those concentrations that were present in the soil.

A lot of work have been conducted on the assessment of hospital waste quality but not much studies have being conducted on the effects of this waste on vegetable production and health risk assessment therefore creating a theory gap for investigation to add to knowledge and literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter explains the procedures and methods used to collect data from the field. It also deals with the area of study and a brief description of the population, instrument used to collect data, sampling procedures, data collection techniques, type and sources of data and the technique used for data analysis.

3.2 Study Area

3.2.1 Physical and Natural Environment

The study was conducted at the University of Ghana Hospital, Legon (Figure 3.1). The hospital is located at the eastern part of the University main campus. The University is located within the Ayawaso West of the Accra Metropolitan Assembly (AMA) which is among the twenty metropolitan, municipals and districts of the Greater Accra Region of Ghana. Accra is the Administrative capital of the Metropolitan Assembly. The AMA has a total land size of 200 sq km and is made up of sub metros namely Okaikoi, Ashiedu Keteke, Ayawaso, Kpeshie, Osu Klotey and Ablekuma. The population of the Accra Metropolitan for the year 2010 housing and population census was 1,848,614 of which 887,673 were males and 960,941 were females with the growth rate of 4.3% (GSS, 2010). The gross density of the Accra Metropolitan area for the year 2010 was 10.03 person per hectare compared to 6.23 in 1970s. This implies great pressure on natural resources and land occupation (GSS, 2010).

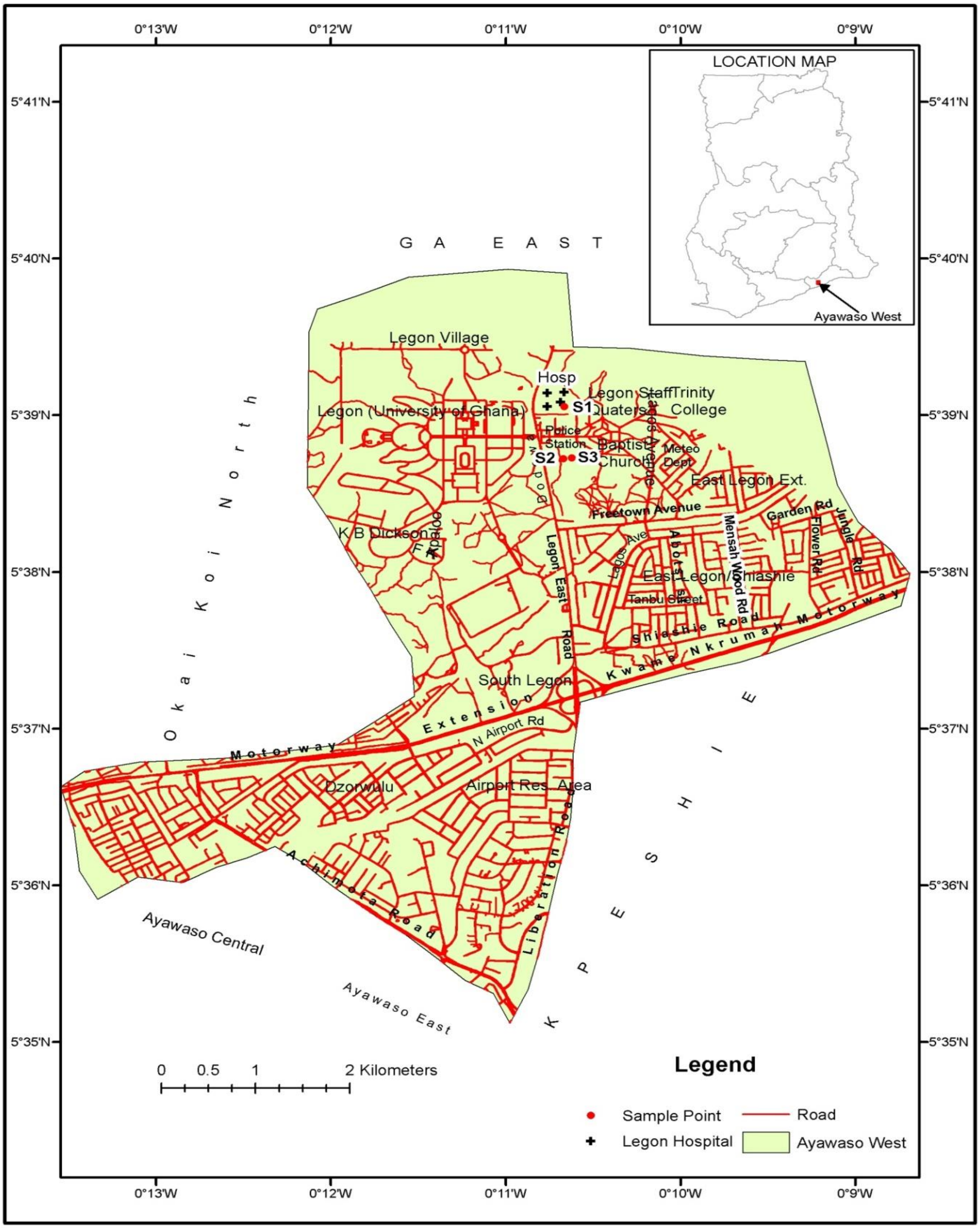

Figure: 3.1 Map of Ayawaso West showing sampling location

3.2.2 Vegetation and Climate

Evidence suggests that the vegetation of the metropolitan areas has been altered in recent century by climate and other factors such as anthropogenic (GSS, 2010). Only a few remnant trees survived from the area that was known to have been covered by dense forest. A climate change combine with the gradients of the plains and cultivation have imposed vegetation structures similar to those of the southern shale, Sudan and guinea savannahs, all of which lied in the Accra plains. There are three broad vegetation zones in the metropolitan area, which comprise shrub land, grass land and costal lands.

The Accra Metropolitan Assembly lies in the savannah zone. There are two rainy seasons: the first begins in May and ends in mid- July; the second begins in mid- August and ends in October. The average annual rainfall is 730 mm, which fall primary during first rainy season.

There is very little variation in temperature throughout the year. The main monthly temperature ranges from 24.7 ^{0}C in August (the coolest) to 28 ^{0}C in March (the hottest) with annual average of 26.8^{0}C. Relative humidity is generally high varying from 65% in the mid afternoon to 95% at night (GSS, 2010).

3.2.3 Soil and Geology

The geology of the AMA consists of sandstone shale and interbedded sandstone-shale with gypsum lenses. Other formations are the Paleozoic sediments. The coastline of Accra comprises of resistant rocks outcrops and plate and sandy beaches near the mouth of lagoons.

The soil in the Accra Metropolitan area can be divided into four main groups: draft materials resulting from deposits by wind-blown erosion; alluvial and marine motted clays of comparatively recent origin derived from underlying shales residual clays and gravels derived from weather quartzites, gneiss and schist rocks, and lateritic sandy clay soils derived from weathered Accraian sandstone bedrock formations. In many low lying poor drainage areas, pocket of alluvial ‘black cotton’ soils are found. These soils have a heavy organic content, expand and contract readily causing major problems with foundation and footings (GSS, 2010).

3.2.4 Topology and Drainage

The Accra Metropolitan drainage catchment area extends from the eastern boundary of the Nyanyanu catchment on the west of greater Accra regional boundary to Laloi east of Tema.

The Densu River catchment and Sakumo Lagoon are the largest of all the four basins within the study area. The total drainage area is about 2,500 km^2. The northern section of the basin extends inland along the Densu River about 100 km, and hilly with the highest point reaching 230 m above sea level. The southern section of the basin is low lying and comprised the Sakumo I lagoon and Panbros salt pans.

The Korle- Chemu Catchment area covers an area of 250 km^2. The principal streams that drain the catchment area are the Odaw river and its tributaries. This area contains the major urbanized areas of Accra. Many of the drainage channel area poorly developed and maintained.

The Kpeshie drainage basin covers relatively small catchment areas of 110 km^2 and the Songo- Mokwe catchment is the smallest basin in the catchment area of the metropolitan and covered about 50 km^2 (GSS, 2010)

3.2.5 Municipal Economy

The AMA economy consists of three major sectors. These sectors include: primary, secondary and tertiary sectors. Primary sector such as farming, fishing, mining and quarrying, and secondary sector such as manufacturing, electricity, gas, water, construction and tertiary sector such as wholesale, trade, retail trade, hotel, restaurant, transportation, storage, communication, financial intermediation, real estate services, public administrations, education, health and other social services. As an urban economy the service sector is the largest, employing about 531,670 people. The second largest, secondary sector employs about 22.34% of the labour force, which is 183,934 people. The unemployment rate in Accra is 12.2% with 114,189 of the labor force being unemployed (GSS, 2010).

3.2.6 Incidence of Diseases

The major health problems of AMA are essentially communicable diseases due to poor environmental sanitation, ignorance, and poverty. Malaria has been the premier disease in AMA, claiming about 53% of all out patients department (OPD) cases in 2001. The major communicable diseases are malaria, sexually Transmitted Infection, Diarrhea, Chicken Pox and Enteric Fever. In 2010, there were 1,671 cases of diarrhea and cholera. Among which there were 42 deaths; most of the cases were in Accra. This endemic disease comes with seasonal outbreak which coincides with the onset of the rainy season (GHS, 2010).

Among the 10 leading disease treated at outpatient visits, malaria ranked highest with an average incident of 53% of OPD. In contrast, the next two most frequent diagnoses were for upper respiratory infections and diarrhea disease at 11% and 6% respectively. Obviously malaria is key to any consideration of health status improvement, nationally and in AMA (GSS, 2010).

3.3 Data Collection

A reconnaissance survey was undertaken to the study site and the community around the study area in order to identify the sampling areas. Effluent samples were collected at three sampling locations within the drain distribution system; the point of discharge within the hospital premises, the mid of the drain line and the final discharged point. These sampling points were selected in order to obtain a true representative of the concentrations of parameters from the source to the final disposal point. The point of discharge is closer to the hospital facility. It is considered the first sampling point from the hospital which is coded as P-1. It is a drain closely located to the hospital facilities. This was the initial point of the sample collection. The mid of the drain line which is considered P-2 is located within the wet land from the hospital and is the second point of sampling. The final sampling area is at the point where the effluents from the hospital emerges and settle down within the wet land. This point is considered and coded as P-3. At this site, irrigations with wastewater and agriculture activities are predominant. Plates 1-3 show the various sampling points.

Plate 1: Effluent Sampling Point 1 (P-1)

Plate 2: Effluent Sampling Point 2 (P-2)

Plate 3: Effluent Sampling Point 3 (P-3)

Plate 4: Farming and Irrigation Site

Plate 5: Vegetables production at site 3

Plate 6: Vegetable production at Site 3

Figure 3.2 Illustration of farming activities
Source: Field Work, 2015.

3.4 Sampling Procedure

Strict sampling safety measures were put in place to avoid any contamination to the researcher. Sampling protocols were strictly followed to prevent influences that could affect the procedure during sampling, transportation and preservation. Water samples were collected in pre-treated polyethylene containers of 500 ml. Treatment was done by washing thoroughly with acetone and distilled water. The bottles were then allowed to dry.

Before use of the sample bottles in the field, they were rinsed again with the samples (effluent). At each sampling site, physical parameters were taken using multimeter. Samples for chemical analysis were stored at the temperature below 4 ℃ in an ice chest before they were transported to the Ecological laboratory of the University of Ghana for analysis.

Samples were collected every two weeks for three months (January, 2015 to March, 2015) and data were taken in three replicates. Parameters that were measured were physico-chemical; pH, Electrical Conductivity (EC), Temperature, Total Dissolved Solid (TDS), Total Suspended Solid (TSS) Biological Oxygen Demand (BOD_5), Dissolved Oxygen (DO) and nutrients such as phosphate phosphorus, Nitrogen Nitrite. Also bacteriological parameters such as Faecal Coliform (FC), *E-coli*, and Total Coliform (TC) were measured.

All the samples were analyzed using standard methods for examination of water and wastewater or effluent (APHA, 1995). The physical parameter such as pH, temperature, conductivities and total dissolved solid (TDS) were measured in-situ using HACH model, multi probe meter (Model YSI 63). The dissolved oxygen was determined with a DO meter and BOD measured using titrimetric methods (Azide modification of the Winkler method). Phosphates Nitrates, TSS were analyzed using HACH direct reading spectrophotometer. Faecal coliform and total coliforms were determined using membrane filtration technique (HACH, 1996, WHO, 2010). The growth media used was lauryl sulphate broth selective media for TC and FC. They were incubated at 35℃ for 48 hrs and 44℃ for 24 hrs for TC and FC respectively.

