KWAME NKRUMAH UNIVERISTY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

Assessment of liquid waste management in health care facilities in Kumasi

By

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A Thesis submitted to the Department of Civil Engineering,

College of engineering

In partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Water Supply and Environmental Sanitation

MAY, 2016

DECLARATION

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

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ABSTRACT

In developing countries, hospital liquid waste management is an issue of major concern. The main objective was to assess the hospital wastewater management practices in three Community-based Health Planning and Service (CHPS compounds), two (02) primary hospitals, and one (01) Specialist hospital in fertility within Kumasi Metropolis. Quantitative and qualitative approaches were used in the methodology for this study. Wastewater samples were collected from main effluent points (pipes, inspection chambers, manholes and drains) inside the health care facilities, in situ measurement and laboratory analysis were performed for the Physical, chemical, biological and heavy metal parameters. The study revealed that five (05) health care facilities discharge their wastewater (grey water) without any treatment directly into drains to be conveyed into the urban drainage system, and only one CHPS compound dispose of it wastewater (grey water) into a soakaway through inspection chambers. The wastewater discharged from the health facilities were estimated between 160 to 480 litres/day for the CHPS compounds and 5,600 to 15,840 litres/day for the hospitals. Findings indicated acceptable iron, chromium, zinc and manganese concentrations, however high COD and BOD values were observed ranging between 98 to 832 and 31.09 to 68.15 mg/l respectively. Nitrate concentration ranged from 2.9 to 424.95 mg/l and phosphorus values were between 1.7 and 4.49 mg/l and above EPA acceptable guideline values. Heavy metals (lead, cadmium and mercury) presence and microbiological contents were found above Ghana EPA effluent guideline values. One out of six health care facilities had a high mercury concentration of 0.014 mg/l, lead concentration were found higher than EPA permissible levels, cadmium concentration for two CHPS compounds were above EPA acceptable levels (0.1 mg/l), thus the need of proper disposal and adequate treatment of hospital wastewater.

DEDICATION

I entirely dedicate this work to my ***LOVELY FAMILY.***

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LIST OF ABBREVIATIONS

APHA	American Public health Association
Avg.	Average
AWWA	American Water Works Association
BOD	Biochemical Oxygen Demand
CHPS	Community- based Health Planning and Services
CFU	Coliform Forming Unit
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E. coli	Escherichia Coli
EC	Electrical Conductivity
GWCL	Ghana Water Company Limited

KNUST	Kwame Nkrumah University of Science and Technology
MPN	Most Probable number
TDS	Total Dissolved Solid
TSS	Total Suspended Solids
WHO	World Health Organization

ACKNOWLEGMENT

To Allah almighty for his favours, graces and mercies for a successful study.

My sincere appreciation goes to my supervisor Dr. Helen Essandoh for her professional guidance, corrections, support and precious time from the beginning of this research to its end. I am very grateful to the program coordinator Dr. Richard Buammah for all his fatherly assistance and advices throughout the programme. My sincere gratitude to the SNOWS project for its support. My thanks to the health care centres Staff for their assistance during my research. Sincere thanks to all my friends for their endless encouragement and support in so many ways but most of all, for always "being there". To my colleagues Abdallah Abubakar, Ing. Ransford Addai, Seth Adjei, Ing. Collins Owusu, I say thank you for your assistance, advice and support. To my dear colleague James Baba Awuni who passed away during the program, may your soul rest in peace.

I am grateful to the staff of Environmental Quality Engineering laboratory and Samuel Kwame Dadzie for their fruitful help during my research phase.

Special thanks to my family who always give me support and keep me in their prayers. May Allah almighty richly bless you.

CHAPTER 1: INTRODUCTION

1.1 Background

Sciortino & Ravikumar (1999) define hospital wastewater as a complex mixtures of pollutants such as microorganisms, chemicals, heavy metals, blood, pharmaceutical compound, body fluids and biodegradable organic material. WHO (1999) classifies the medical waste into: pathological wastes (body fluids from surgery), infectious waste (from laboratories), pharmaceutical wastes (out-of- date pharmaceutical products), chemical wastes (used solvents, disinfectants, pesticides and diagnostic chemicals), aerosols (aerosol containers and gas), and open sources used in vitro diagnosis or nuclear medical therapy.

Health care activities generating wastewater are surgery, delivery, radiology, drug treatment, cleaning of premises, chemical and biological laboratory analysis (UN-Water, 2012). Due to the chemical and biological nature of the waste an adequate management comprising special treatment is essential (Babanyara, 2013).

Surface and ground water contamination, environmental and aquatic life pollution, sewerage network obstruction and human health problems can occur if there is improper effluent disposal without preliminary and adequate treatment (Carr, 2001).

In developing countries health care institutions waste management is a critical issue of a major concern (Cohen *et al*., 2009). Many Studies have found and reported a poor management of health care waste in developing countries, African continent alone has over 67,000 healthcare facilities that generates over 283, 000 tonnes of clinical wastes annually (Wiafe *et al*., 2016). In 2002 WHO assessment on medical waste management in 22 developing countries showed that the proportion of health care facilities that do not use proper waste disposal methods ranges from 18%-64% (Shinee *et al*., 2007).

From health care facilities large quantities of wastewater containing potentially infectious and hazardous materials are being discharged, and seen as threats to public health and environment safety (Wiafe *et al*., 2016).

1.2 Problem Statement

Currently in Ghana, poor health care establishment waste treatment methods and practices are creating serious environmental problems in cities and local communities, exposing residents and neighbours to foul odours, and water contamination (Asante *et al*., 2014).

In Ghana, an investigation on pharmaceutical waste management in five (05) health facilities located in Accra, Kumasi, and Koforidua revealed that more than 95% of the selected hospitals are not connected to Waste Water Treatment plant (WWTP) (Samuel, 2008). The same study informed that Korle-bu Teaching Hospital in Accra directly discharge its wastewater in the Korle-lagoon (Samuel, 2008). Boadi & Kuitunen (2002) stated that Korle Lagoon has become one of the most polluted water body.

The Globe (2012) reported a medical wastewater scandal, that for more than a year wastewater from 37 military hospital in Ghana has been flowing freely into main drains in Accra city, the sources of this water being the hospital mortuary, theatres, labour wards, where residents living around the immediate surroundings of this hospital were at risk of contracting tuberculosis, and hepatitis from this waste water. They were complaining about being sick often during those days and blamed the hazardous waste from the hospital. Also this wastewater from 37 military hospital was reused by farmers in vegetables crops growing (garbage, carrots, tomatoes, onions), which exposes communities to cholera and typhoid.

According to Ammakiw *et al*. (2013), there is actually a major concern about the waste management situation since this waste type refers to hazardous, and from its physico chemical, microbiological and toxicological components it can be harmful and potentially expose health-care facilities workers, patients and the public to infections due to their toxic effects, as well as increasing the risk of polluting the environment (WHO, 2015).

1.3 Objectives

The main objective is to assess the liquid waste management in six (06) health care facilities in Kumasi.

The specific objectives are:

a) To identify sources and wastewater generation rates in the health care facilities.
b) To assess the wastewater management practices in the health care facilities.
c) To determine the quantity and quality of effluent discharged from the facilities into the environment.

1.4 Research Questions

In the view of the above problems mentioned this study sought to answer these following questions:

a) What are the activities at the hospitals generating the waste?
b) What is the current wastewater management system in the health care establishment in Kumasi?
c) How much effluent is discharged and does it meet the discharge criteria?

1.5 Justification

Knowledge of the current management practices as well as the composition of health care wastewater will help in putting up in place sustainable measures in place which

will address wastewater from health care facilities management challenges in developing countries.

The output of this study is to provide the necessary data about the quantity and quality of the wastewater generated, and put in place applicable measures and methods for an efficient and effective management of the discharged water.

The study areas are three CHPS compounds, two primary hospitals and one specialist hospital within Kumasi Metropolis.

1.6 Scope of Work

The research will focus on two (02) primary hospitals coded as PH1,PH2 , one specialist hospital as SH and three (03) Community -based Health Planning and Services (CHPS compounds) coded as CC1, CC2, CC3.

1.7 Report Structure

Chapter 1: comprises the background, problem statement, research questions, and justification.

Chapter 2: focuses on pertinent literature on hospital wastewater management practices.

Chapter 3: talks about the methodology and study area.

Chapter 4: discusses about the data analysis and the laboratory results. Chapter

5: contains conclusions and recommendations from the study.

CHAPTER 2: LITERATURE REVIEW

2.1 General

This chapter reviews previous studies, literatures on wastewater management from health care facilities, proper discharge, the impact of wastewater improper handling on human health and environment. Reports and books from different countries and continents are examined.

US Department of Energy (1998) defines hospital liquid wastes as complexes mixture containing harmful pollutants such as infectious, pathogenic microorganisms (bacteria, viruses) pathogens like antibiotic-resistant bacteria and viruses, laboratory and pharmaceutical residuals, radioactive elements, toxic substances, chemicals, other heavy metals and toxic chemical compounds such as Cupper, Iron, Cadmium, Lead, Mercury, Phenol and biodegradable organic compounds.

Due to the actual health care development technology, there is an increase of the quantity of waste disposed from the health institutions with the main reason being the utilization of disposable products (Sarojini, 2013; Amouei *et al*., 2015). Consequently human beings, animals and plants can be impacted (Prüss et al., 1999).

Hussain *et al*. (2001) stated that in developing countries, even though wastewater and its nutrient contents can be used for crop production, thus providing significant benefits to the farming communities and society in general, its use could however also impose negative impacts on communities and on ecosystems. The use of wastewater containing toxic wastes coupled with the lack of adequate finances for treatment is likely to cause an increase in the incidence of water borne diseases as well as more rapid environmental degradation (Idris-nda et *al*., 2013).

2.2 Medical Liquid Waste Categorization

Hospitals discharge considerable amounts of chemicals and microbial agents in their wastewaters. Probable chemicals present in hospital wastewater belong to different groups, such as antibiotics, X-ray contrast agents, disinfectants and pharmaceuticals (Pauwels & Verstraete, 2006). They end up in surface waters where they can influence the aquatic ecosystem and interfere with the food chain (Simachew, 2008).

Medical wastewater is categorized according to the type of pollutant such as: infectious waste, pathogenic waste, pharmaceutical waste, genotoxic waste, chemicals, and heavy metal content (WHO, 1999).

Sarojini, (2013); and Windfeld & Brooks, (2015) stated that about 85% hospital waste is non-hazardous, 10% infective and 5% not infective but hazardous in the United States while in India, it was reported that the value can increase from 15% to 35% depending on the total amount of hospital waste generated (Babu *et al*., 2009).