3.5 Biological Oxygen Demand (BOD_5) and Dissolved Oxygen (DO) Sampling

Two bottles, one plain and the other dark (painted with bitumen to prevent photosynthetic production of oxygen) were used for sampling. The plain ones were used for dissolved oxygen sampling and the dark bottles were used for BOD_5 sampling. The bottles were filled with effluent to overflow to avoid air bubbles from getting trapped in the bottles. The dissolved oxygen samples were fixed on site with 2 ml each of Winkler 1 (Manganous chloride) and Winkler 2 (alkaline-iodide-azide reagent). Samples, which were not analyzed within 30 minutes of collection, were kept at or below 4^0C before analysis in the laboratory.

3.6 Bacteriological Sampling

Effluent sample for bacteriological analysis was taken at each site. Glass bottles with a metal cap were used to collect the water samples. These bottles were sterilized before use and the mouths covered with aluminum foil to avoid contamination during sample collection. After collection, the samples were stored on ice to avoid multiplication of bacteria.

3.7 Soil Sampling

Soil samples were collected from the selected farm plots using a soil auger. The soil samples were taken to a depth of about 0-20cm. At each site three subsamples of soil were collected and mixed, to ensure that the sample was representative for this site. The soil were put in air-sealed plastic bags and kept cool in the field before transporting it to Ecological Laboratory for analysis.

3.8 Plant Sampling

Leaves of lettuce, cabbage and cauliflower (made up of 8-10 leaves) at each site were randomly sampled at maturity and were also composited. These samples were also kept in clipper rubber bags.

3.9 Laboratory Analysis of wastewater samples

Analyses were carried out at the Ecological Laboratory of the University of Ghana, Legon. All samples that were not analyzed immediately were kept in the refrigerator below 4^0C and later brought back for analysis.

3.9.1 Nitrate - Nitrogen (NO_3 - N) Analysis

The method used for the nitrate analysis was the Cadmium reduction method. The nitrate level in each sample was measured using Nitrate powdered pillows in a direct reading HACH spectrophotometer (Model DR. 2010). Twenty five (25) ml of the sample was measured into sample cell of the spectrophotometer. One Nitraver 5 nitrate reagent powder pillows was added to the sample. The mixture was then shaken vigorously for 1 minute. Five minutes was allowed for the solution to react after which another sample cell was filled with 25 ml of only the sample (blank). After five minutes reaction period, the blank sample was placed into the spectrophotometer for calibration. Then the prepared sample was placed into the cell holder to determine nitrate concentration at 500 nm. An orange colour of the mixture indicates the presence of nitrate.

3.9.2 Nitrite - Nitrogen (NO_2- N) Analysis

The nitrite level in each sample was measured using nitrite reagent powdered pillows in a direct reading HACH spectrophotometer (Model DR.2010). Twenty five (25) ml of the sample was measured into sample cell. One (Nitraver 3) nitrite reagent powder pillows was added to the sample. The mixture was then shaken vigorously to dissolve the powder for 20 minutes for the solution to react. A pink colour of the mixture indicates the presence of nitrite. A blank was placed into the cell holder to calibrate it (zeroing). The prepared sample was placed into the cell holder to determine the nitrite concentration at 507 nm in mg/l (HACH, 1996).

3.9.3 Nitrogen- Ammonia (NH_3-N)

The method used for ammonia- nitrogen analysis was the salicylate and spectrophotometric methods. The nitrogen ammonia level in each sample was measured using salicylate reagent powder pillows (reagent 1) and cyanurate reagent powder pillows (reagent 2) in a direct reading HACH spectrophotometer (Model DR. 2010). Twenty five (25) ml of the sample was measured using graduated mixing cylinder. Another graduating mixing cylinder was filled with the 25 ml of dematerialized water as (blank). Three drops of Mineral stabilizer was added to each of the cylinder. The solution was inverted several times to mix. Three drops of polyvinyl Alcohol dispenser was added to each cylinder and inverted several times to mix in order to aid the color formation in the reaction of Nessler reagent with ammonia ions. One milliliter of Nessler reagent was pipetted into each cylinder. Stoppered and inverted several times to mix. A 1-minute reaction period was allowed during which each solution was poured into respective blank and prepared cells. The blank was placed into holder cell to calibrate and then the prepared samples were also placed into the holder cell to determine the Nitrogen Ammonia level at 425 nm. A yellow color is formed proportional to the ammonia concentration (APHA, 1999).

3.9.4 Phosphate- Phosphorus (PO_4^{3-} -P)

Twenty five millelitres (25 ml) of water (prepared sample) was placed in the sample cell. Phosphate three phosphate reagent powder pillow was added to the sample content and swirled immediately to mix. A two- minute reaction period was allowed. A blue coloration of the mixture indicates the presence of phosphate. A blank was placed into the cell holder to calibrate it. After reaction period, the prepared sample was placed into the cell holder and the level of phosphate-phosphorus was determined at 890 nm. The spectrophotometer displayed the results in mg/l PO_4^{3-} (HACH, 1996).

3.9.5 Biochemical Oxygen Demand (BOD_5)

The BOD_5 test was done by filling the BOD bottle with the sample of water and incubating it at the specified temperature for five days. The Dissolved oxygen was measured initially and after incubation, the BOD_5 was found by the difference between the initial and the final DO. The samples taking from the field for the BOD_5 analysis were diluted. The dilution was done because BOD_5 concentration in the effluent sampled was suspected to exceed the concentration of DO available in the effluent sample as initial measurements recorded very low values. Because the initial DO was determined immediately after the dilution was made, all oxygen uptake, including that occurring during the first 15 minutes was included in the BOD_5 measurement. The dilution water was prepared by 1 ml each of Phosphate buffer, Magnesium Sulphate, Calcium Chloride and Iron (III) Chloride solution per liter of water (APHA, 1995).

Mathematically, the BOD_5 was computed as below:

Where, $BOD_5\ mg/l = \frac{DI - D2}{P}$

D1= DO of diluted sample immediately after preparation, mg/l

D2= DO of diluted sample incubated for 5 days at 20℃ mg/l

P= Decimal volumetric fraction of sample used.

3.9.6 Chemical Oxygen Demand (COD)

Fifteen milliliter COD digestion tubes (pre washed with dilute H_2SO_4) was used. One milliliter (ml) of the effluent sample was transferred (inlet) into the 250 ml Erlenmeyer flasks. A 2.5 ml standard Potassium dichromate reagent was gently added and mixed slowly with the samples. 3.5 ml of sulfuric acid reagent was added to the sample through the side of the bottle and allow it penetrate to the bottom of the bottle. The sample was then capped and mixed and allowed to get cold at room temperature. The samples in the Erlenmeyer flask were transferred to the preheated COD digested tube at 150^0C and digested for two hours minimum. The same procedures were followed in preparing a blank sample.

Titration

After two hours of digestion a light greenish color was formed. Samples were taken off and allowed to cool at room temperature. The content of the sample from the COD digestion tube was transferred into 100 ml beaker. Distilled water was added to the sample up to 50 ml mark. Three drops of ferroin were added as indicator and titrated against 0.05M of Ferrous Ammonium Sulfate solution.

Calculation

$$\text{COD as mg } O_2/L = \frac{(A-B) * M * 8000}{\text{ml sample}}$$

where:

A is ml Ferrous Ammonium Sulfate used for blank

B is ml Ferrous Ammonium Sulfate used for sample

M is Molarity of Ferrous Ammonium Sulfate

3.10. Bacteriological Analysis of wastewater samples

Samples collected from the field were analyzed within 24 hours. The total and faecal coliform bacteria present in the wastewater sample were determined by Membrane filtration (MF) technique using membrane lauryl sulphate broth. The membrane filter with 0.45μm pore size was sterilized in an incubator and used to filter 100 ml of water mixed with 10ml of the sampled water. The membrane filter was lifted from the system with a sterilized forceps after filtration and carefully placed on the sterile media in petri dish. *Escherichia coli/* coliform selective media were used as the growth medium for the culture of the faecal and total coliforms. The petri dish were covered and incubated at 37 ℃ for total coliform and 44℃ for faecal coliforms for 24hrs. After the 24 hours the petri dishes were removed from the incubator and the colonies were counted using a colony counting chamber (Gallenkamp, UK) and recorded in coliform forming units per 100ml (CFU/100ml) (APHA, 2010).

3.11. Laboratory Determination heavy metals in soil samples

The samples were air-dried, powdered and sieved. A gram (1g) of soil samples were digested with a mixture of concentrated nitric acid (3ml), per chloric acid (4ml) at 75-80^{0}C for 1-2 hours on heating mantle till a clear solution is obtained**.** After the digestion, the sample was allowed to cool and add about 50ml distilled water and filter. After the filtration you make it up to the 100ml mark corked and shake. Various element of interest were determine using Atomic Absorption Spectrophotometer (AAS) of model PinAAcle 900T.

3.12. Laboratory Determination heavy metals in plant samples

The plant samples used to determine the concentration of the heavy metals were dried for 5days at temperature of 70 °C, and ground to a powdered form. 0.1g of plant samples were weighed into digestion tubes. A volume of 5ml of ternary mixture (prepared by mixing 20 ml of $HClO_4$, 500 ml of Conc. HNO_3, and 50 ml Conc. H_2SO_4) was added to the plant material in each boiling tube under a fume hood. The content of the boiling tube were mixed and heated gently at low to medium temperature on hot plate under fume hood. The heating was continued until dense white fumes appeared. A volume of 50 ml distilled water was then added to the mixture and boiled for hal a minute at a medium heat. The mixture was then allowed to cool and was filtered completely through 9cm Whatman No. 42 filter paper with a was bottle into a 100 ml round bottle flask and up to the mark. The final solution was ten used for the determination of the heavy metals in the vegetables using an Atomic Absorption Spectrophotometer (AAS).

3.13 Human Health Risk Assessment of Heavy Metals in vegetables

3.13.1 Estimated weekly intake of vegetables

The dietary exposure of trace metal was estimated using average concentrations of vegetables species. The estimated dietary intake was compared with the current provisional tolerable daily intake set by the Joint FAO/WHO Expert Committee on Food Additive online database (FAO/WHO, 2011). The estimated daily intake (EDI) of metal from vegetables per meal of consumption was determined according to the equation used by Chary et al., (2008) below

$$EDI = \frac{\mathrm{Cmetal} \times \mathrm{C\ factor} \times \mathrm{FIR}}{\mathrm{BW}} \text{..Eq(1)}$$

Where, C_{metal} is heavy metal concentration in the vegetable (mg/kg), C_{factor} is the conversion factor (0.085), *FIR* is the food ingestion rate of Ghana [g/person/day], and BW is the average body weight for a Ghanaian. The BW of an adult Ghanaian was estimated as 60 kg (above 18 years) (Chary et al., 2008).

Table 3.1 below gives the different Food Ingestion Rates (FIR) of the vegetables consumed in Ghana. The ingestion rates of cauliflower and lettuce were however, adopted from India and Uganda respectively because that of Ghana was not available in literature.

Table 3.1: Food Ingestion Rates (FIR) of vegetables consumed in Ghana.

Vegetable	Adult(kg/day)	Children (kg/day)	References
Cabbage	0.345	0.232	Arora et al., 2008
Lettuce	0.137	0.137	Ruel et al., 2005
Cauliflower	0.182	0.118	Nabulo et al., 2012

3.13.2 Human Health Risk Assessment

The human health risk was determined using the hazard quotient (HQ) and hazard index (HI). The hazard quotient (HQ) is an estimation of non- carcinogenic health risk to the exposed population and it is defined as the ratio of the exposure (EDI) and the oral reference doses of each heavy metal. The Hazard index (HI) is the sum of all the hazard quotients of the heavy metals. An HQ and HI values less than 1 is an indication that there would not be any adverse human health risk. Thus, a daily exposure at this level is not likely to cause any adverse effects during the lifetime of an individual. On the other hand, a population exposed to a HQ and HI value greater than 1 will experience health risks (USEPA, 2011). The formula for the Hazard quotient is as shown in Equation 2 below

$$\text{HRI} = \frac{\text{EDI}}{Rfd} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Eq (2)}$$

Where EDI represents the estimated daily intake of the metal and Rfd is the oral reference dose of the metal. In this study, the oral reference doses were based on values suggested by the United States Environmental Protection Agency. These are; Hg (0.003), As (0.0003), Cd (0.001), Pb (0.004), Ni (0.02) and Cr (1.5) mg/kg/day (USEPA, 2010). The dose calculations were carried out using standard assumptions from an integrated United States EPA risk analysis and that cooking has no effect on the metals concentration.

3.14 Quality Control Measures

Proper quality control measures and precautions were taken to ensure the reliability of the results. The samples were carefully handled to avoid any external influences that could interfere with the integrity of the sample and further contamination. Glass wares were properly cleaned, and reagents were of analytical grades. Deionized water was used throughout the study. For the spectrophotometric analysis, reagent blanks were used to calibrate the instrument. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/standard reference material (SRM-1570) of National Institute of Standard and Technology were used. With the exception of temperature, multi probe meters were calibrated together using the same standard and procedures. Electrical conductivity was calibrated against 0.005, 0.05 and 0.5M standard potassium chloride solution; pH was calibrated with standard buffer at pH of 4 and 9.2. Temperature was checked against standard mercury thermometer for consistency.

3.15 Statistical data analysis

After testing for normality, the data were subjected to single factor analysis of variance (ANOVA) using STATA software package version 20. Differences were declared significant at $p \leq 0.05$ and treatment means found to be significantly different were separated using Least significant difference (LSD) (Post hoc test) at $p \leq 0.05$. Analysis of variance (ANOVA) was used to compare the significant differences in means between the three sampling locations i.e, the source (P-1), Mid drain (P-2) and discharge point (P-3). A correlation analysis (Pearson’s product moment correlation) was carried out to determine the direction, strength and association between the physico chemical and microbiological counts.

CHAPTER FOUR

RESULTS OF THE STUDY

4.1 Physico-chemical Parameters

The average values for the parameter measured for three months are computed below with their corresponding standard errors.

4.1.1 Temperature

The mean effluent wastewater temperature ranged from a minimum of 24.7℃ at sampling point P3 (discharge point) and a maximum of 27.0℃ at point P2 (middle drain) (Fig 4.1). Analysis of variance at 95% confidence level (5% level of significance) revealed that the temperature of the wastewater at the sampling sites was statistically significant (p=0.02) (Appendix 16). However when multiple comparison test (post hoc analysis) was conducted using the Least significant difference (LSD), it showed that, there was no statistically significant differences in temperature between the P1 (source) and P2 (mid drain) but was however statistically different from the P3 (discharge point). When Pearson's product moment correlation coefficient (PPMC) (Appendix 18) was carried out to establish the degree of relationship, strength and direction between the temperature and microbiological counts, it was noted that a highly strong positive and negative correlation exist between temperature and the following variables at 5% level of significance; (Temp-EC, r=-0.653), Temp-Ammonia, r= 0.770), (Temp-nitrate, r=-0.753), (Temp-TC, r= 0.6)(Table 4.1).The values for the individual sites are presented in (Appendix 1).

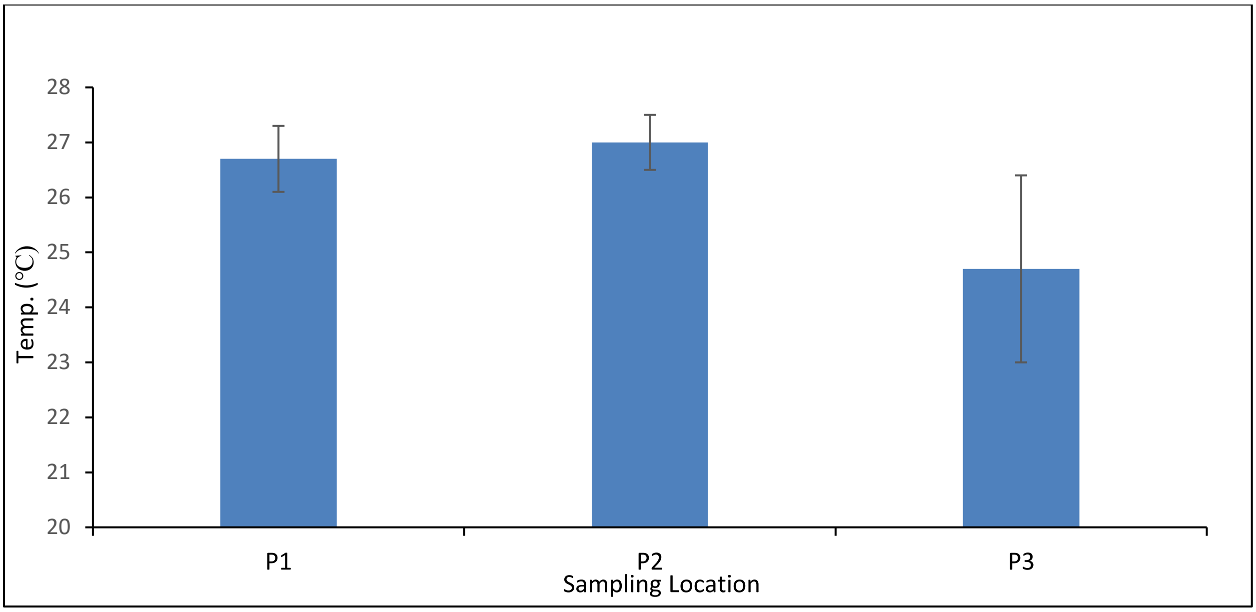

Figure 4.1: Mean values in temperature of hospital waste effluent from University of Ghana hospital

4.1.2 pH

Figure 4.2 shows the graphical illustration of the mean pH values of the wastewater effluent for the various sampling locations. The values for the individual sites are presented in Appendix 2. Analysis of variance at 95% confidence level (5% level of significance) did not show any statistically significant differences (p>0.05) in pH over the entire study period. However, the mean pH value ranged from a minimum of 8.2 both at site P1 (Source) and P2 (Mid drain) and a maximum of 8.9 at point P3 (discharge point). Pearson's product moment correlation coefficient (PPMC) analyses between the Physico-chemical and faecal coliform and total coliform revealed a significant positive correlation between pH, nitrate and ammonia at 5% level of significance (pH-nitrate, r = 0.548, pH-ammonia, r = 0.748) (Appendix 18)

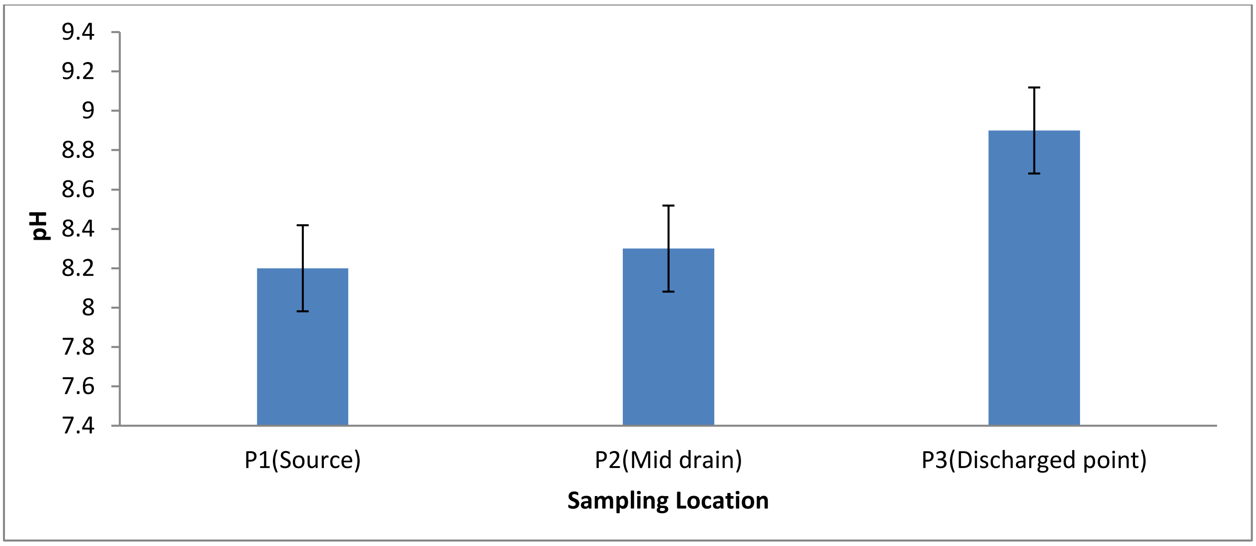

Figure 4.2: Mean variation in pH of hospital effluent waste from University of Ghana Hospital.

4.1.3 Electrical conductivity (EC)

The mean electrical conductivity of the wastewater sample ranged from a minimum of 1522 µS/cm at sampling location P2 (Mid drain) to a maximum of 2220µS/cm at point P3(discharge point). The mean conductivity values and their sampling location is illustrated below (Fig 4.3). The conductivity recorded during the sampling period differ significantly (p = 0.01, Appendix 16). When the Least significant difference (LSD) was used to compare the means, there were no differences in conductivity between the P2 (mid drain) and P1 (Source) but were however significantly different from P3 (discharge point). Absolute values recorded for the entire study period are presented in Appendix A3. Pearson's Product Moment Correlation coefficient (PPMC) analyzed between the Physico- chemical parameters revealed a highly strong positive and negative correlation between conductivity and the following variables; (EC-TDS, r= 0.678, P < 0.01), EC-Ammonia, r = 0.833, p<0.05), EC-nitrate, r= 0.775, p<0.05), (EC-Phosphate, r= -0.95, P< 0.01) (Appendix 18).

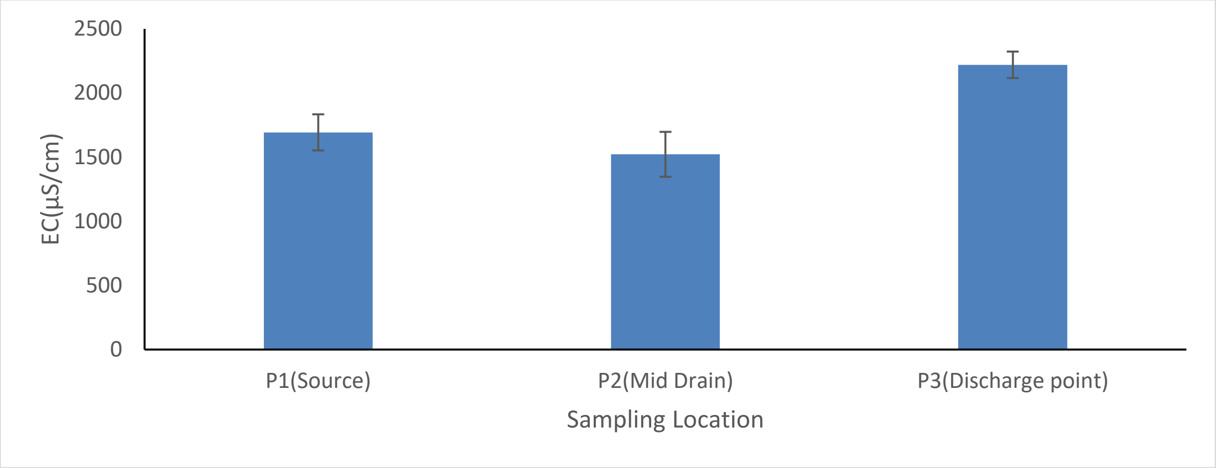

Figure 4.3: Mean value in conductivity of hospital effluent waste from University of Ghana Hospital

4.1.4 Total Dissolved Solids (TDS)

The mean values for total dissolved solids for the wastewater sampled at various sampling locations are illustrated in Figure 4.4 below. The mean TDS ranged from a minimum of 947 mg/l at point P1 (source) to a maximum of 1410.7mg/l at point P3 (discharged point). Analysis of variance at 95% confidence interval (5% level of significance) revealed that TDS was statistically significant ($p<0.05$) over the study period. However, when the LSD was used to compare the means, there were no differences in total dissolved solids between P1 (Source), mid drain (P2) but was significantly different from the discharge point (P3). TDS shows a significant positive correlation with Electrical Conductivity during the study period (TDS- EC, r=0.648, $p<0.01$) (Table 4.2) (Appendix 18).

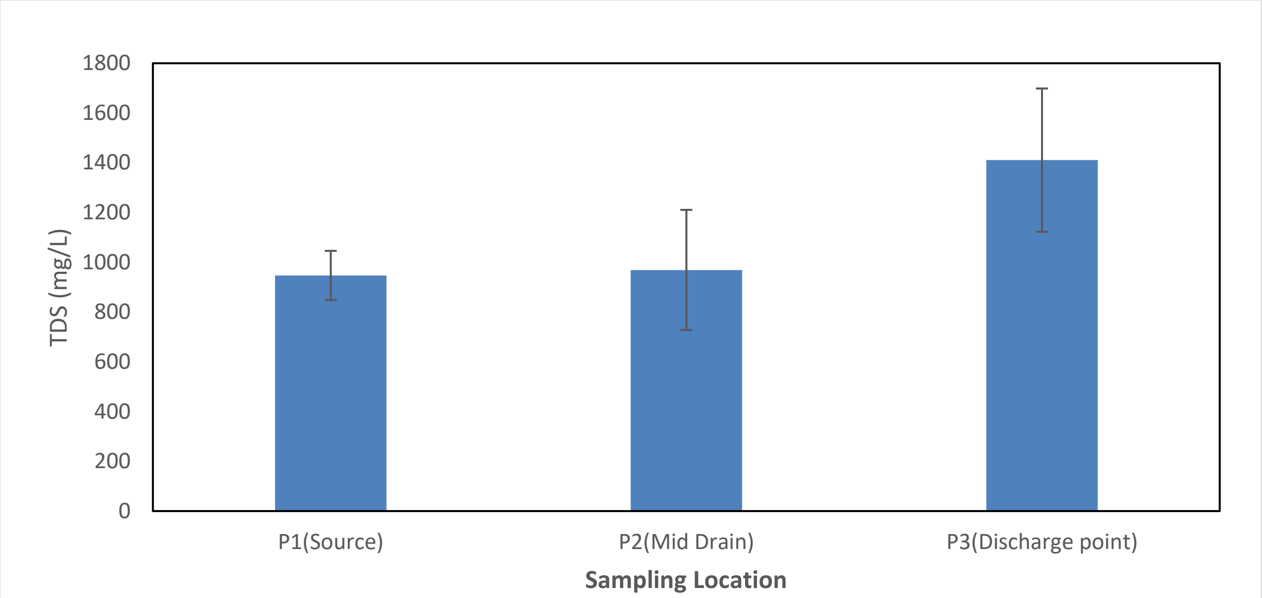

Figure 4.4: Mean value in TDS of hospital effluent waste from University of Ghana Hospital

4.1.5 Total Suspended Solids

The mean total suspended solids in the wastewater effluent ranged from a minimum of 377.2 mg/l at point P2 (Mid drain) and a maximum of 717.3 mg/l at point P3 (discharge point) (Fig.4.5). Analysis of variance at 95% confidence level (5% level of significance) revealed a statistically significant difference (p>0.05) in total suspended solids over the study period (Appendix 16). When the LSD was used to compare the means, there were no differences in total suspended solids between the P1 (Source) and P2 (Mid drain) but were however significantly different from P3 (discharge point).The values for the individual sites are presented in Appendix 5.