Wastewater from health-care establishments is of a similar quality to urban wastewater, but may also contain various potentially hazardous components (WHO, 1999). Figure 2.1 shows the classification of clinical wastewater.

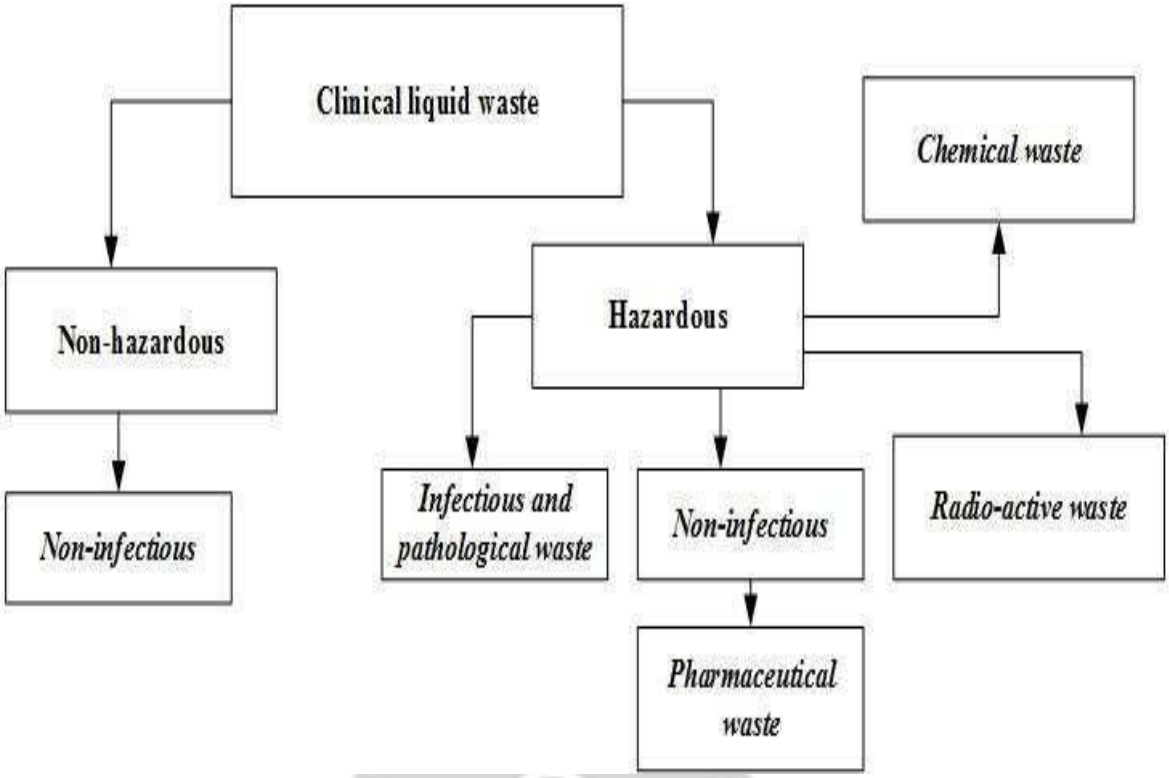

Figure 2.1: Clinical wastewater classification

Source: (Wiafe et al., 2016)

2.2.1 Infectious waste

Infectious waste is defined as waste suspected to contain pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentration to cause disease in susceptible hosts (WHO, 1999). This category includes: waste from laboratory work such as cultures, samples (example of stool and blood samples), waste from surgical wards, and infectious diseases treatment units (UN-Water, 2012).

2.2.2 Pathological waste

Pathological waste consists of tissues, blood, and body fluids. This category is also called also called anatomical waste (Prüss *et al*., 1999). Pathological waste should be considered as a subcategory of infectious waste, even though it may also include healthy body parts (Prüss *et al*., 1999).

2.2.3 Pharmaceutical waste

Pharmaceutical waste is waste from pharmacies, dispensaries or drug stores inside health facilities, it includes spilt, expired, unused, contaminated pharmaceutical products such as drugs, and vaccines (WHO, 1999).

Hospitals discharge considerable amounts of chemicals and microbial agents in their wastewaters. Chemicals present in hospital wastewater belong to different groups, such as pharmaceutical products. Many of these chemical compounds resist to normal wastewater treatment. They end up in surface waters where they can influence the aquatic ecosystem and interfere with the food chain (Pauwels & Verstraete, 2006).

2.2.4 Genotoxic waste

Nwachukwu et al. (2013) defines genotoxic waste as waste highly hazardous and may have mutagenic, teratogenic, or carcinogenic properties that should be given special treatment. Vomit, urine and ingested drugs from patients treated with cytotoxic drugs or antineoplastic drugs (used in chemotherapy of cancer and defined as a substance with the capability to kill or stop the growth of certain living cells), chemicals and radioactive material, are the main sources of genotoxic waste (Prüss et al., 1999).

2.2.5 Chemical waste

This type of waste consists of discarded liquid, and gaseous chemicals, for example from diagnostic and experimental work, from cleaning, and disinfecting procedures (Prüss et al.,1999).

2.2.6 Organic chemicals, inorganic chemicals and heavy metals

Every element in managing and disposal of clinical waste is dealing with waste generators and contractor. Generation of clinical waste in hospital need complete and

arranged management in order to take full responsibility of each job. Poor management can cause high exposure of disease such as Hepatitis (Ibrahim, 2005).

According to Ibrahim (2005), inorganic chemicals consist mainly of acids and alkalis (e.g. sulphuric, hydrochloric, nitric, and chromic acids, sodium hydroxide and ammonia solutions) including oxidants, such as potassium permanganate (KMnO4), and reducing agents such as sodium.

Hospital Wastewater with high heavy-metal content represents a subcategory of hazardous chemical waste, which is usually highly toxic. Mercury wastes are typically generated by spillage from broken clinical equipment and from chemicals used but their volume are decreasing with the substitution of solid-state electronic sensing instruments such as thermometers (Njiru, 2015). **2.3 Effluent Discharge Criteria**

2.3.1 Water quality physical Characteristics

2.3.1.1 Total Dissolved Solids

Solids occur either in solution or in suspension in water. The total dissolved solid (TDS) is known as the solids that remain after filtration and evaporation as residue. It comprises inorganic salts (mainly calcium, magnesium, potassium, sodium, bicarbonate, chlorides and sulphate) and dissolved organic matter (Bartram & Ballance, 1996).

2.3.1.2 Total Suspended Solids

The suspended or colloidal particles, commonly referred to as total suspended solids (TSS), are known as the extremely small suspended solids in water which will not settle out by gravity (Bartram & Ballance, 1996).

2.3.1.3 pH pH (hydrogen ion concentration) indicates the intensity of acidity or alkalinity in water, and affects biological and chemical reactions. Water's chemical balance (equilibrium relationships) is strongly influenced by pH (Bartram & Ballance, 1996).

2.3.1.4 Conductivity

Electric Conductivity (EC) is actually a measure of the ionic activity of a solution in terms of its capacity to transmit current (El-Mouhty *et al*., 2014).

2.3.1.5 Temperature

Temperature affects chemical dissolved and reaction rates. The change in temperature affects the solubility of oxygen, the rate of bacterial activity and gases transfer rate in surface waters. Temperature affects chemicals dissolved and reaction rates (ElMouhty *et al*, 2014).

2.3.1.6 Turbidity

Water clarity is usually measured against a turbidity index. It measures light passage interference. Insoluble particulates scatter and absorb light rays, impeding the passage of light through water (Bartram & Ballance, 1996).

2.3.2 Chemical water quality characteristics

These parameters Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) are used to characterize the organic matter contents of wastewater (Penn et *al.,* 2002).

Organic matters in water cause oxygen depletion in streams due to metabolism of organic material by microbes, as well as colour and odour problems (Brown & Caldwrll, 1999).

The BOD is a major parameter used for water quality measurement and for the design of treatment plants (Chapman, 1996).

The determination of BOD_5 involves the measurement of the dissolved oxygen (DO) used by microorganisms in the biochemical oxidation of organic matter in a given volume of water over a five- days incubation period at 20°C and is a measure of organic pollution (Bai *et al*., 2010).

$BOD_5$is supposed to measure the amount of food (or organic carbons) that bacteria can oxidize. The COD is defined as the total amount of chemicals present in the water that can be oxidized if the oxygen is not continually replaced (Al-ajlouni *et al*., 2013).

2.3.3 Metals

Heavy metals are a group of metals with density greater than 5 g/cm^3. In water they are harmful in relatively small amounts are classified as toxic metals while other metals are classified as nontoxic because they are not harmful (Duruibe *et al*., 2007; Tchounwou *et al*., 2012). In natural waters other than groundwater, metal sources includes dissolution from natural deposits, discharges from laboratories (preservatives), dental department, thermometers, and sphygmomanometers (US EPA, 2006) .

Many of these metals are necessary for growth of biological life but only in trace concentrations. If the required concentrations are exceeded they can become toxic and thus interfere with the potential beneficial uses (Bai *et al*., 2010). The risks of exposure to heavy metal is showed in Table 2.1.

Table 2.1: Health risks of heavy metal exposure

Element	**Acute exposure** usually a day or less	**Chronic exposure** often months or years

Cadmium	Pneumonitis (lung inflammation)	Lung cancer Osteomalacia (softening of bones) Proteinuria (excess protein in urine; possible kidney damage)
Mercury	Diarrhea Fever Vomiting	Stomatitis (inflammation of gums and mouth) Nausea Nephrotic syndrome (nonspecific kidney disorder) Neurasthenia (neurotic disorder) Parageusia (metallic taste) Pink Disease (pain and pink discoloration of hands and feet) Tremor
Lead	Encephalopathy (brain dysfunction) Nausea Vomiting	Anemia Encephalopathy Foot drop/wrist drop (palsy) Nephropathy (kidney disease)
Chromium	Gastrointestinal hemorrhage (bleeding) Hemolysis (red blood cell destruction) Acute renal failure	Pulmonary fibrosis (lung scarring) Lung cancer
Arsenic	Nausea Vomiting Diarrhea Encephalopathy Multi-organ effects Arrhythmia Painful neuropathy	Diabetes Hypopigmentation/Hyperkeratosis Cancer

Source: (Wikipedia, 2016)

2.3.4 Biological water quality characteristics

Most water-borne microbes are particularly used as food chain decomposers. Only a few microorganism species are causes of human beings diseases and damage the environment. These pathogens include bacteria species, virus, algae, protozoa, and parasitic worms that are able to infect, and transmit diseases to both humans and animals (Taylor et al., 1996).