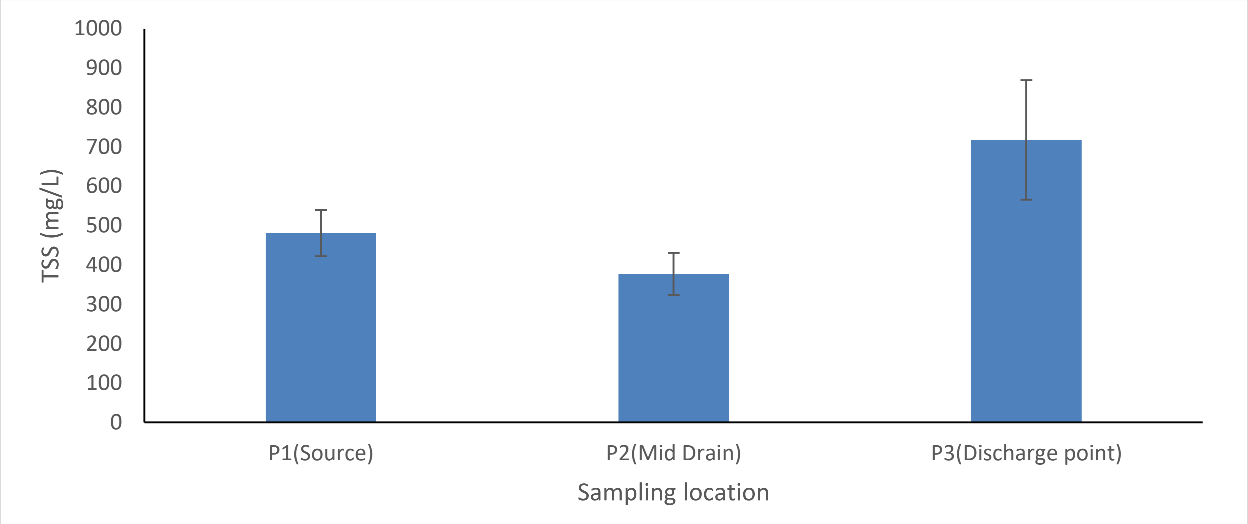

Figure 4.5: Mean values in total suspended solids of hospital wastewater effluent from University of Ghana Hospital.

4.1.6 Dissolved Oxygen (DO)

The mean values of dissolved oxygen recorded in the wastewater effluent are 0.8mg/l, 1.0mg/l and 1.4 mg/l for P1 (source), P2 (Mid drain) and P3 (Discharge point) respectively (Figure 4.6). Analysis of variance at 95% confidence level showed that dissolved oxygen differs significantly (p <0.05) (Appendix 16). However, the Least significant difference (LSD) revealed that, there were no differences in means of the total dissolved solids between P1 (Source) and mid drain (P2) but differs significantly from the discharged point (P3). The correlation matrix revealed that dissolved oxygen had a very high significant negative correlation with Biological oxygen demand (BOD) during the study period (DO-BOD, r=-0.849, p <0.01) (Table 4.2). Figure 4.6 shows graphical illustration of the mean dissolved oxygen of the wastewater for the various sampling locations. The individual values of DO are presented in Appendix 6.

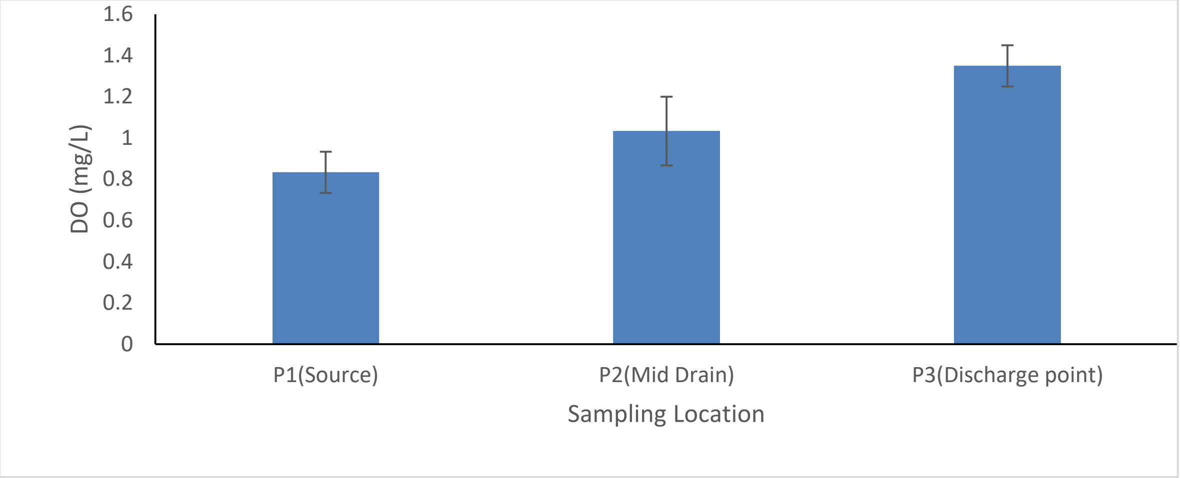

Figure 4.6: Mean values in dissolved oxygen of hospital effluent waste from University of Ghana Hospital

4.1.7 Biological Oxygen Demand (BOD)

Figure 4.7 shows the mean biological oxygen demand of the wastewater sample for the various sampling locations. The mean values ranged from a minimum of 34.8 mg/l at point P3 (Discharged point) to a maximum of 66.8 mg/l at sampling point P1 (Source) (Appendix 8). Analysis of variance at 95% confidence level showed that biological oxygen demand differs significantly ($p<0.05$)(Appendix 16). However, the Least significant difference (LSD) revealed that, there were no differences in means of the BOD between P1 (Source) and mid drain (P2) but differs significantly from the discharge point (P3). The correlation matrix revealed that dissolved oxygen had a very high significant negative correlation with Biological oxygen demand (BOD) during the study period (DO - BOD, r=-0.849, $p<0.01$) (Table 4.2).

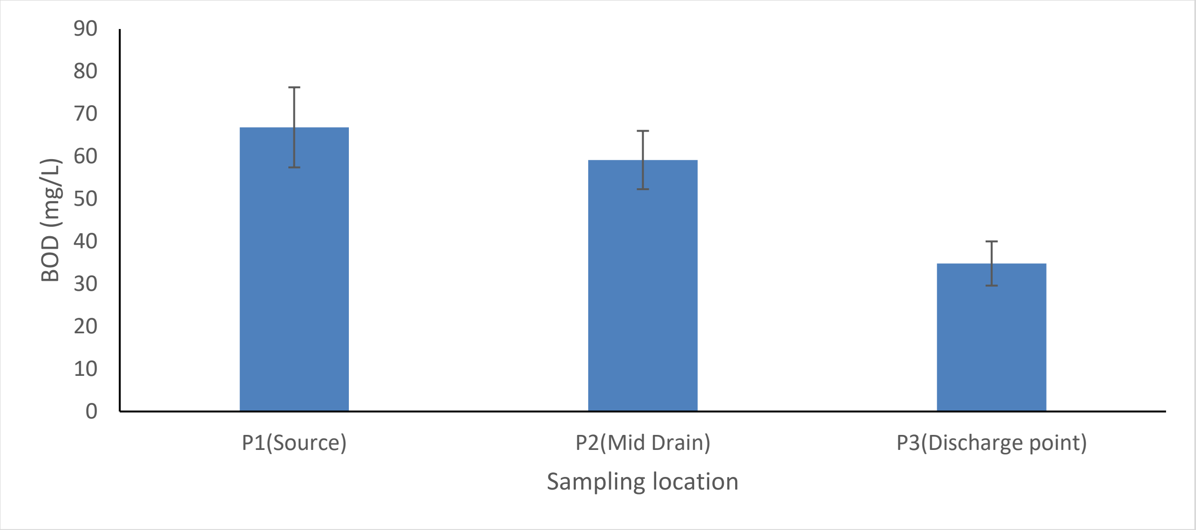

Figure 4.7: Mean values in biological oxygen demand of hospital effluent waste from University of Ghana Hospital.

4.1.8 Chemical Oxygen Demand (COD)

The Figure below shows graphical illustration of the mean chemical oxygen demand of the wastewater sample for the various sampling locations. The mean values ranged from a minimum of 548.0 mg/l at point P1 (source) to a maximum 775.1667 mg/l at sampling point P2 (Mid drain). Analysis of variance at 95% confidence level showed that chemical oxygen demand differs significantly ($p < 0.05$) (Appendix 16). However, the Least significant difference (LSD) revealed that, there were no differences in means of the COD between P1 (Source) and mid drain (P2) but differs significantly from the discharged point (P3). Pearson's product moment correlation coefficient also revealed that COD had a very high significant positive correlation with nitrite during the study period (COD- nitrite, r=0.788, $p<0.01$) (Appendix 18).The values for the individual sites are presented in (Appendix 9).

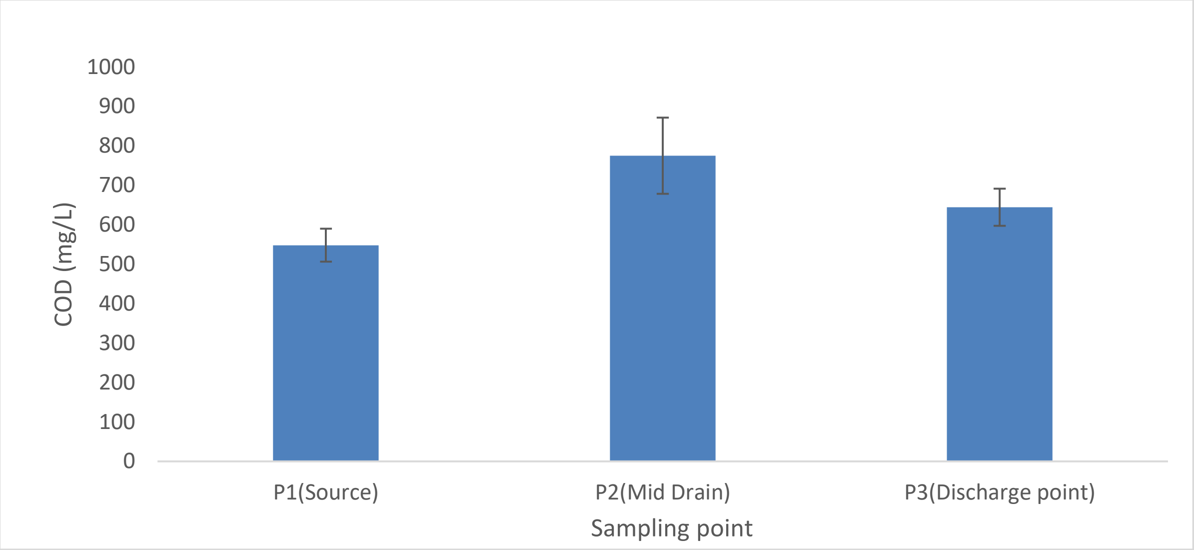

Figure 4.8: Mean values in chemical oxygen demand of hospital effluent waste from University of Ghana Hospital.