Bacteria are contained in water, intestines of humans and animals, but most encountered are harmless. The waterborne pathogenic bacteria are causes of diseases having common symptoms of gastrointestinal disorder. Coliform group testing indicates a proportion of contamination relative to an easily defined quantity of water. Fecal coliform bacteria do not cause disease by themselves. These organisms are present in intestinal tract of all mammals. Human body wastes contain literally millions of coliforms. The number of fecal coliform bacteria present effectively indicates the pollution levels of the water source (Keyser, 1997).

2.3.5 Nutrients

Johns (2015) stated that the different nutrients sources in the health care facilities are laundries, pharmacies, laboratories, and cleaning detergents.

NO_3-N is a necessary primary macronutrient for plants that stimulates plant growth and is usually added as a fertilizer but can also be found in wastewater as nitrate, ammonia, organic nitrogen or nitrite. In water, nitrogen in the form of nitrate (NO_3) is sign of sewage contamination. Which is an immediate health threat to both human (infants) and animals (Chapman, 1996).

Phosphorus is also a primary macronutrient that is essential to the growth of plants and other biological organisms but quantities in excessive can cause algae blooms,

Phosphorous sources include phosphates from detergents (Abhilash *et al*., 2014).

2.4 Wastewater physical, chemical, and Biological quality characteristics

2.4.1 Laboratory wastewater

According to Torke (1996), most of the chemicals used in laboratories are for preparation of slides. Many of the stains contain heavy metals or other hazardous ingredients.

2.4.2 Wastewater from patient care unit and lying in wards

Wastewaters discharged from Patient care areas, lying in wards have a very similar quality to domestic wastewater. The primary contributing flows include showers, rest rooms and cleaning water. The potential concerns include disinfection supplies (Phenolics), the use of medicine and other pharmaceutical products, and mercury spills from some equipment such as thermometer and blood pressure cuffs (WHO, 2008).

2.4.3 Pharmacy wastewater

Pharmacies have as primary function to dispense drugs and prepare solutions. These solutions are prepared with salts and the addition of medicines or nutrients (Eltayeb, 2004). It is in addition another source of heavy metals such as silver, cadmium, chromium, copper, cyanide, lead, mercury and nickel (Omer, 2002).

2.4.4 X-ray unit wastewater

Wastes from the x-ray units are mainly x-ray fixer solution, x-ray developer solution x-ray cleaner solution. Because of its high silver content the x-ray fixer solution is considered as hazardous. In the environment, free ionic silver acts as an enzyme inhibitor by interfering with the metabolic process X-ray developer should be treated properly and separately, many cleaners for x-ray developer system contain chromium (Sushma *et al*., 2016).

2.4.5 Dental unit wastewater

Dental amalgam particles are sources of mercury, which is known to be neurotoxic and nephrotoxic. Fetuses and newborn babies are more sensitive to mercury than adults , and there seems to be a great difference in sensitivity among individuals (Agarwal *et al*., 2011).

2.4.6 Labour ward wastewater

Blood and body fluids from this unit may contain blood-borne viruses (e.g. Hepatitis B and HIV) or other bacterial and viral pathogens. These can present a risk to other patients and health care workers. As it is not always possible to know who is infected with these pathogens (Omar, 2011).

2.5 Management of hospital liquid waste

The hospital waste management must receive increasing attention where hospitals generate a considerable amount of medical waste each year as a result of advance in medical services and products (Abah & Ohimain, 2011).

2.5.1 Water consumption

Quantities of liquid waste generated vary with type and size of the healthcare facility, number of patients who visit the hospitals and type of services provided (Wiafe *et al*., 2016).

Amouei *et al*. (2012) calculated 1000 litre per day per bed wastewater production per capita in American hospitals, also Mendoza *et al*. (2015) stated that the medium request in water of the establishments of health is 968 litres by bed and a day.

The average demand for water by hospitals in developing countries is estimated at 500 l per bed per day (Evens et al., 2004). Emmanuel *et al*. (2002) estimated that the water consumption value in general for hospitals varies from 400 to 1200 liters by bed a day.

The important consumption of water by hospitals, gives rise to large volumes of wastewater. A study carried in hospitals in Tehran province in 2013 indicated that wastewater per capita (L/b/d) in the Emam Khomeini and Bank Meli hospitals with

1000 and 268 beds have 750 and 200 m^3/d discharge rate with 750 and 746 Liter/bed/day Wastewater per capita respectively, while the Atiyeh hospital with 350 beds, 400 m^3/d discharge rate and 1142 Liter/bed/day Wastewater per capita (Bidhendi & Tabatabaee, 2013).

Simachew (2008) audit showed that 33,000 liters per month of liquid waste was generated from washing and laboratory cleaning and 162 liters of chemical waste per month.

Jamrah & Ayyash (2008) investigated on the water consumption in three cities Irbid, Rusaifa, and Zarqa concluded that the total grey percentage was averagely 75%, and the percentage of sink water was 27%, water for laundry 17% of the total water used. The percentage of water used for toilets flushing was averagely 15%.

In health facilities water consumption was estimated as follow: 5 litres per OutPatient; 40-60 litres per in-patient hospital (with laundry facilities), camp administration (staff accommodation not included) 5 liters per capita per day and 30 liters per capita/ day for staff accommodation (WHO, 2005).

Mohee (2005) assessed the characteristics of liquid waste generated in Mauritius health care institutions, the waste quantifying process revealed that at Sir Seewoosagur Ramgoolam National (SSRN) hospital 0.654 m^3 of water was consumed per patient per day and the amount of wastewater produced daily was estimated at 500 m^3/d.

At Jeetoo hospital in Pakistan, water usage was around 560 m^3/day with an occupancy rate of 435 beds; the average water consumption per patient was found to be 0.645 m^3 /day (Anon, 2014).

Wiafe et al. (2016) conducted a study in Ghana on Clinical liquid waste management in three health care facilities in the municipality of Sunyani, shows that the wards generate the highest liquid waste (7,817 L/day) of which 199 L is pathological waste and 7,618 L is infectious waste. The surgical theatre followed with a total of 1,020 L. The mortuary generates 9, 87 L of liquid waste of which 412 L is pathological waste and 575 L is infectious waste. Allied department generates 363.5 L of infectious waste but no pathological waste. The laboratory generates 192.5 L of which 162 L is pathological waste and 30.5 is infectious waste. The pharmacy and clinics generate
45.5 L and 19 L.

2.5.2 Hospital wastewater quality

Although the quality of hospital wastewater is similar to municipal wastewater, the effluent of hospitals wastewater may contain non-metabolized pharmaceutical compounds, antibiotics, disinfectants, anaesthetics, radioactive elements, X-ray contrast agents and other persistent and dangerous compounds (Amouei *et al*., 2012).

Mohee (2005) investigated on the liquid wastes physico-chemical and biological parameters generated in Mauritius healthcare institutions and the result showed that the wastewater generated has total coliform level of 10^6 MPN/100 ml, the COD and BOD average values were 600 mg/l and 300 mg/l respectively. The low COD/BOD ratio meant that the problem of toxicity would not arise. Therefore wastewater treatment has to be considered to reduce the contaminant load, otherwise if discharged untreated into the water body its pollution load on the oxygen concentration would drastically decrease and this might lead to septic conditions. There is therefore, contamination of the receiving environment (water, soil and air) due to the discharged hospital wastewater, which could probably be hazardous to human health.

2.6 Medical Wastewater Impact on Human Health

Hospital wastes could be dangerous to the ecological balance and public health. Pathological, radioactive, chemical, infectious and pharmaceutical wastes if untreated could lead to outbreaks of communicable diseases, diarrhea epidemics, water contamination, and radioactive pollution (Azwiendasari & Oginawati, 1995).

A serious concern regarding wastewater is the high content of enteric pathogens including bacteria, viruses, protozoa and helminthes, which are easily transmitted through water (Jiménez, 1999). Wastewater of hospitals where patients with enteric diseases are hospitalized is a particular problem during outbreaks of diarrheal diseases (Amouei *et al*., 2015).

Transmission of disease through infectious waste is the greatest and most immediate threat from healthcare waste. If waste is not treated in a way that destroys the pathogenic organisms, dangerous quantities of microscopic disease causing agentsviruses, bacteria, parasites or fungi will be present in the waste. These agents can enter the body through punctures and other breaks in the skin, mucous membranes in the mouth, by being inhaled into the lungs, being swallowed, or being transmitted by a vector organism (Asante et *al*., 2014).

Medical wastewater is potentially dangerous, since it may possess pathogenic agents. Some of the pathogenic organisms are dangerous, because they may be resistant to treatment and possess high pathogen content (Amouei *et al*., 2015). Inadequate waste management will cause environmental pollution, unpleasant smell, growth and multiplication of insects, rodents and worms and may lead to the transmission of diseases like typhoid, cholera, hepatitis (Babanyara, 2013). Some of the substances found in wastewaters are toxic and suspected to be a possible cause of the cancers

observed in the lasts decades (Jolibois & Guerbert, 2006) . World Health Organization has recently published a world health report where cancer is ranked as the second cause of death (Welfare *et al*., 2011).

Health care workers are often exposed to hepatitis B virus (HBV), human immunodeficiency virus (HIV) and other dangerous blood borne pathogens on a daily basis (Bugando, 2012).

Medical wastewater can have a high content of heavy metals, defined as any metal with a specific gravity of 5 or more, they can be poisonous and cause irreversible damage to human body (Abhilash *et al*., 2014).

The most common heavy metals are mercury, lead arsenic, Zinc, Cadmium, Manganese, Chromium, copper, Nickel, These heavy metals can be causes of bladder cancer, cancer of lungs, skin, kidney, nasal passages, and liver, cardiovascular diseases, hypertension, diabetes, prostate also Alzheimer's disease, autism, and neurodevelopment disorder (Fernández-luqueño *et al*., 2013).

2.7 Impact of Medical Wastewater on Environment

Kumar *et al*. (2014) stated that hospital wastes, because of their infectious nature, are one of the most dangerous causes of environmental pollution.

Hospital Effluents if not properly treated contains high loads of antimicrobial residues and resistant determinants that are continuously released into the environment (Harris *et al*., 2014) .

One of the main environmental problems caused by hospital effluents is due to their discharge in urban sewerage systems without preliminary treatment (Magdaleno *et al*.,

2014). Disinfectants in particular are often highly complex products or mixture of active substances that after use may finally pollute surface and ground waters (Banjoko, 2014).

2.8 Effluent Discharge Criteria

According to Strauss (2007), wastewater effluent must not exceed the local guidelines values for wastewater effluent disposal (EPA,2012) (Table 2.2) , and global effluent guidelines requirements (Table 2.3).

Proper sampling, qualified laboratory, correct samples storage procedure were relevant for effluent guidelines parameters determination.

Table 2.2. Ghana EPA effluent quality guidelines

Maximum permissible level before discharge	**Hospitals and Clinics**
Temperature increase	< 3°C above ambient
pH	6-9
BOD_5 (mg/l)	50
COD (mg/L)	250
Total Dissolved Solids (mg/l)	1000
Total Suspended Solids (mg/l)	50
Total Phosphorus (mg/l)	2
Sulphide (mg/l)	0.1
Total Coliforms (MPN/100 ml)	400
E. Coli (MPN/100 ml)	10
Conductivity (uS /cm)	50
Turbidity (N.T.U.)	75
Lead (mg/l)	0.1
Nitrate (mg/l)	0.1
Mercury (mg/l)	0.005
Chromium (+6) mg/l	0.005
Cadmium (mg/L)	<0.1

Source: (EPA, 2012)

Table 2.3. Global effluent guidelines

Water parameters	Guidelines limits
pH	6– 9
Temperature	≤ 37 °C

Total Suspended Solids (TSS)	≤ 30 mg/l
5-day Biological Oxygen Demand (BOD5)	≤ 30 mg/l
Chemical Oxygen Demand (COD)	Test required; limit currently not established.
Mercury (Hg)	≤ 0.01 mg/l
Cadmium (Cd)	≤ 0.01 mg/l
Lead (Pb)	≤ 0.10 mg/l
Arsenic (As)	≤ 0.01 mg/l
Cyanide (Cn)	≤ 0.20 mg/l
Copper (Cu)	≤ 0.25 mg/l
Nickel (Ni)	≤ 0.20 mg/l
Chromium (Cr)	≤ 0.10 mg/l
Zinc (Zn)	≤ 1.00 mg/l
Sewage	Biological treatment, or an on-site wastewater treatment plant, or a septic tank system.

Source: (Strauss, 2007)

2.9 Best Practices for Wastewater Management

According to Amouei *et al*. (2015), various services in health-care centres have affected the quantity and quality of wastewater. To protect the ecosystem, public health and natural resources there is the necessity of a continuous monitoring health care facilities wastewater quality and quantities (UNEP, 2010).

Prüss et al. (1999) advised heavy metal reuse/recovery in countries where industries are specialized in heavy metal recovery, e.g. waste with mercury and cadmium components can be recover to valuable material by these facilities. It may also be possible to send back the waste to the suppliers of the original equipment, with a view of reprocessing or proper final disposal.

The health-care establishment should ideally be connected to a sewerage system (EPA Ghana, 2002). Hazardous chemicals present in medical waste water are from cleaning activities and disinfection in the health care establishment. The pollutant concentration, suspended solids contents, rate of discharge, temperature and pH should be restricted to

avoid presence of large quantities of chemicals in the medical liquid waste, the disposal and damage of sewage (Brown, 1997).

Wastewater with pH not between 6 and 10 must be adjusted manually on a batch basis, or through an automated pH correction system before discharge to sewer and unwanted samples of human blood or bodily fluids are disinfected before disposal to sewer (Prüss et al., 1999).

The heavy metals in wastewater shall be removed by precipitation, ion exchange or other acceptable pre-treatment process (WHO, 1999) .

CHAPTER 3: STUDY AREA AND METHODOLOGY

3.1 Profile of Study Area

Kumasi is located in the transitional forest zone and is about 270 km north of the national capital, Accra. It is between latitude 6.35°-6.40° and longitude 1.30°-1.35°, an elevation which ranges between 250-300 meters above sea level with an area of about 254 square kilometers. The metropolitan area shares boundaries with Kwabre East District to the north, Atwima District to the west, Ejisu-Juaben municipal to the east and Bosontwe to the south (Kumasi Metropolitan Assembly, 2006).

Kumasi encompasses about 90 suburbs, many of which were absorbed into it as a result of the process of growth and physical expansion. With a growth rate of 2.7 per cent, the Ashanti region is considered as the third fastest growing region in Ghana. Kumasi population was 4,780,380 in year 2010 and expected to approach 2.75 million in 2015 (Ghana Statistical Service, 2012).

The city has over two hundred (200) known private health institutions and 13 industrial clinics in the metropolis. These facilities are distributed over space. The Ghana health service working with the private sector provides clinical and public health services including OPD, In-patient, Surgery, eye care, dental care, obstetrics and gynecology etc. the public health services include expended programs on immunization, reproductive and child health, disease control, nutrition, health information management, social mobilization for community support, collaboration with other sectors and the community, and the environmental health department.

3.2 Study Location

Study is carried out at six (06) health care institutions comprising three Communitybased Health Planning and Services (CHPS) compounds which are Ayeduase community clinic, Anwomaso community clinic, Apatrapa clinic located at Adwaase,

Anwomaso and Apatrapa respectively; two (02) primary hospitals which are Kwame Nkrumah University of science and technology (KNUST) hospital Suntreso hospital located at KNUST University and Suntreso respectively; and Trust care that is specialist hospital located at Ohwimase. The health care facilities offered services such as surgery, maternity clinic, out-patients care, radiology**,** pharmaceutical proceedings**,** x-ray**,** eye clinic, dental clinic. Activities such as cleaning and laundry take place in these health facilities.

3.3 Study Sites Selection

The study area choice was done according to the following criteria:

i. One general public hospital (that encompass five main departments:

medical; surgical; obstetrics, and gynaecology; paediatrics and the laboratory).

ii. One specialized hospital.

iii. Ten percent (10%) of the health care centres in the city of Kumasi (centres with any level or type of surgical services).

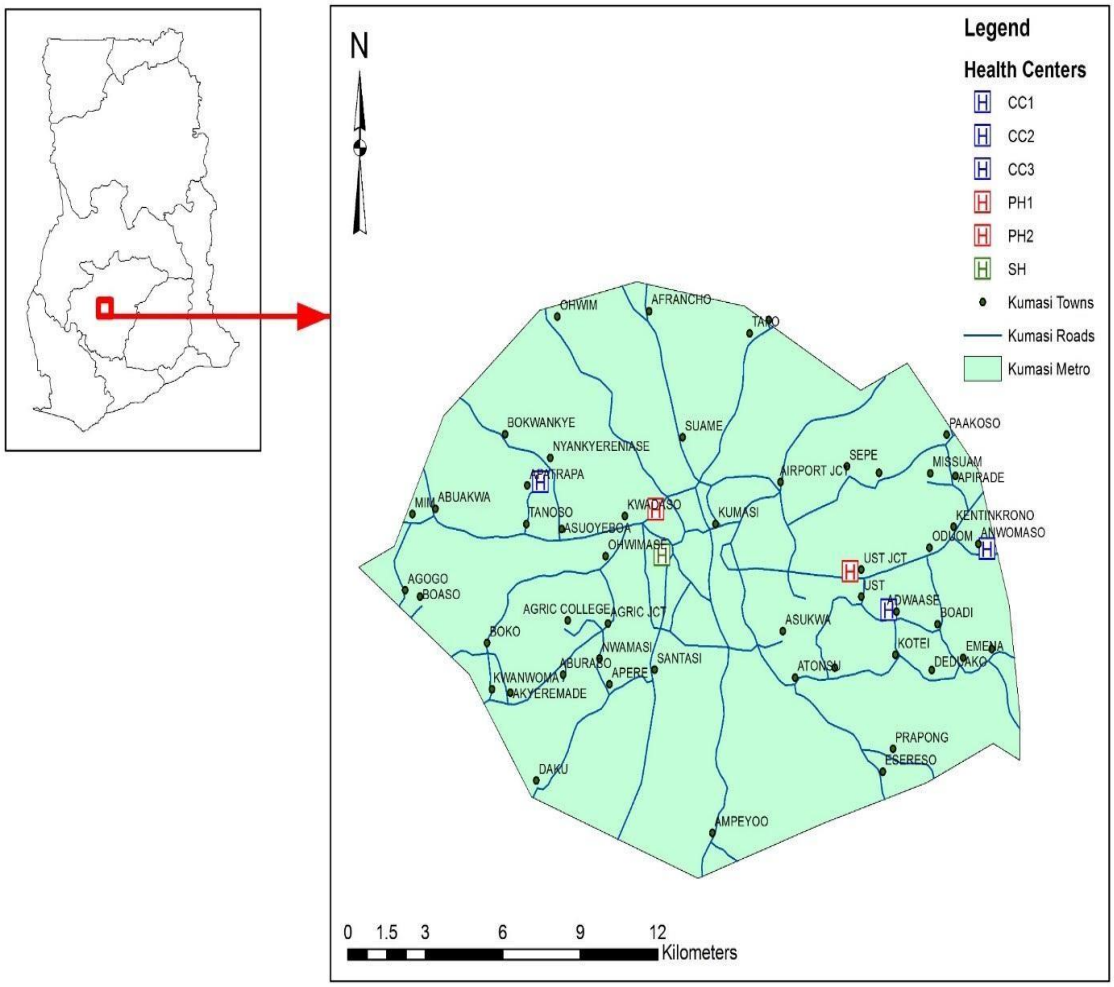

Figure 3.1: Study area map

3.4 Data collection

3.4.1 Desk study

This section is to give a view and knowledge about the already existing literature on the wastewater management in hospital in Africa and all over the world, through published reports, journals, articles, websites and books.

3.4.2 Field work

- Global Positioning System (GPS) was used for an accurate location of the sampling points (pipes, drains, inspection chambers) for a simpler mapping of the study area.

- In situ measurement instruments: A PC 300 Waterproof Handheld pH/Conductivity/ TDS/ was used to ensure more accuracy and avoid degradation of analytical parameters during the sample transfer to the laboratory.
- Sampling containers and labels**:** plastic bottles of 1.5 liters were used for the sampling. From 8:00 am to 4:00 pm hourly samples were collected from facility's pipes, manhole, and drains. Additionally, treatments were applied to sampling containers for some parameters to ensure the sample integrity (addition of 1 ml of nitric acid for the heavy metal analysis samples).
- Decontamination of sampling equipment: all sample bottles were decontaminated and cleaned to avoid any risk of contamination between samples.
- Cooler, ice blocks and refrigerator were used to ensure the conservation of samples between the temperature of 1°C and 4°C. All the samples required chilling as means of preservative.
- Other sampling equipment**:** buckets were used for waste water mixing to get a daily composite sample.

3.4.3 Computer programs used

1. Microsoft excel was used for laboratory results analysis, graphs and comparison to the guideline values
2. Arc-GIS was used to map out the study area and also the sampling points

3.4.4 Data collection instruments and procedures

Qualitative and quantitative research methods was used as research approach, questionnaires were administered to health care centres workers to assess the current liquid waste management practices.