4.1.9 Phosphate-Phosphorus (PO_4^{3-} - P)

The mean phosphate-phosphorus values in the wastewater sample ranged from a minimum of 6.3 mg/l at sampling location P3 (discharged point) to a maximum of 9.8 mg/l at site P2 (mid drain) (Appendix 12). Analysis of variance at 95% confidence level (5% level of significance revealed statistically significant differences (P=0.02) in phosphate over the study period (Appendix 16). However, the Least significant difference (LSD) revealed that, there were no differences in means of phosphate-phosphorus between P1 (Source) and mid drain (P2) but was statistically different from the discharged point (P3). Pearson's product moment correlation coefficient (PPMCC) revealed that phosphate had a very high significant negative correlation with the following variable; Phosphate-TDS, r=-0.951, Phosphate-Nitrate, r=-0.755), Phosphate- Ammonia, r=-0.808), (Phosphate- EC, r=-0.951). A significant positive association however existed between phosphate with the following variables at 1% level of positive relationship existed between phosphate, BOD and Nitrite (Phosphate-BOD, r=0.767, Phosphate-nitrite, r=0.758) (Appendix 18).

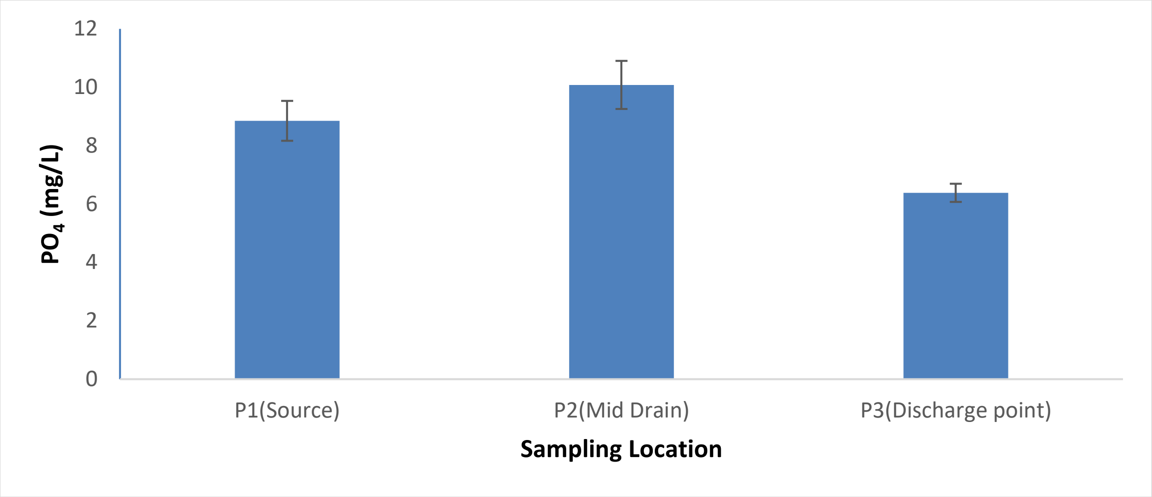

Figure 4.9: Mean values in phosphate of hospital waste effluent sample from University of Ghana Hospital.

4.1.10 Nitrate- Nitrogen (NO_3-N)

The mean nitrate levels in the wastewater sample ranged from a minimum of 34.5 mg/l at sampling location P2 (Mid drain) to a maximum of 101.1 mg/l at site P3 (discharged point) (Figure 4:10) (Appendix 7)

However, the Least significant difference (LSD) revealed that, there were differences in means of nitrates between the three sampling locations, P1 (Source), mid drain (P2) and the discharged point (P3). Pearson's product moment correlation coefficient (PPMCC) revealed that nitrate had a very high significant correlation with the following variables at 1% level of significance. (Nitrate-EC, r=-0.775), (Nitrate- Temp, r=-0.753), (Nitrate-Nitrite, r=-0.716), (Nitrate- Ammonia, r=0.927), (Nitrate –TC, r=0.817) (Nitrate- *E. coli*, r=0.707), (Nitrate-Phosphate, r=-0.755) (Appendix 18).

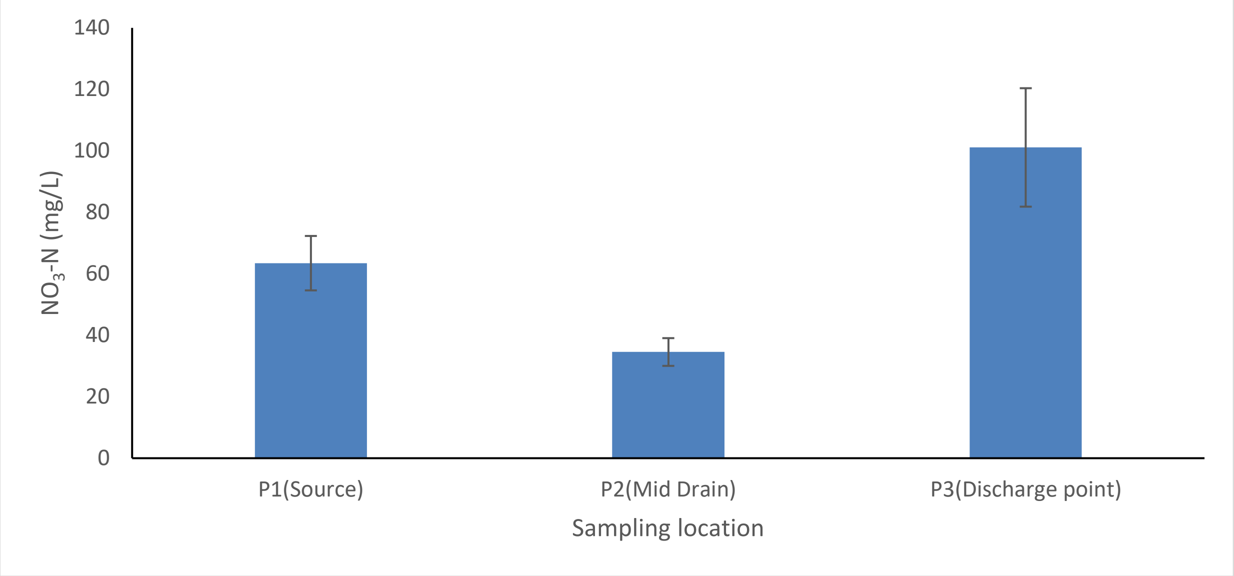

Figure 4.10: Mean values in concentration of nitrate of hospital effluent waste from University of Ghana Hospital.

4.1.11 Nitrite - Nitrogen (NO_2^- -N)

The mean nitrite levels in the wastewater sample ranged from a minimum of 0.2418 mg/l at sampling location P3 (discharged point) to a maximum of 0.4547mg/l at site P2 (mid drain) (Figure 4.11). Analysis of variance at 95% confidence level (5% level of significance revealed a statistically significant difference ($P<0.05$) in nitrite over the entire study period (Appendix 16). However, the Least significant difference (LSD) revealed that, there were no differences in means of nitrites between P1 (Source) and P3 (the discharged point) but were different from P2 (Mid drain). Pearson's product moment correlation coefficient (PPMCC) revealed that nitrite had a very high significant positive and negative correlation with the following variables at 1% level of significance. (Nitrite-EC, r=-0.775), (Nitrate-Temp, r=-0.753), (Nitrite-Nitrate, r=-0.716), (Nitrite- Ammonia, r=0.927), (Nitrite –TC, r=0.817) (Nitrite- *E. coli*, r=0.707), (Nitrite-Phosphate, r=-0.755) (Appendix 18). The raw data and individual values are shown in (Appendix 10).

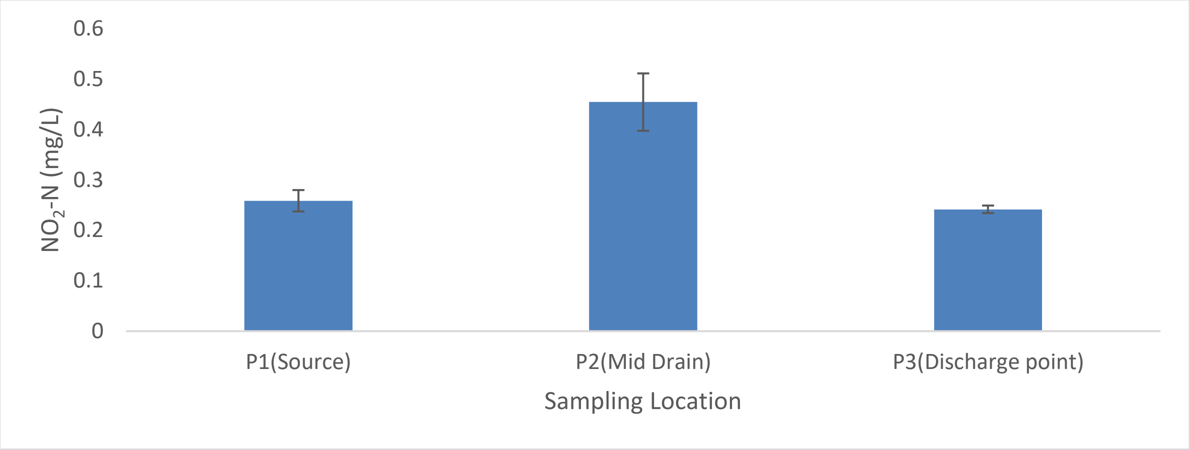

Figure 4.11: Mean value in concentration of nitrite of hospital effluent waste from University of Ghana Hospital

4.1.12 Ammonia - Nitrogen (NH_3-N)

The nitrogen ammonia levels were relatively high recording 28.8mg/l at sampling location P3 (discharged point), to a minimum value of 15.923 mg/l at point P2 mid drain (Fig 4.12). However, the Least significant difference (LSD) revealed that, there were no differences in means of Nitrogen- ammonia between P1 (Source) and mid drain (P2) but was statistically different from the discharged point (P3). Pearson's product moment correlation coefficient (PPMCC) revealed that ammonia had a very high significant negative correlation with the following variables at both 5% and 1% level of significance: Ammonia -Temp, $r=-0.770$, $p<0.01$; Ammonia- Phosphate, $r=-0.808$, $p<0.01$; Ammonia- BOD, $r=-0.647$ $P<0.05$. However a highly significant positive correlation existed between ammonia and the following variables: Ammonia-EC, $r=0.833$, $p<0.01$; Ammonia-nitrate, $r=0.927$, $p<0.01$ (Appendix 18).

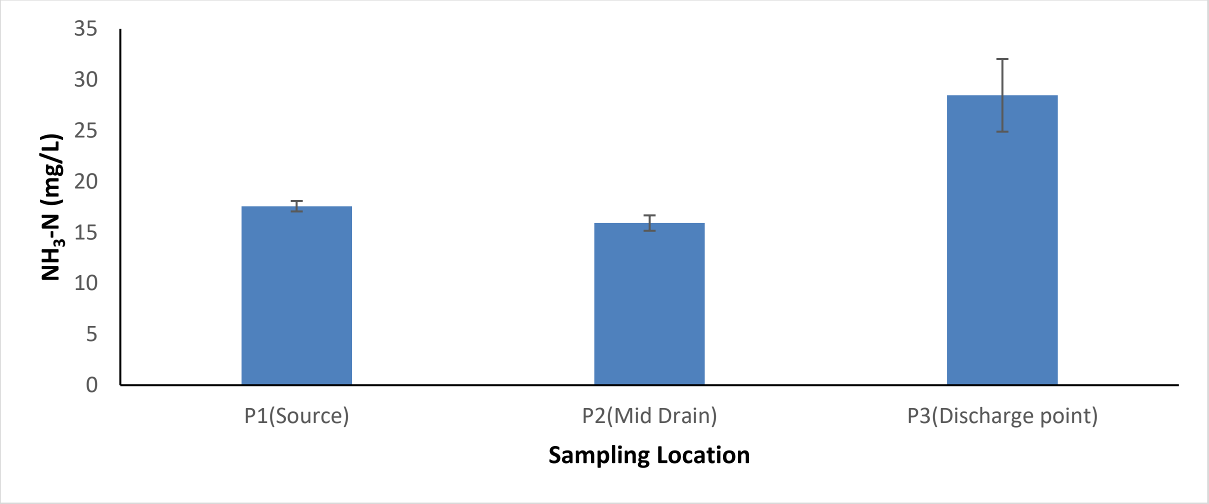

Figure 4.12: Mean values in ammonia nitrogen concentration of hospital effluent waste from University of Ghana Hospital.

4.2 Bacteriological Parameters

4.2.1 Total Coliform (TC)

Figure 4.13 shows the mean total coliform/100ml of the wastewater effluent for the various sampling locations. However, the mean TC ranged from a minimum of 3.1×10^3 cfu/100ml at site P2 (Mid drain) to a maximum of 4.5×10^3 cfu/100ml at site P3 (discharge point). The Source also recorded as high as 4.4×10^3 cfu/100ml (Fig 4.13). The correlation matrix revealed that total coliform had a very high significant positive correlation with nitrate during the study period with a correlation coefficient of r = 0.817 at 1% level of significance (Table 4.1).