Field observation was conducted to identify different wastewater sources in the different facilities. Medical wastewater samples were collected from outfalls (pipes and drains) to be analysed for their physical (pH, temperature, conductivity, TSS); chemical (TDS, Nitrate, Phosphate, Sulphate, Phosphorus); Heavy metals (Mercury,
Lead, Cadmium, Chromium, Zinc, Iron, Manganese); and micro-biological (E.Coli, Salmonella, Total coliforms, Non Fecal Coliforms), parameters determination and compared to the health care effluents standards of disposal given by Ghana Environmental Protection Agency (EPA, 2012). The sampling was carried out carefully to ensure collector protection and avoid personal risk or contamination from the nature of the samples or the location of sampling point.

Samples were stored in ice chests in order to keep samples between 1°C and 4°C to preserve the majority of physical, chemical and biological characteristics.

Characterization of samples were done at the EQE laboratory at the department of Civil Engineering, KNUST for the physico- chemical and microbial parameters.

Between the intervals of sampling and analyses in the laboratory, physical, chemical and biochemical reactions may take place in the sample container leading to changes in the intrinsic quality of the sample, it was necessary to prevent or minimize these

changes. For this reason highly unstable parameters such as pH, temperature, turbidity, Total Dissolved solids, and conductivity had theirs measurements done at the sampling site. Water samples were collected from pipes outlets, drains, inspection chambers, from January to February 2016, the sampling was carried out hourly from 8:00 am to 4:00 pm during 5 days for each health care facility.

Each ward in the hospital has its own wastewater characteristics**.** These wards were selected for the sampling to give an idea about the hospital wastewater characteristics: laboratories, labour ward, lying in wards, pharmacies/dispensaries, X-ray unit, dental units, eye clinics, laundries, consultation rooms and final effluent point for all the wastewater in the facility.

The preservation procedure for samples used for heavy metals analysis includes the addition of nitric acid for sample oxidization before analysis, keeping the samples in the dark and lowering the temperature to retard (UNEP ,2004; UNEP, 2014) (Table 3.1).

Table 3.1: Preservation method used before the laboratory analysis

Experiment	**Preservatives**	**Max. holding time**
BOD	Cool, 4°C	4 hours
Calcium	Cool, 4°C	7 days
Chloride	Cool, 4°C	7 days
COD	Cool, 4°C	24 hours
Dissolved Oxygen	Fix on site	6 hours
Fluoride	Cool, 4°C	7 days
Magnesium	Cool, 4°C	7 days
Nitrate + Nitrite	Cool, 4°C	24 hours
pH	None	6 hours
Phosphorus*		
Inorganics	Cool, 4°C	24 hours
Ortho	Cool, 4°C	24 hours
Potassium	Cool, 4°C	7 days
Specific conductance	Cool, 4°C	24 hours

Sodium	Cool, 4°C	7 days
Heavy metals		
Cadmium	2 ml conc. nitric acid/L sample	6 months
Chromium	2 ml conc. nitric acid/L sample	6 months
Copper	2 ml conc. nitric acid/L sample	6 months
Iron	2 ml conc. nitric acid/L sample	6 months
Lead	2 ml conc. nitric acid/L sample	6 months
Nickel	2 ml conc. nitric acid/L sample	6 months
Zinc	2 ml conc. nitric acid/L sample	6 months

Source: (Limgis, 2001)

3.4.5 Sampling method

The quality of hospital wastewater varies with time due to various activities that takes place in the hospital. The sampling was undertaken during five (05) working days in the week (Monday, Tuesday, Wednesday, Thursday and Friday) in a sampling interval time from 8:00 am to 4:00 pm during the sampling days.

A sample bottle of 1.5 litters was continuously filled hourly from effluent points from 8:00 am to 4:00 pm during five days for each health care facility, then proceed to a complete mixing of the different discrete grab samples collected from the pipes, drains or inspection chambers to have an average estimate of water quality called composite sample.

3.4.6 Information source

Open discussions were held with the health workers (midwife, nurses, doctors, different wards workers, laboratory workers, cleaners, and environmental department officer, administrators) in the various health facilities to obtain general information on the wastewater management practices. Information on wastewater types, collection system, and their disposal methods in the different, CHPS compounds, hospitals, and specialized hospital were obtained.

The collected data includes: number of beds, number of outpatients, average daily number of patients, average daily beds occupancy, number of workers, water consumption (on a daily, weekly or monthly basis), rate of overhead tanks refilling, capacity of the tanks.

3.4.7 Laboratory procedure

In-situ measurement was carried for parameters such Temperature, pH, EC, and TDS. The rest of the parameters were tested in the laboratory.

Potable field test kit was carried to measure in-situ parameters like Temperature, pH, Electrical Conductivity and Salinity. HANNA turbidimeter HI 93414 was used to measure the turbidity by gravimetric method. The BOD was measured using the DO meter, where 10 ml of wastewater sample was poured into 300 ml BOD bottle and mixed with aerated water until it overflow and then stopped. For the blank another BOD bottle was filled with only 300 ml of aerated water, then measured the initial dissolved oxygen concentration for the two bottles (blank and diluted sample) using a DO meter. The bottles were stored in the incubator at 20°C for five days, the remaining amount of DO was measured on the fifth day.

Open reflux titrimetric method was used for the COD value measurement using potassium dichromate in sulphuric acid as oxidation agent. Chromocult agar method was used for the microbiological parameters determination (E. coli, salmonella and total coliforms). The (APHA/AWWA/WEF, 2012) Standard Methods for Examination of Water and Wastewater was used as methodology for the wastewater laboratory analysis.

3.5 Wastewater Estimation

The focus was on estimating the waste water generation rate using the water consumption was only a mean. The primary hospitals and specialist hospitals were connected to the municipal water supply Ghana Water Company Limited GWCL, the water consumption was estimated through reading of water bills.

Concerning the CHPS compounds, the water supply sources were boreholes, pumped with motorized pump and stored in an overhead tank. The CHPS compounds water consumption was calculated using the capacity of the water overhead tank and the refilling rate of the overhead tank.

As stated by Samir (2010) about 60 to 80 per cent of the water consumption is converted to wastewater, at the CHPS compounds CC1, CC2 and CC3 water was mainly used for cleaning of the facility, personal hygiene and laundry, however for Health care center PH1, PH2 and SH water usages were premises cleaning, personal hygiene, laundry water quantity used for garden watering, garden watering.

3.6 Hospital Wastewater Characteristics Determination

Hospitals included in this section are:

1. CC1: wastewater samples were collected from the wastewater main collection point and pipes
2. CC2: wastewater samples were collected from the main drain.
3. CC3: wastewater samples were collected from the wastewater inspection chambers before the discharge into the soakaway pit.
4. PH1: sample of wastewater was taken from manholes, inspection chambers, drains and pipes outlets.

5. PH2 wastewater samples were collected from the main drain collecting all the wastewaters from different units in the hospital.
6. SH: wastewater samples were collected from the main drain collecting all the wastewater from, laundry, labour ward, theater, patient-care areas through pipe system and discharged in the urban drain outside the specialized hospital.

3.7 Data analysis

Microsoft Excel was used to analyze the results obtained from laboratory analysis and in situ measurements.

CHAPTER 4: RESULT AND DISCUSSION

4.1 General Data

Among the health care facilities three CC1, CC2 and CC3 are categorized as CHPS compounds, two general hospitals PH1, PH2 and one specialist hospital SH. The number of beds varied from 4 to 130, the Out patients cases between 2 and 220, and the number of workers varies from 7 to 233. The communities' health facilities had less number of beds, out- patients' cases and workers and less offered services (consultation service, dispensary, maternity, planning unit).

4.2 Actual Wastewater Management Practices

The study of the general current management practice in the visited health care facilities showed that for all the health facilities the black water was properly stored, and the main concern was on grey water management (Table 4.1). All black waters were collected into septic tank for desludging after a specific number of weeks, months, or years. Five (05) hospitals over six (06) discharged their grey water from different units without any treatment into the facilities drains and flowed to the urban drainage system.

Table 4.1: Actual wastewater management situation

Health care facilities	Type of treatment	Final disposal	Septic tank desludging rate
CC1	• No treatment for grey water • Onsite treatment for Black water(septic tank)	Urban Drain _	10 years
CC2	• No treatment for grey water • Onsite treatment for Black water(septic tank)	Urban Drain _	10 years
CC3	• onsite treatment for grey water (manhole) • Onsite treatment for Black water(septic tank)	_	10 years
PH1	• Onsite treatment for Black water(septic tank) for waste water from X-ray unit, laboratory, • No treatment for grey water From the rest of wards	_ Urban Drain	1 years
PH2	• No treatment for grey water • Onsite treatment for Black water(septic tank)	Urban Drain _	1 year
SH	• No treatment for grey water • Onsite treatment for Black water (septic tank)	Urban Drain _	Every 2 Weeks

Health care facilities CC1, CC2, PH1, PH2, and SH grey water (from sinks and bathhouses) were connected to the drains and finally discharged in the urban drainage system without treatment, while black waters were discharged into a septic tank (Figure 4.1).

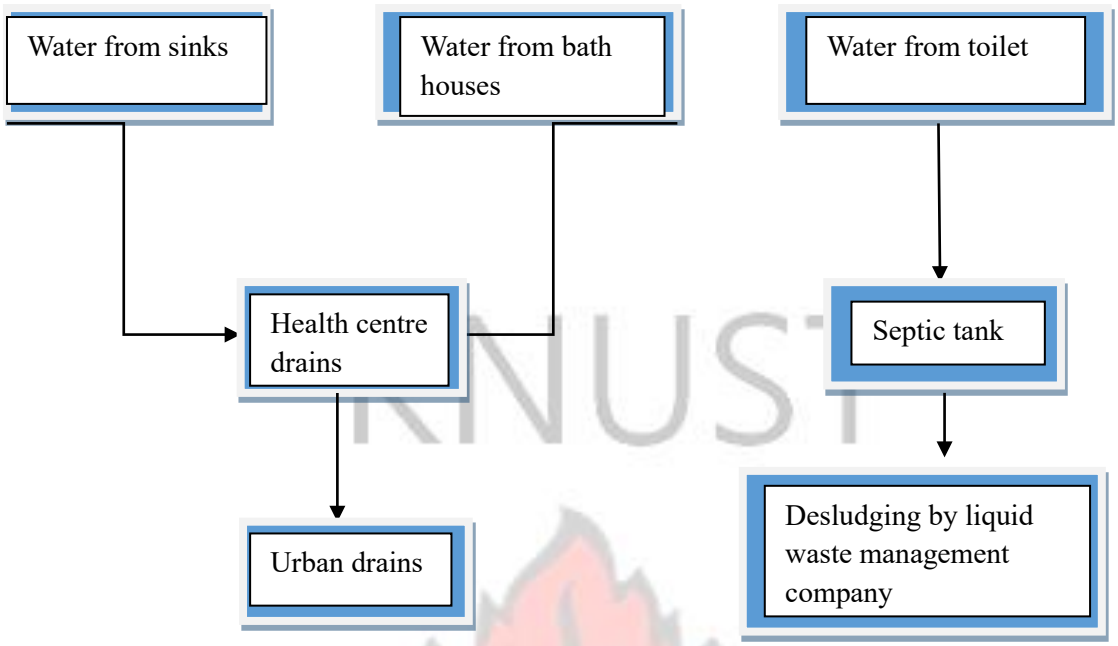

Figure 4.1: Wastewater disposal in health care facilities CC1, CC2, PH1, PH2, and SH

Health care facility CC3 grey water (from sinks and bathhouses) were connected to a soakaway pit for treatment and infiltration into the ground, while black water while discharged into a septic tank (Figure 4.2).

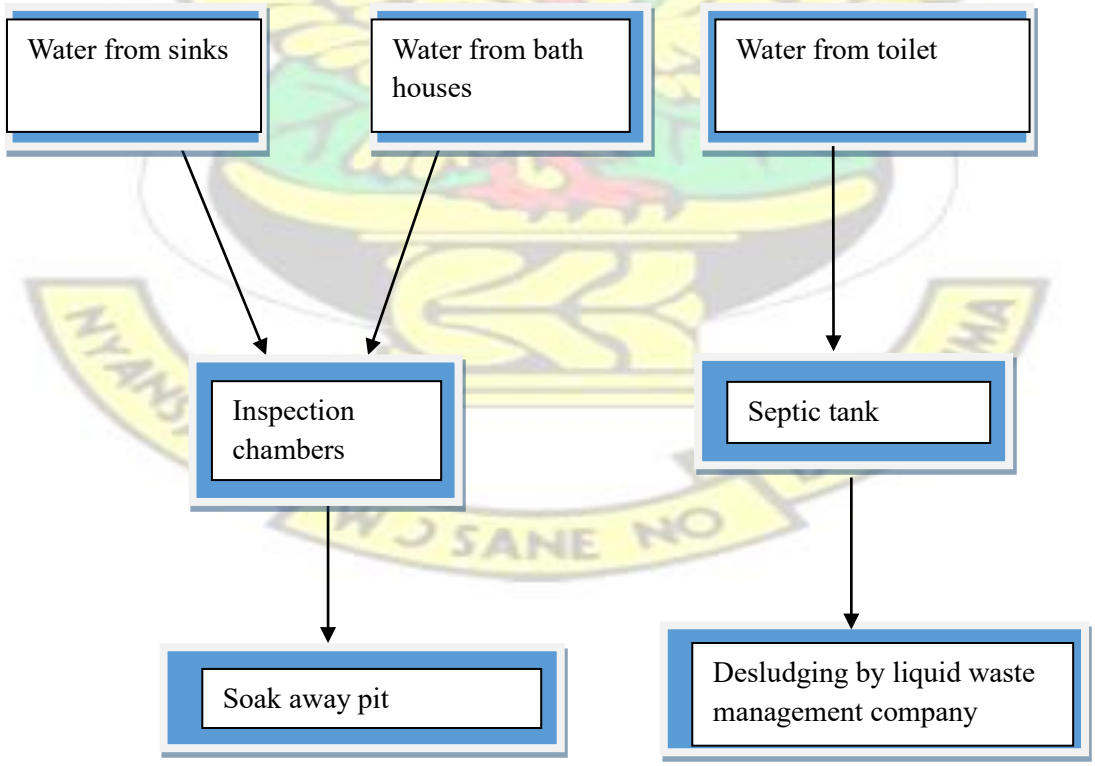

Figure 4.2: Wastewater disposal in health care facility CC3

4.3 Existing Sanitation Practices in the Individual Health Care Centres The different tables below explain more the sanitation practices in individual community health care centres and hospitals, inside the individual units and wards. The different activities undertaken, the means of disposal and final discharge point.

The laboratory and theatres, x ray, dental units considered as infectious and containing heavy metals or toxic compounds had their pipes directly connected to individual soakaway.

The study showed that patient's urines and vomits from lying in wards and theatres were disinfected inside each unit with a chlorine solution (0.5 per cent) before disposal into toilets, the body fluids and parts after deliveries or surgeries were incinerated as solid waste, including the diverse activities undertaken in each unit of the health care centres and the means of wastewater disposal (Table 4.2, 4.3, 4.4. 4.5, 4.6, 4.7 and 4.8).

4.3.1. Health care facility CC1

Table 4.2: CC1 wastewater management situation

CC1	Activities undertaken	Categories of waste from these activities	Wastewater disposal system
Family planning unit	Consultation, hand washing	Non-hazardous waste, chemical waste	Into the drain
Consulting room	Consultation, hand washing, floor cleaning	Chemical waste, pharmaceutical waste	Into the drain
Labour ward	Delivery, washing of body fluids and blood, hand washing, disinfection.	Pathological, chemical waste	Septic tank
Laboratory	Analysis (malaria, syphilis, typhoid, hepatitis etc.	Infectious, genotoxic, chemical waste	Into drain
Wash room	Hand washing, and discharge of vomit, blood, defecation	Pathological waste	Connected to the septic tank

Eye clinic	Washing of tools, hand washing	Pharmaceutical waste	Connected to the septic tank
Lying in room, patients wards	Hand washing, drug treatment	Chemical waste, genotoxic waste	Into the drain

4.3.2. Health care facility CC2

Table 4.3: CC2 wastewater management situation

CC2	Activities undertaken	Categories of waste from these activities	Wastewater disposal system
Maternal health care	Consultation, hand washing	Pharmaceutical waste, chemical waste	Into the drain
Lying in room	Hand washing, drug treatment	Chemical waste, genotoxic waste	Into the drain
Consulting room	Consultation, hand washing(sink)	Pathological, chemical waste	Into the drain
Labour ward	Delivery, instruments decontamination with chlorine solution	Infectious, pathological, genotoxic, chemical waste	Placenta and other membranes are given back to the women. After cleaning the blood is disposed of in the toilet to be flushed.
Dispensary	Drugs, hand washing	Pharmaceutical, chemical waste	Septic tank
Wash room	Hand washing, and discharge of vomit, blood, water used for cleaning and washing, defecation	Pathological waste, chemical waste	Connected to the septic tank

4.3.3. Health care facility CC3

Table 4.4: CC3 wastewater management situation

CC3	Activities undertaken	Categories of waste from these activities	Wastewater disposal system
Family planning unit	Consultation, hand washing	Pharmaceutical waste, chemical waste	Into the drain
Lying in room	Hand washing, drug treatment,	Chemical waste, genotoxic waste	Into the drain
Consulting room	Consultation, hand washing(sink)	Pathological, chemical waste	Connected to the septic tank
Labour ward	Delivery	Infectious, pathological, genotoxic, chemical waste	Septic tank
Dispensary	Drugs, hand washing	Pharmaceutical, chemical waste	Septic tank

Wash room	Hand washing, and discharge of vomit, blood, water used for cleaning and washing, defecation	Pathological waste, chemical waste	Connected to the septic tank

4.3.4 Health care facility PH1

Table 4.5: PH1 wastewater management situation

PH1	**Activities undertaken**	**Categories of waste from these activities**	**Wastewater disposal system**
Laboratory	Tests, hand washing,	Infectious, genotoxic, chemical waste	Into septic tank
Lying in ward	Toilet, bathing, drug treatment	Chemical waste, genotoxic waste	Connected to the septic tank
Consulting room	Consultation, hand washing(sink)	Pathological, chemical waste	Into the septic tank
Labour ward	Decontamination with chlorine solution of delivery instruments	Infectious, pathological, genotoxic, chemical waste	Placenta and other membranes are disposed of into the placenta pit. After cleaning and decontamination, the liquid waste is disposed of in the septic tank
Pharmacy	Drugs, hand washing	Pharmaceutical, chemical waste	Septic tank
Theatre	Hand washing, and discharge of urine after disinfection with Chlorine into sinks. The body parts after intervention are incinerated	Infectious, pathological, genotoxic waste	The sinks and toilets are connected to the septic tank
Dental unit	Dental care, amalgam placement	Hazardous waste, chemical waste, infectious waste	Fluids are discharged into the sink that is connected to the septic tank
X-ray unit	Films development and usage of x ray developer solution and cleaner solution	Hazardous, radioactive, chemical waste	After usage the solution is disposed into the sink connected to the septic tank
Eye clinic	Eye care, hand washing	Pharmaceutical, chemical	Disposal into septic tank

4.3.5. Health care facilityPH2

Table 4.6: PH2 wastewater management situation

PH2	Activities undertaken	Categories of waste from these activities	Wastewater disposal system
Laboratory	Laboratory tests, hand washing,	Infectious, genotoxic, chemical waste	Into septic tank
Male, female, children wards	Consultation, hand washing, toilet, toilet (defecation) bathing, drug treatment	Chemical waste, genotoxic waste	Into the toilet, connected to the septic tank
Consulting room	Consultation, hand washing(sink)	Pathological, chemical waste	Into the drain
Labour ward	Delivery, instruments decontamination with chlorine solution	Infectious, pathological, genotoxic, chemical waste	Placenta and other membranes are disposed of into the placenta pit. After cleaning and decontamination, liquid is disposed of in the toilet to be flushed.
Pharmacy	Drugs, hand washing	Pharmaceutical, chemical waste	Septic tank
Theater	Hand washing, and discharge of urine after disinfection with Chlorine into sinks.	Infectious, pathological, genotoxic waste	Sinks are connected to the septic tank
Dental unit	Dental care, amalgam placement	Hazardous waste, chemical waste, infectious waste	The fluids are discharged into the sink that is connected to the septic tank
X-ray unit	Films development and usage of x ray developer solution and cleaner solution	Hazardous, radioactive, chemical waste	After usage the solution is disposed into the sink connected to the septic tank
Eye clinic	Eye care, hand washing	Pharmaceutical, chemical	Disposal into septic

4.3.6. Health care facility SH

Table 4.7: SH wastewater management situation

SH	Activities undertaken	Categories of waste from these activities	Wastewater disposal system
Laboratory	Laboratory tests, hand washing,	Infectious, genotoxic, chemical waste	Into septic tank

Lying in ward	Consultation, hand washing, toilet (defecation), drug treatment	Chemical waste, genotoxic waste	Into the toilet, connected to the septic tank
Consulting room	Consultation, hand washing(sink)	Pathological, chemical waste	Connected to a drain
Labour ward	Delivery, instruments decontamination with chlorine solution	Infectious, pathological, genotoxic, chemical waste	Placenta and other membranes are disposed of into the placenta pit.
Pharmacy	Drugs, hand washing	Pharmaceutical, chemical waste	The sinks are connected to a drain
Theatre	Hand washing, and discharge of urine after disinfection with chlorine into sinks.	Infectious, pathological, genotoxic waste	The sinks are connected to a drain
Laundry	Daily washing	Chemical waste	Connected to the septic tank

4.4 Estimation of Wastewater Generation Rate

Two different water sources were identified as water supply sources for the health care facilities. The CHPS compounds had boreholes as water sources and through a daily or weekly pumping system the water was stored in overhead tanks. While the two (02) hospitals and the specialized hospital were all connected to the municipality water supply system managed by GWCL, and received on monthly basis water consumption bill from the supply company.