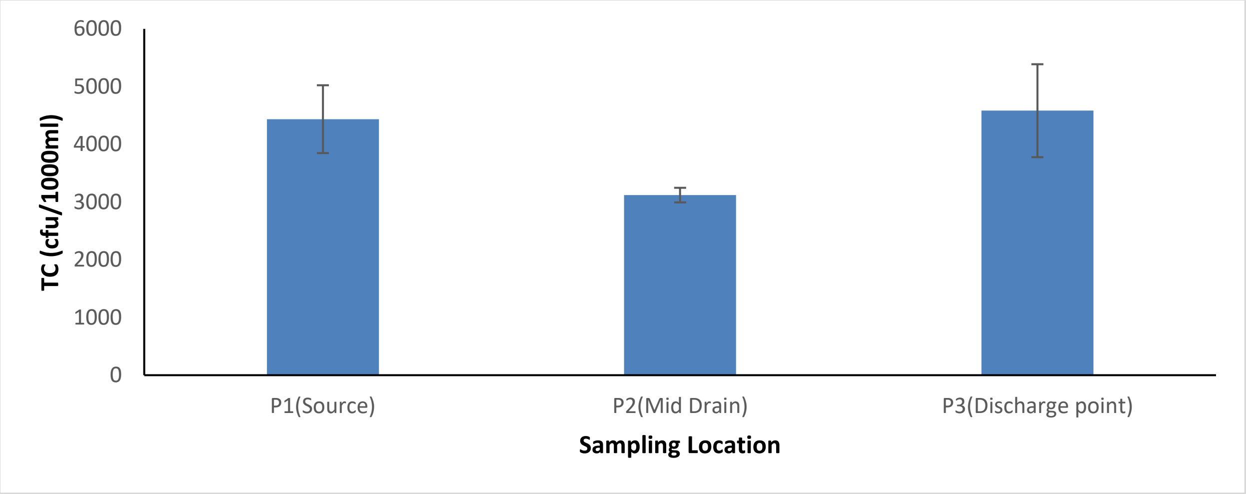

Figure 4.13: Mean values in concentration of total coliform of hospital effluent waste from University of Ghana Hospital.

4.2.2 *Escherichia coli* (EC)

Illustration in Figure 4.14 shows the mean Escherichia *coli (E. coli)* per 100ml of the wastewater effluent for the various sampling locations. The means of *E. coli* concentrations recorded in the wastewater effluent were 2.0 x10^1cfu/100ml, 1.4 x 10^2cfu/100ml and 2.9 x 10^2cfu/100ml for P1 (source), P2 (Mid drain) and P3 (Discharge point) respectively (Appendix 15). However, the Least significant difference (LSD) revealed that, there were no differences in means between P1 (Source) and mid drain (P2) but differs significantly from the discharge point (P3). The correlation matrix revealed that *E .coli* had a very high significant positive correlation with nitrate during the study period with a correlation coefficient of r=0.707 at 1% level of significance (Appendix 18).

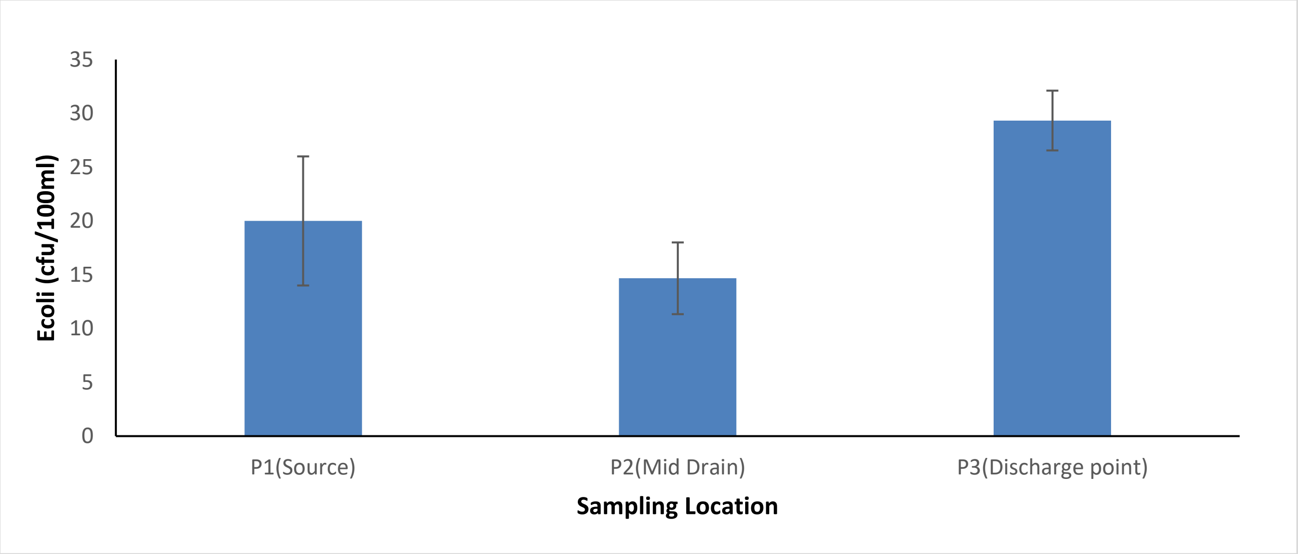

Figure 4.14: Mean values in concentration of *Echerichia coli* of hospital waste effluent sample from University of Ghana Hospital.

Table 4.1: Correlation Coefficient between Parameters of hospital Effluent

VAR	pH	EC	TDS	DO	BOD	PO_4^{3-}	NO_3^-	NH_3	TC	*E. Coli*
pH	1							0.748*		
EC		1	0.678*			-0.95*	0.775*	0.833*		
TDS			1							
DO				1	-0.849*					
BOD					1					
PO_4^{3-}						1	-0.755*	-0.808*		
NO_3^-							1	0.927*	0.787*	0.707*
NH_3^+								1		
TC									1	0.742*
E.Coli										1

* Correlation is Significant at the 0.05 level (2-tailed). EC- Electrical Conductivity; TDS- Total dissolved solid; TC- Total Coliform

4.3 Heavy metal concentrations in effluent water used for irrigation

Table 4.2 below illustrates the concentrations of heavy metals in hospital effluent water used for irrigation of vegetables at the downstream sampling site. The results indicated that, Cd levels in the water ranged from 0.004 -0.015mg/l with mean value of 0.019mg/l. The Cr concentrations ranged from a minimum of 0.087mg/l to a maximum of 0.286 mg/l. The Pb levels also ranged from <0.001-0.001 with mean value of 0.001mg/l. The Ni levels ranged from 0.024-0.033 with mean value of 0.057mg/l and that of Hg ranged from 0.001-0.004mg/l. lastly, the As concentrations ranged from <0.001-0.001mg/l with mean value of 0.001mg/l (Table 4.2).

Table 4.2: Heavy metal levels in hospital Effluent water used for irrigation

Heavy metals	Range (Mean)	FAO Limit
Cd	0.004-0.015(0.02)	0.01
Cr	0.087-0.286 (0.37)	0.05
Pb	<0.001-0.001(0.001)	0.10
Ni	0.024-0.033(0.06)	0.01
Hg	0.001-0.004(0.01)	0.001
As	<0.001-0.001(0.001)	0.01

4.4 Heavy metal levels in soils

The Cd levels in soil ranged from 2.22 -3.3mg/kg with mean value of 2.8mg/kg whilst that of the control soil sample ranged from 2.2-2.5mg/kg with mean value of 2.4mg/kg. The Cr levels ranged from a minimum of 48.2mg/kg to a maximum of 67.6mg/kg and the control site recorded levels between 4.2-11.4mg/kg. The Pb levels in the vegetable growing soils ranged from 0.2-1.1mg/kg whilst that at the control site ranged from 0.05-0.20mg/kg. The Ni levels ranged from 12.1-13.3mg/kg at the vegetable growing soils whilst Ni in control soils ranged from 2.5-6.2 mg/kg. The Hg concentrations in soil ranged from 19.8-21.1mg/kg and that at the control site ranged from 1.2-3.2mg/kg. The As concentrations in soils ranged from 3.3-20mg/kg whilst that of the control sample ranged from 0.02-1.1mg/l (Table 4.3).

Table 4.3: Heavy metal concentration in soil where vegetables are cultivated (mg/kg)

	Vegetable growing site	**Control site**	**FAO limit**
Heavy metals	**Range (Mean)**	**Range (Mean)**	
Cd	2.22-3.3(2.8)	2.2-2.5(2.4)	3.0
Cr	48.2-67.6(57.9)	4.2-11.4(15.6)	0.20
Pb	0.2-1.1(0.7)	0.05-0.2(0.1)	0.50
Ni	12.1-13.3(12.7)	2.5-6.2(4.4)	0.20
Hg	19.8-21.1(20.4)	1.2-3.2(2.2)	0.01
As	3.3-20(11.7)	0.02-1.1(0.6)	0.30

4.5 Heavy metal concentrations in vegetables

With respect to heavy metal concentration in vegetables, the highest cadmium levels was recorded in cabbage with mean value of 0.0018mg/kg that of lettuce recorded a value of 0.00011mg/kg. Cadmium was however not detected in cauliflower. The highest level of Cr was recorded in cauliflower with mean value of 0.0314mg/kg and the lowest value was recorded in lettuce with mean value of 0.0194mg/kg. That of cabbage also recorded a mean value of 0.0102mg/kg. The Cr levels in vegetables followed the decreasing order of ranking Cauliflower> cabbage>lettuce.

With regards to Pb in vegetables, it was only detected in cabbage samples with mean value of 0.0001mg/kg. Lead was however below detectable limit in lettuce and cauliflower during the sampling period.

The highest level of Ni was recorded in cabbage with mean value of 0.0116mg/kg and the lowest value was recorded in cauliflower with mean value of 0.0112mg/kg. The nickel levels in lettuce also recorded a mean value of 0.0113mg/kg. With regards to Hg in vegetables, the highest mean value of 0.003mg/kg was recorded in both cabbage and cauliflower and the lowest was recorded in lettuce with mean value of 0.002mg/kg. The highest Arsenic level was recorded in cabbage with mean value of 0.0004mg/kg and the lowest value was recorded in cauliflower with mean value of 0.0002mg/kg. That of lettuce recorded a mean value of 0.0003mg/kg. The overall heavy metal concentrations in vegetables in this study followed the decreasing order of ranking; Cabbage > lettuce > cauliflower (Table 4.4)

Table 4.4: Heavy metals concentrations in vegetables (mg/kg)

Vegetable type	Cd	Cr	Pb	Ni	Hg	As
Cabbage	0.0018	0.0102	0.0001	0.0116	0.003	0.0004
Lettuce	0.00011	0.0194	<0.002	0.0113	0.002	0.0003
Cauliflower	<0.001	0.0314	<0.001	0.0112	0.003	0.0002
FAO limit	0.10	0.02	0.3	0.06	0.001	0.001

4.6 Human Health risk of heavy metals

Table 4.5 below shows the human health risk assessment of the heavy metals in vegetables. The Hazard Quotients (HQ) for all the heavy metals studied in vegetables were all below one. In cabbage samples, the highest HQ was recorded for Cd with a value of 8.8×10^{-4} and the lowest was recorded for As with a value of 6.6×10^{-6}. The overall hazard index observed in cabbage was 2.3×10^{-3}

The highest Hazard quotient for heavy metals in lettuce was recorded for As with a value of 2.8×10^{-4} and the lowest was recorded for Cr with a value of 3.3×10^{-6}. The overall hazard index observed in lettuce samples was 6.4×10^{-4}

The highest hazard quotient for cauliflower was recorded for Hg with a value of 1.9×10^{-4} and the lowest was recorded for Cr with a value of 4.1×10^{-6}. The overall hazard index observed in lettuce was 2.5×10^{-4}.

Table 4.5: Noncarcinogenic risk (HQ and HI) of heavy metals in vegetables (adults)

Vegetable	Cd	Cr	Pb	Ni	Hg	As	HI
Cabbage	8.8×10^{-4}	6.6×10^{-6}	1.22×10^{-5}	2.83×10^{-4}	5.4×10^{-4}	6.6×10^{-4}	2.3×10^{-3}
Lettuce	2.8×10^{-5}	3.3×10^{-6}	0.00	1.46×10^{-4}	1.8×10^{-4}	2.8×10^{-4}	6.4×10^{-4}
Cauliflower	0.00	4.1×10^{-6}	0.00	1.09×10^{-4}	1.9×10^{-4}	1.4×10^{-4}	2.5×10^{-4}

CHAPTER FIVE

DISCUSSION

5.1 pH and Temperature

The pH of the entire effluent sample at the three sampling sites were within the Ghana EPA permissible limit of 6-9 (EPA, 2010)for wastewater that is supposed to be discharged into the environment. The mean pH of the raw effluent at the source was 8.2 and that recorded at the discharged point was 8.8. It is required that pH of wastewater discharged into an environment should be in the range of 6-9 (EPA, 2010). The results of the study agrees with Mahvi, (2009) who reported that pH values in wastewater sampled from a hospital varied from 6.13 to 9.2.Mesdaghinia *et al* (2009) also reported a pH range between 6.2 and 8 in a hospital waste effluent.