4.4.1. Community -based Health Planning and Services Compounds (CHPS) In the CHPS compounds water is mainly utilized for cleaning and laundries. The main water source are boreholes, with different pumping rates (Table 4.8).

Table 4.8: CHPS Compounds water consumption

Health care facilities	Source of water supply	Storage tank capacity/ liters	Frequency of pumping/ liters	Daily consumption / liters	Water consumption per bed/ liters	Water usage

CC1	Borehole	1400	7 days	200	50	Cleaning of premises , washing, personal hygiene(for detained patients)
CC2	Borehole	1000	3 days	334	27.11	Cleaning of premises , washing, personal hygiene(for detained patients)
CC3	Borehole	1200	2 days	600	42.85	Cleaning of premises , washing, personal hygiene(for detained patients)

The study showed that CC1, CC2, and CC3 water consumption per bed varies from 27.11 to 50 liters per bed/day (Table 4.8). This was confirmed by Wiafe *et al*. (2016) who conducted a clinical liquid waste management in three health care centers in Sunyani municipality (Ghana) and obtained the consumed water value being 33 L/bed/day MH , 20 L/bed/day was found at RH whilst S.D.A had the lowest of 2.5 L/bed/day.

The wastewater flow measured in health facilities CC1, CC2, CC3 varied between 0.033l/s and 0.072l/s (Table 4.9).

Table 4.9: CHPS Compounds wastewater generation rate

Health care facilities	**Measurement point**	**Average waste water flow (liters/second)**
CC1	Drain	0.072
CC2	Drain	0.016
CC3	Inspection chamber	0.033

4.4.2. Hospitals and Specialist hospital

In the hospitals, the water was mainly used for cleaning, use by detained patients and Out-patients laundry, car washing, and trees watering. The two hospitals and specialist hospital were connected to the municipality water supply system managed by GWCL as main source of water supply. Due to the high number of out-patients and detained patients the water consumption was very high (Table 4.10).

Table 4.10: Hospitals water consumption

Health care facilities	Source of water supply	Monthly water consumption (liters)	Daily consumption in (liters)	Water consumption per bed (liters)	Water usage
PH1	GWCL	594,000	19,800	152,3	Cleaning of premises , laundry, personal hygiene, car washing, garden watering, kitchen
PH2	GWCL	500,000	17,000	132,81	Cleaning of premises , laundry, personal hygiene, car washing, kitchen
SH	GWCL	200,000	7,000	233.33	Cleaning of premises , laundry, personal hygiene, car washing, garden watering, kitchen

Table 4.11: Hospitals wastewater generation rate

Health care facilities	Measurement point	Average waste water flow (liters/second)
PH1	Pharmacy unit	0.0075
	Lying-in ward	0.43
	Dental clinic	0.0035
	Eye clinic	0.029
	X-ray unit	0.0438

	Theater	0.1315
PH2	Drain	0.016
SH	Inspection chamber	0.033

4.5 Wastewater Produced Estimation

In the visited community health care centres, hospitals and specialist hospital, it was observed that the black water. Water from toilets was disposed into septic tanks for treatment and desludging, but there was an improper management of the grey water from sinks, bathhouses, showers and water used for premises cleaning. The wastewater quantification was calculated using 80 per cent of the water consumption.

Table 4.12: Wastewater generated

Health care facilities	Daily water supplied (liter)	Total wastewater generated (80% of total water supplied) (liter)	Wastewater generated (liter/ hour)	Wastewater generated (liter/ second)
CC1	200	160	6.6667	0.0018
CC2	334	267.2	11.1333	0.0031
CC3	600	480	20	0.0055
PH1	19,800	15,840	660	0.1833
PH2	17,000	13,600	566.6667	0.1574
SH	7,000	5,600	233.3333	0.0648

4.6 In situ and laboratory results

Five (05) samples were taken from each of the health facility giving a total of 30 samples. The laboratory results from each daily composite sample were listed below.

4.6.1 Physical parameters

The physical parameters tested were pH, Temperature, Turbidity, Conductivity, TDS, and TSS

4.6.1.1 Hydrogen ion concentration pH

The pH values ranged between 6.5 to 12.3 and were exceeding the standards values (EPA, 2012),

However hospitals PH1, recorded the highest pH ranges of 8.1 to 12.3 and CHPS compound CC3 recorded the lowest pH range varying from 6.5 to 8.1 (Figure 4.3). The causes of these high pH values were most probably the use of detergents, washing powders, bleaches with high alkalinity, this was confirmed by US EPA (2006) stating that the waste water quality is highly influenced by the water supply source but also the cleaning products, also according to Bai *et al*. (2010), high pH values above 8.5 were often caused by high bicarbonate and carbonate concentrations, known as alkalinity.

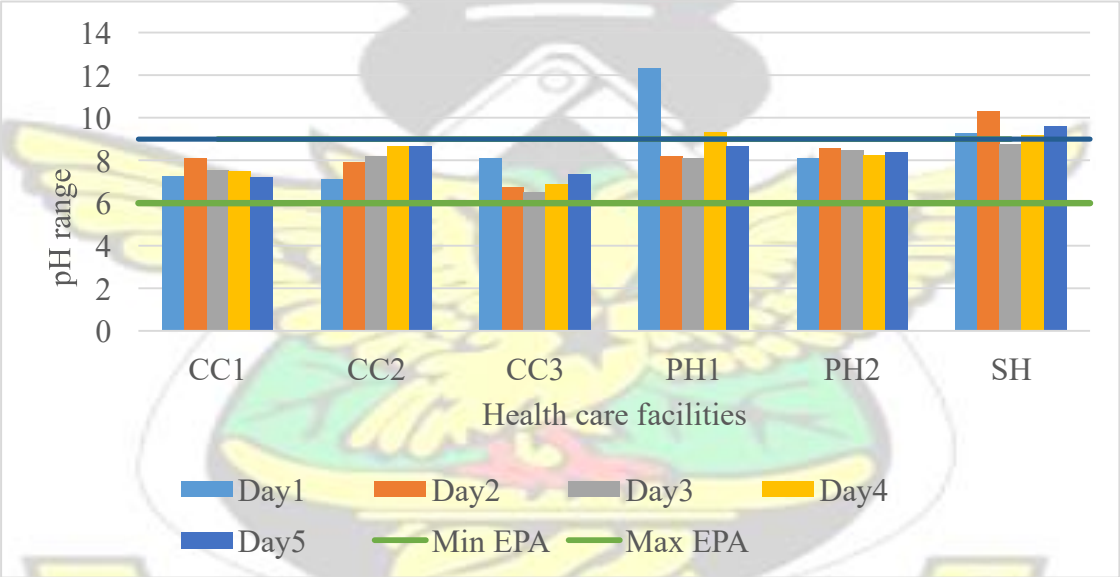

Figure 4.3: pH range compared to Ghana EPA permissible values before discharge into water bodies.

4.6.1.2 Electrical conductivity (EC)

The acceptable EPA value of EC for before disposal to any water body is 1500 µs /cm (EPA, 2012). From the laboratory analysis, the results showed that the average results obtained for all the EC values were within acceptable range from 103.06 and 819.33 µs

/cm (Figure 4.4). Similar results were found by Beyene & Redaie (2011) who recorded 1098.00±288.54 as EC average values from the hospital wastewater of Hawassa University Referral Hospital in Ethiopia that was lower than the EPA permissible values (EPA, 2012). The main causes of such electrical conductivity values might be the use of many detergents (Alderlieste *et al*., 2006).

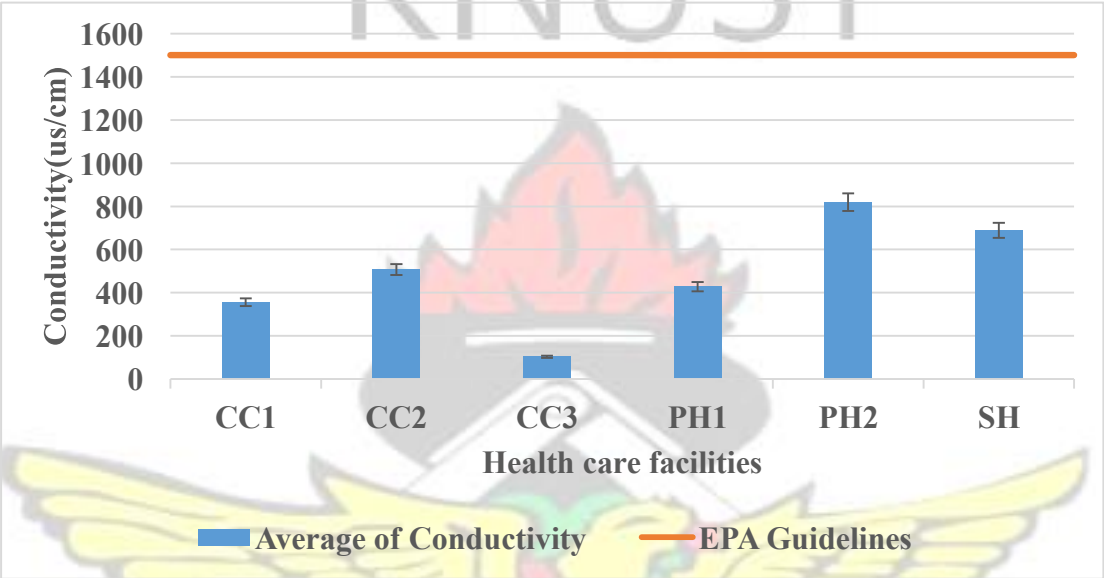

Figure 4.4: Average conductivity values compared to Ghana EPA permissible values before discharge into water bodies

4.6.1.3 Turbidity

The average values for the turbidity ranged between 37.03 and 287.75 NTU while the EPA standard value is 75 NTU (EPA, 2012). These values were comparatively higher. High turbidity value is considered as a barrier to the light absorption in the wastewater (Wilson, 2010). Only CC1 average turbidity value met the EPA guideline values. Five health facilities (CC1, CC2, PH1, PH2, and SH) among six failed to meet the EPA guidelines showing high turbidity values (Figure 4.5). these high turbidity values were due to the presence of colloidal particles (Igwemmar *et al*., 2013).