The effluents have slight variations in temperature with average temperature of 26 ºC during the sampling period. The water temperature showed a significant variation between the source, mid drain and discharged point. The temperature variation could be attributed to the depth at which the samples were taken. The temperature values obtained from sampled water for the entire study period were all above the natural background limit. Temperature is a critical factor of significant importance for aquatic ecosystems as it affects the water organism as well as the physico-chemical properties of water (Nkansah, 2010).

5.2 Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical oxygen Demand (COD)

There were relatively low dissolved oxygen levels observed at all the three sampling points. This may be explained by the high organic content of the wastewater from the hospital activities. Characteristically, the discharged point recorded the highest dissolved oxygen of 1.4mg/l. This could be attributed to the influence of green vegetation surrounding the area since the discharged point happens to be wetlands with conducive microclimate environment. This condition may enrich the wastewater with oxygen during photosynthesis by the green plants. The low DO recorded in the water samples may be due to high levels of oxidizable substances in the effluent sample such as nitrogenous compounds and also the decomposition of organic matter. The different depth with which the samples were taken could also influence the DO as dissolved oxygen decreases with depth. Dissolved oxygen consumption and production is influenced by plant and algal biomass, light intensity and water temperature are subject to diurnal and seasonal variations (Suthanom, 2011). This was not the case for this study because of the fact that, the sewage system is underground and the effect of these climatic factors were not pronounce to improve on the oxygen level. The low levels confirm the argument by Mahvi, (2009) who reported raw sewage has almost zero oxygen. This result is an evidence of the fact that the natural conditions add a lot of oxygen to exposed sewage to aid in treatment. Dissolved oxygen is a key element in water quality that is necessary to support aquatic life. A demand is placed on the natural supply of dissolved oxygen by many pollutants in wastewater. If the effluent has a high content of organic pollutants, it will demand more oxygen from the water and leave the water with less oxygen for supporting fish and other aquatic life (Suthanom, 2011).

High values of BOD and COD are indicative of excessive organic matter contained in the effluent from both domestic and industrial sewage. The EPA requires that the permissible BOD and COD in wastewater discharges into an environment should not exceed 50 mg/l and 250 mg/l respectively. The lowest level of BOD was reported at the discharged point and could be due to the relatively high dissolved oxygen at the site replenished by the wetland vegetation through photosynthetic activities which helps to break down the organic materials in the effluent.

The high value at the source of generation however could be attributed to the possibility of poor mixing of atmospheric oxygen into the wastewater since it happens to be a covered drain. The low BOD values did not indicate severe pollution threat at the discharged point and its environs in spite of the discharge of raw sewage from the university hospital. However the BOD level at the source of generation and mid drain sampling sites was slightly above the recommended limit. The COD values recorded for the study however exceeded the permissible levels of 250 mg/l. The BOD results of this study were higher than other values reported by other researchers in hospital effluent. Mahvi et al (2009) in a research work conducted at Kerman Province Hospital in Iran reported an average BOD and COD values to be 73mg/l and 162 mg/l respectively; Suthanom, (2011) reported an average value of 374 mg/l and 60.5 mg/l for COD and BOD_5 in a hospital waste effluent in Iran respectively; Mahvi et al (2009) also reported that BOD_5 and COD in hospital waste effluent in Nigeria were 113 mg/l and 188mg/l respectively. The results from this study however is consistent with research work reported by Sarafraz (2007) who obtained BOD_5 and COD values in hospital effluent to be 125.3 mg/l and 517 mg/l respectively which were all below the maximum permissible limits for wastewater discharged into the environment.

5.3 Phosphate, Nitrate, Ammonia

Phosphate is a limiting nutrient for algae growth and a major cause of eutrophication in surface waters. The presence of phosphate in water is a significant indicator of anthropogenic pollution. The phosphate level in the hospital effluent ranged from 6.3 mg/l (discharged point) to 8.8 mg/l (Source). The EPA guidelines for wastewater states that, phosphate levels in wastewater should not exceed 2 mg/l. The phosphate levels recorded for all the sample sites were generally higher and fell above the EPA permissible limit of 2 mg/l. The higher levels recorded at the source could be attributed to phosphorus rich human excrement or phosphate detergents and cleaning products from the hospital waste generated

(Pieterse *et al*, 2003). Relatively, the lower level of phosphate recorded at the discharged point could be due to the fact that phosphate is normally bound to ferric iron in oxygenated or oxic waters and as such the phosphate might have been bound to the sediments and were not available (Suthanom, 2011).

5.4 Nitrate-Nitrogen, Nitrite- Nitrogen, Ammonia-Nitrogen

The nitrate levels recorded during the entire study period ranged from 34.5 mg/l (mid drain) to 101.1 mg/l (discharged point). The mean concentration of nitrate at the source of generation was 63.4 mg/l and were above the EPA maximum contamination level of 50 mg/l. The higher levels recorded at the discharged point could be attributed to anthropogenic factors such as animal waste, human waste and mineral fertilizers (Robertson and Cherry, 2005).

The result of this research has higher values of nitrates opposed to other similar research reported by Sarafraz (2007) who reported average values of nitrate and nitrite to be 12.26 mg/l and 2.28 mg/l respectively in a hospital effluent in Nigeria. Hamilton et al., (2007) also reported Nitrate levels within the range 0.1 mg/l - 38.8 mg/l in hospital effluent in Rafsanjan Ali Ebn Abi Taleb Hospital in Kerman Afzalipour Doctor hospital, Iran. The research results deviate from other research work conducted in hospital effluent due to the fact that most research conducted normally conduct a survey on the treated wastewater to ascertain if the parameters are permissible to be discharged into a receiving environment but the university of Ghana hospital discharge its waste without prior treatment.

Ammonia is toxic to aquatic organisms but the toxicity however depends mainly on pH and temperature (Amoatey & Bani, 2010). The EPA guideline for ammonia in waste effluent is 1.0mg /l (EPA, 2010). The ammonia levels in all the effluent during the entire study period were higher than the EPA permissible limit. This may probably be due to the low dissolved oxygen recorded during the study period as this could enhance de-nitrification where nitrogenous compounds are reduced to ammonia in anoxic waters (Baird, 1999).

5.5 Total Coliform and *Escherichia Coli (E. coli)*

Results from the study showed high levels of total coliform and *E. coli* population. For wastewater to be considered safe to be discharged into a receiving environment, total coliform bacterial and *E. coli* should not exceed 4×10^2 cfu/100ml and 1.0×10^1 cfu/100ml, respectively (EPA, 2010). The Source (PI) recorded 4.435×10^3 cfu/100ml total coliform population and the discharged point (P3) recorded 4.582×10^3 cfu/100ml. This poses significant environmental threat as the concentrations far exceed the permissible limits set by the EPA. The high levels of total coliform and *E. coli* population at the discharged point could be due to the nutrient rich environment which enhances the growth of coliforms in the soils (Gelderich et al., 2011). Aluyi et al (2006) reported high faecal load with high concentration of *E. coli* in wastewater discharged from university of Benin teaching hospital and this was attributed to human activities. The results confirm a similar research conducted by Ekhaise and Omavwoya, 2008 who also reported total coliform counts ranging from $1.9\text{x}10^7$cfu/ml to $8.3\text{x}10^{18}$ cfu/ml in hospital wastewater. Mesdaghinia (2009) reported that, the minimum and maximum numbers of total coliforms obtained in the wastewater of Razi Hospital and Bahrami Hospital ranged from 2.2×10^7 and 3.8×10^8 MPN/100mL respectively.

5.6 Conductivity, Total dissolved solids and total suspended solids

The conductivity of the effluent recorded during the study period exceeded the Ghana EPA regulatory limit of 1500µS/cm (Chapman 1992). The source of generation recorded a conductivity value of 1693.3 µS/cm whilst the final discharged point recorded as high as 2220 µS/cm indicating that the dissolve ions were too high to be discharged into a receiving environment. The high values recorded at the final discharged point could be attributed to the farming activities as a result of the use of fertilizers which also contain some dissolved ions. The geochemistry in the study area could also be a contributing factor since soils and rocks contain dissolved ions and could be released into the wastewater. Research has found that there is a positive correlation between conductivity and total dissolved solids (TDS) and the later may be obtained by multiplying conductivity by a factor between the ranges of 0.55-0.75 (Chapman, 1992).

Total dissolved solids are a measure of the total organic and inorganic substances dissolved in water (ANZECC, 2000). The mean TDS ranged from a minimum of 947 mg/l at point P1 (source) to a maximum of 1410.7 mg/l at point P3 (discharged point). The EPA requires that the TDS of wastewater discharged into a receiving environment should not exceed 1000 mg/l. With the exception of the discharged point, the TDS in the wastewater sampled at the source and mid -drain were below the permissible limit. The differences in concentration is not surprising since the source of generation happens to be a covered concrete drain whilst the mid-drain is a partially opened concrete drain with the discharged point enclosed within a wetland with a lot of farming activities and human settlements. The results of the study agrees with Maiti, (2004) who also reported TDS value as high as 1166.89 mg/l in a hospital waste effluent in Nigeria.

Total Suspended Solid (TSS) relatively measure the visual observation of water sample. The TSS of the effluent at the source was 480.2 mg/l whilst the discharged point recorded TSS value as high as 717.3 mg/l. The EPA value guideline recommends that, wastewater must have a TSS value not exceeding 50 mg/l for it to be considered safe to be discharged into a receiving environment (EPA, 2010). The values of TSS recorded for the entire study period was far above the recommended limit. This result indeed revealed the fact that hospital waste contains a lot of suspended materials generated from laboratories such as untreated water, body tissues and blood fluids. The results disagrees with Ekhaise & Omavwoya,

(2008) and Mesdaghinia, (2009) in a similar research who reported mean TSS values of a hospital wastewater to be 61 mg/l and 147 mg/l respectively.

Heavy metal concentrations in effluent water used for irrigation

With the exception of lead and arsenic in water that fell below the recommended guideline of 0.1 and 0.01mg/l respectively for water used for irrigation of vegetables, Cd, Cr, Ni and mercury exceeded the FAO guideline limit for irrigation water. The high levels of mercury in effluent water might be attributed to the use of mercury thermometers in the hospitals and as such mercury have been reported to be critical in the composition of hospital waste. The high levels of Cd, Cr and Ni could be attributed to the use of these metals in medicines and when disposed could be part of the waste stream.

With the exception of lead and arsenic in water that fell below the recommended guideline of 0.1 and 0.01mg/l respectively for water used for irrigation of vegetables, Cd, Cr, Ni and mercury exceeded the FAO guideline limit for irrigation water. According to the FAO, Cd, Cr, Ni and Hg levels in in water used for irrigation should not exceed 0.01, 0.05, 0.01 and 0.001mg/l respectively (FAO, 2011). The high levels of mercury in effluent water might be attributed to be the use of mercury thermometers in the hospitals and as such mercury have been reported to be critical in the composition of hospital waste. The high levels of Cd, Cr and Ni could be attributed to the use of these metals in pharmaceuticals during the preparation of medicines and when not properly treated and disposed could form part of the waste stream (Dube et al., 2001).

The heavy metals in soil revealed that mercury, nickel and chromium were above the FAO recommended guideline for Agricultural soils of 0.01, 0.20 and 0.20mg/kg respectively (FAO, 2011). That of Cd, Pb and As however, fell within the recommended limit of 3.0, 0.50 and 0.30mg/kg respectively. Though the natural processes of weathering release heavy metals into the soil, high levels could be attributed to anthropogenic sources and its concentrations depend on soils physicochemical properties such as density, conductivity, reactivity and also on the physicochemical properties of the soil including; pH, organic matter content, clay fraction content and mineralogical composition (Dube et al., 2001). All these collectively determine the binding ability of soil. The high levels of mercury and nickel and chromium in the Agricultural soil could be attributed to the high levels in the effluent water used for irrigation. The high levels of Ni and Cr could partly be attributed to excessive application of chemicals like fertilizer and pesticides that would increase plant growth of their vegetables. The results obtained for heavy metals in agricultural soils in this study is not consistent with a study conducted in the Northwest of Thessaloniki, North Greece (Kasassi et al. 2008) in which low concentrations of Cr, Cu, Ni, Pb and Zn were found in Agricultural soils samples irrigated with wastewater.

The main routes of heavy metal entry in vegetables are usually through soil, water and atmospheric depositions. Many vegetables have been reported to contain some metals as at high concentrations which pose a health threat to humans (Anim-Gyampo et al., 2012). All the heavy metals under investigation in cabbage, lettuce and cauliflower in this study were all below recommended limit set by the FAO for vegetables wholesome for human consumptions. According to the FAO, Cr, As, Ni, Hg, Cd in vegetables should not exceed 0.02, 0.001, 0.06, 0.001 and 0.10mg/kg respectively. This findings is inconsistent with the study conducted by Arora et al. (2008), who found out that there was a substantial build-up of heavy metals in vegetables (Cabbage, lettuce) irrigated with wastewater from different sources such as hospital waste, domestic waste and industrial waste. The results however is consistent with the work of Boamponsem et al. (2012) who analyzed for heavy metal contents in vegetables such as lettuce, cabbage and carrots irrigated with wastewater from

Nagodi, northern Ghana where Pb, Ni, Cr, and Cd were found below detection limit in all the analyzed samples.

The lower levels of heavy metals obtained in vegetables in this current study could be attributed to lower levels of absorption of this metals into the vegetables due to the higher pH of the soil since heavy metals are mobile in low pH soils. The age of the vegetables could also not be ruled out since most of the vegetable samples were about three months old and may have not accumulated enough metals from the soil since high levels were recorded in the soils.

The human health risk assessment of the vegetables revealed that the hazard index and Hazard quotient for the vegetables under investigation (cabbage, lettuce and cauliflower) were all less than 1 which indicates that consumers are not at risk to the consumption of these vegetables in the short term. This finding disagrees with the work of Sudthanom et al, (2011) who reported that both adults and children consuming vegetables such as cabbage and lettuce grown in wastewater-irrigated soils ingest significant amount of heavy metals and poses potential human health risk to the consuming population although the metal values analyzed were below the tolerable levels.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The microbial load and the high densities of the physico chemical parameters suggests that the activities of hospital effluent in the environment is a major health and environmental threat, which therefore calls for a proper regulatory system on disposal of the hospital waste by the management of the hospital. The concentrations of the physico-chemical parameters such as conductivity, total dissolved solid, total suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and major nutrient such as nitrate, phosphate were all higher than the EPA permissible limit for wastewater safe to be discharged into a receiving environment. The pH was generally good and the DO was also generally low throughout the entire study period. High level of nutrient such as ammonia, Nitrate and phosphate are significant enough to stimulate algae growth and alter eutrophic condition at different level of the environment (WHO, 2010). The entire study period recorded a high microbial load at the source of generation and the final discharged point of the study area (P-3). The microbial load and the high densities of the physico chemical parameters suggest that the activities of hospital wastes in the environment is a major health and environmental threat. The levels of compliance of effluent with the microbial parameters were all above the Ghana EPA permissible standards for wastewater discharge into an environment.

With the exception of lead and arsenic in water that fell below the recommended guideline of 0.1 and 0.01mg/l respectively for water used for irrigation of vegetables, Cd, Cr, Ni and mercury exceeded the FAO guideline limit for irrigation water. The heavy metals in soil revealed that mercury, nickel and chromium were above the FAO recommended guideline for Agricultural soils. That of Cd, Pb and As however, fell within the recommended limit.

All the heavy metals under investigation in cabbage, lettuce and cauliflower in this study were all below recommended limit set by the FAO for vegetables wholesome for human consumptions. The human health risk assessment of the vegetables revealed that the hazard index and Hazard quotient for the vegetables under investigation (cabbage, lettuce and cauliflower) were all less than 1 which indicates that consumers are not at risk to the consumption of these vegetables in the short term.

6.2 Recommendation

- The local and international laws governing the safe re-use of wastewater must be strictly enforced by the University authorities in order to ensure compliance.
- Health based institution like hospitals which discharge liquid waste into drains flowing into streams and the environment should be made to install pretreatment facilities. In addition, control measures to ensure a pollution free environment should be intensified. The Environmental Protection Agency should monitor pollution discharged closely to ensure great minimization of pollution to local and international standards.

- There should be regular monitoring of heavy metals levels from the hospital effluents and in vegetables grown in the downstream which is the collection point of the entire hospital effluent to prevent excessive build-up in the food chain

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APPENDICES

Appendix 1: Temperature at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	26.4	28.3	25.8	26.8	26.3	27.2	25.8	28.3	26.8
P2	26.8	28.7	26.5	26.4	26.8	26.8	26.4	28.7	27.0
P3	21.1	23.0	25.3	26.3	26.2	26.3	21.1	26.3	24.7

Appendix 2: pH at the sampling site

MONTH									
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	8.1	8.6	8.3	7.7	8.5	8.1	7.7	8.6	8.2
P2	8.8	9.3	7.9	7.2	7.3	8.8	7.2	9.3	8.2
P3	9.0	9.5	8.4	8.9	8.2	9.1	8.2	9.5	8.9

Appendix 3: Conductivity (µS/cm) at the sampling site

MONTH									
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	1488	1540	1630	1820	1842	1840	1488	1840	1693
P2	1240	1320	1480	1642	1720	1730	1320	1730	1522
P3	2206	2508	2014	2230	2130	2232	2014	2508	2220

Appendix 4: Total dissolved solids (mg/l) at the sampling site

MONTH									
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	704	893	961	1019	1013	1092	704	1092	947
P2	567	766	873	1642	946	1021	567	1642	969
P3	1103	1455	1188	2230	1172	1316	1103	2230	1410

Appendix 5: Total suspended solids (mg/l) at the sampling site

MONTH									
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	353	432	484	530	545	540	353	545	480
P2	362	487	341	325	428	320	320	487	377
P3	454	526	882	790	820	832	454	882	717

Appendix 6: Dissolved oxygen (mg/l) at the sampling site.

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	0.9	0.7	0.7	0.8	0.9	1.0	0.7	1.0	0.83
P2	0.8	0.9	1.2	1.1	1.3	0.9	0.8	1.3	1.03
P3	1.2	1.4	1.5	1.4	1.2	1.4	1.2	1.5	1.35

Appendix 7: Nitrogen nitrate (mg/l) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	74.8	74.9	67.2	58.8	56.3	48.7	48.7	74.9	63.45
P2	37.8	38.2	27.4	32.5	30.2	41.2	27.4	41.2	34.55
P3	127.6	132.4	95.6	89.7	81.7	79.6	79.6	127.6	101.1

Appendix 8: Biochemical oxygen demand (mg/l) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	78	84	64	59	64	52	52	84	66.83
P2	64	75	48	54	58	56	48	75	59.16
P3	44	40	33	28	36	28	28	44	39.5

Appendix 9: Chemical oxygen demand (mg/l) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	560	630	580	460	528	530	460	630	548
P2	840	910	860	780	663	598	780	910	775
P3	640	750	680	540	624	633	540	750	644

Appendix 10: Nitrogen nitrite (mg/l) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	0.264	0.282	0.272	0.281	0.232	0.222	0.222	0.282	0.259
P2	0.429	0.531	0.522	0.482	0.388	0.376	0.376	0.531	0.455
P3	0.231	0.248	0.241	0.231	0.248	0.252	0.231	0.252	0.242

Appendix 11: Nitrogen ammonia (mg/l) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	18.08	18.01	17.50	16.30	17.40	18.20	16.30	18.20	17.58
P2	16.8	17.32	15.21	14.85	15.92	15.44	15.21	17.32	15.92
P3	32.8	34.62	28.70	24.70	25.3	26.50	24.70	34.62	28.77

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Appendix 12: Phosphate (mg/l) at the sampling sites

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	9.6	9.8	9.2	8.8	7.5	8.2	7.5	9.8	8.9
P2	10.7	11.2	10.4	9.8	8.3	8.5	8.3	11.2	9.8
P3	5.9	6.2	6.5	6.2	7.2	6.3	5.9	7.2	6.4

Appendix 13: Total coliform (cfu/100ml) at the sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week2**	**Week1**	**Week3**	**Week1**	**Week2**	**MIN**	**MAX**	**MEAN**
PI	5761	4873	4320	4220	4200	3240	3240	5761	4435
P2	3260	3140	3040	3240	3220	2820	2820	3260	3120
P3	5822	5420	4920	3930	3950	3450	5822	3450	4582

Appendix 14: Faecal coliform (cfu/100ml) at sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	136	120	110	97	99	120	97	136	114
P2	78	65	72	68	62	72	62	78	70
P3	124	120	120	120	108	110	108	124	117

Appendix 15: E. coli (cfu/100ml) at sampling site

	MONTH								
	JAN		**FEB**		**MAR**				
SITE	**Week1**	**Week3**	**Week1**	**Week3**	**Week1**	**Week3**	**MIN**	**MAX**	**MEAN**
PI	34	24	20	10	17	15	10	34	20
P2	14	9	15	20	11	19	9	20	15
P3	28	25	32	35	28	28	25	35	29

Appendix 16: ANALYSIS OF VARIENCE (ANOVA) FOR EFFLUENT QUALITY PARAMETERS

Variable	Source of variation	Sum of squares (SS)	Degrees of freedom (d.f)	Mean sum of squares (MSS)	F- Ratio	P-Value
Temperature	Between groups	19.480	2	9.740	4.710	0.02
	Within group	31.020	15	2.068		
pH	Between groups	1.604	2	0.802	2.191	0.06
	Within group	5.492	15	0.366		
Conductivity	Between groups	1587873.7	2	793936.889	24.696	0.01
	Within group	482221.33	15	32148.089		
Total Dissolved Solid	Between groups	820800.77	2	410400.389	3.744	0.04
	Within group	1644352.1	15	109623.478		
Total Suspended Solid	Between groups	364873.444	2	182436.722	12.849	0.32
	Within group	212983.500	15	14198.900		
Dissolved oxygen	Between groups	.814	2	.407	17.878	0.03
	Within group	.342	15	.023		
Biological Oxygen demand	Between groups	3349.778	2	1674.889	18.439	0.02
	Within group	1362.500	15	90.833		
Chemical Oxygen demand	Between groups	155981.444	2	77990.722	10.278	0.04
	Within group	113816.333	15	7587.756		
Phosphate	Between groups	37.613	2	37.613	23.722	0.02
	Within group	11.892	15	11.892		
Nitrate	Between groups	13363.270	2	13363.270	29.587	0.01
	Within group	3387.410	15	3387.410		
Nitrite	Between groups	.168	2	.084	48.205	0.02
	Within group	.026	15	.002		
Ammonia	Between groups	585.931	2	292.966	48.113	0.04
	Within group	91.337	15	6.089		
Total coliform	Between groups	7779672.444	2	3889836.222	7.209	0.12
	Within group	8093657.333	15	539577.156		
E coli	Between groups	661.333	2	330.667	9.867	0.03
	Within group	502.667	15	33.511		

Appendix 17: Ghana EPA wastewater quality guidelines for discharges into water bodies

Column 1 Parameter/ description	Column 2 Maximum Permissible level (New Facilities)	Column 3 Maximum Target Permissible Level Old Facilities
pH	6-9 (in the range of)	6-9 (in the range of)
Temperature	Less than 30^{0}C above ambient	Less than 30^{0}C above ambient
BOD mg/L	50	200
COD mg/L	250	1000
Total Dissolve Solid	1000	1000
Total Suspended Solid	50	50
Conductivity (uS/cm)	1500	1500
E- Coli (MPN/100m)	10	10
Total Coliform (MPN/100m)	400	400
Ammonia as N mg/L	1.0	10
Nitrate mg/l	75	100
Total Phosphorus (mg/l)	2	10
Dissolve Oxygen		

Ghana EPA wastewater quality Guideline. **Source: EPA, Ghana**

Appendix 18: Correlation Matrix between the Physico chemical and Microbiological Parameters

VAR	EC	pH	TDS	TEM	TSS	BOD	DO	COD	NO3-	NO_2^-	PO_4^{3-}	NH_3	FC	TC	E. Coli
EC	1	0.328	0.648	-0.653	0.641	-0.785	0.699	-0.370	0.755	-0.678	-0.951	0.833	0.520	0.384	0.544
pH		1	0.076	-0.268	0.264	-0.167	0.117	0.173	0.548	-0.223	-0.309	0.578	0.312	0.249	0.282
TDS			1	-0.257	0.480	-0.679	0.596	-0.220	0.372	-0.298	-0.602	0.414	0.225	0.021	0.487
TEM				1	-0.105	0.482	-0.452	0.067	-0.75	0.414	0.662	-0.770	-0.42	-0.617	-0.426
TSS					1	-0.694	0.585	-0.283	0.472	-0.566	-0.676	0.576	0.448	0.130	0.499
BOD						1	-0.849	0.071	-0.43	-0.323	0.767	-0.646	-0.199	0.040	-0.447
DO							1	0.135	0.423	-0.179	-0.692	0.662	0.140	0.076	0.465
COD								1	-0.25	0.788	0.462	-0.031	-0.554	-0.300	-0.447
NO_3									1	-0.716	-0.755	0.927	0.787	0.817	0.707
NO_2^-										1	0.758	-0.567	-0.867	-0.619	-0.591
PO_4^{3-}											1	-0.808	-0.557	-0.410	-0.599
NH3												1	0.604	0.609	0.630
FC													1	0.786	0.742
TC														1	0.602
*E.*Coli															1