Turbidity can also be affected by several factors in water such as presence of dissolved and suspended solids, size and shape of particles (El-Mouhty *et al.*, 2014).

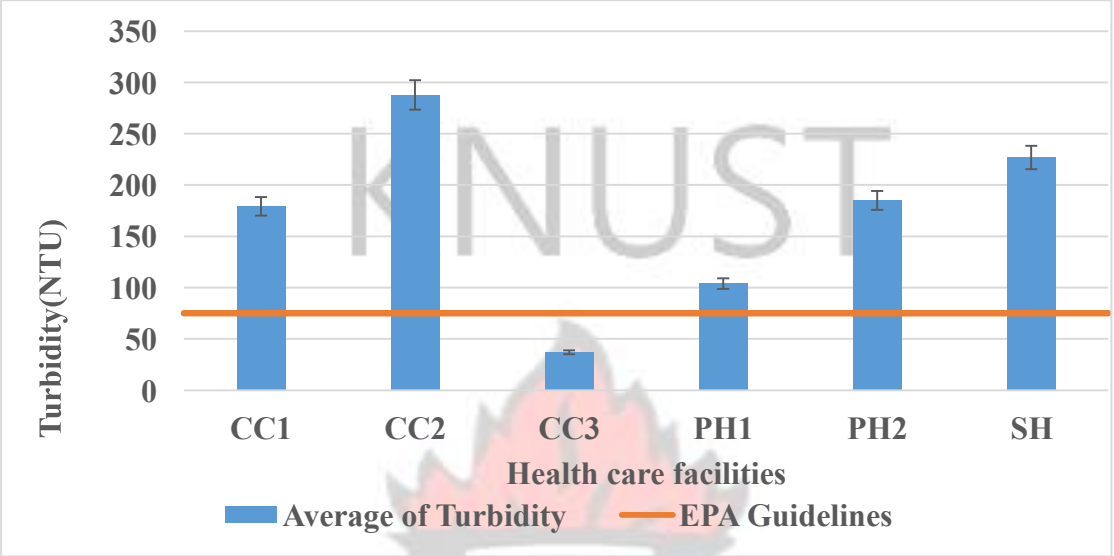

Figure 4.5: Average turbidity values compared to Ghana EPA permissible values before discharge into water bodies

4.6.1.4 Total Suspended Solids (TSS)

TSS is one of the commonly used parameter. The laboratory results showed TSS concentration ranging from 55 to 383 mg/l (Figure 4.6).Health care facilities CC1, CC2, CC3, PH1, PH2, SH had their TSS values higher than the EPA standards values. Similar results were found by Kumar *et al*. (2007) from hospital raw wastewater in India where total solids concentration was 280 mg/l, that was very high compared to the standards values. The highest TSS values of 148.33 and 3492.5 mg/l were recorded by CC1 and CC2 respectively 1483.33 and 3492.5 mg/l. Health care facility CC2 TSS values was more than 10 times PH1, PH2 and SH TSS values.

CC1, CC2 and CC3 wastewater discharged are less diluted due to the lower quantity of wastewater compared to PH1, PH2 and SH.

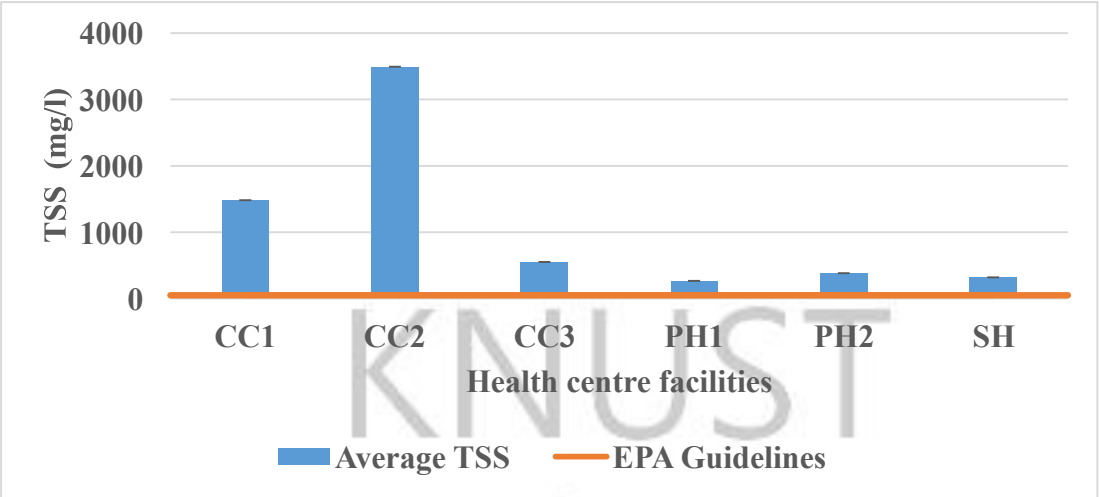

Figure 4.6: Average TSS values compared to Ghana EPA permissible values before discharge into water bodies

4.6.2 Chemical parameters

The BOD_5, COD, Sulphate, Nitrate, Phosphate and Phosphorus were measured as chemical parameters

4.6.2.1 Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD)

The BOD_5 and COD parameters are characteristics of organic matters content of wastewater (El-Gawad & Aly, 2011). According to Al-ajlouni *et al*. (2013), the biodegradability of organic substances is a measure of the speed and completeness of their degradations by microorganisms. The obtained range of BOD_5 values were between 41.77 mg/l to 70.9 mg/l (Figure 4.7), while the COD values ranged from 98 mg/l to 466 mg/l (Figure 4.8). These results were supported by Nasr & Yazdanbakhsh (2008) who reported BOD5, COD mean values for Iran hospital wastewater as 348 mg/l, and 527 mg/l respectively. These were also confirmed by Ekhaise & Omavwoya (2008) who had BOD_5 and COD values of 51.27 mg/l and 658.74 mg/l respectively from Benin hospital wastewater sample, that were higher than the permissible EPA values. CC2,CC3, PH1,PH2 gave BOD values higher than the standards which showed

a high organic matter load content and low biodegradability due to the chemical nature of the wastewater. Again high BOD values can be a cause of odour to water bodies. The acceptable EPA standards of 50 mg/l and 250 mg/l respectively for the BOD_5 and COD (EPA, 2012).

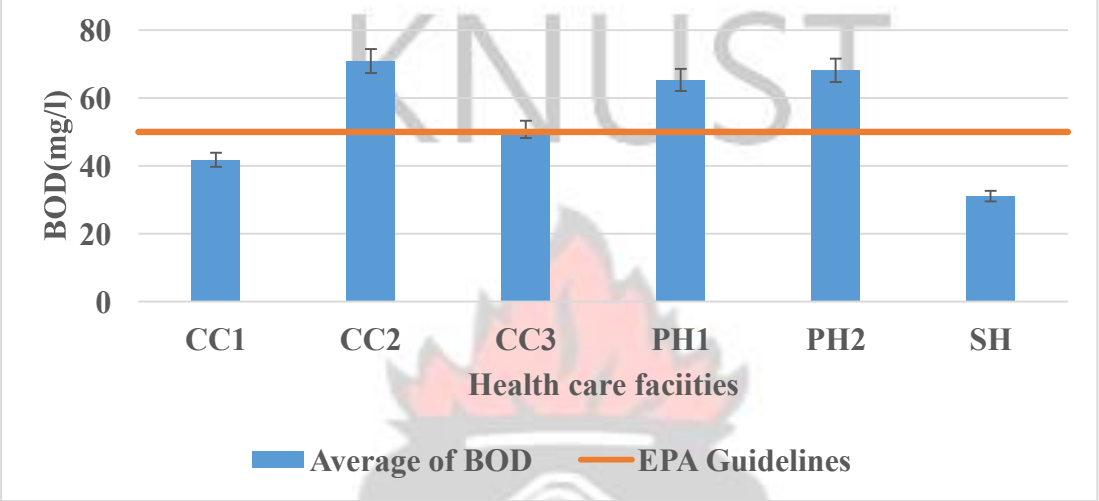

Figure 4.7: Average BOD values compared to Ghana EPA permissible values before discharge into water bodies

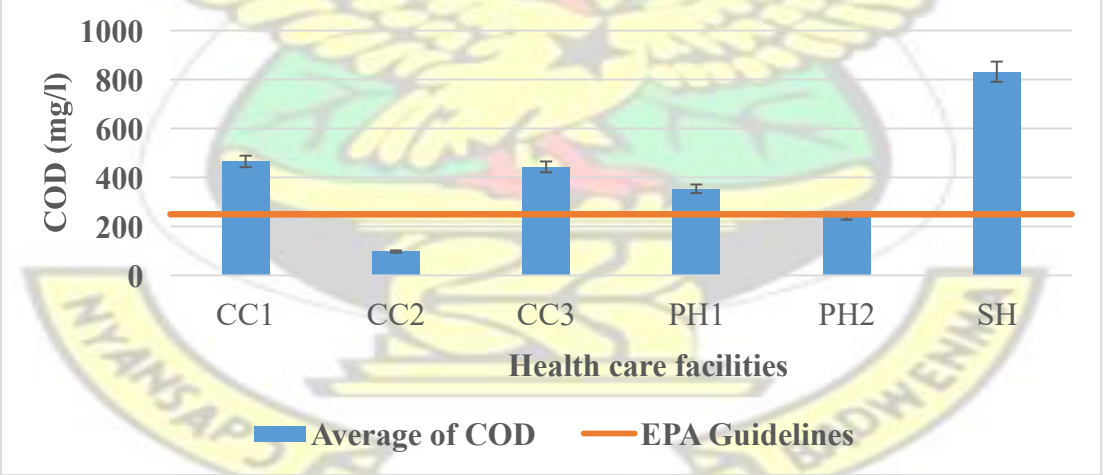

Figure 4.8: Average COD values compared to Ghana EPA permissible values before discharge into water bodies

4.6.2.2 Nitrate and Phosphorus concentration

The concentration of nitrate in water samples depends on the nitrification activities of micro-organisms (El-Gawad & Aly, 2011).

CC1, CC2, CC3 wastewater showed very high nitrate concentration it ranges from 29 mg/l to 424.95 mg/l compared to the acceptable EPA values of 50 mg/l (EPA, 2012) (Figure 4.9). This can have a negative impact on human health and the environment if the wastewater is improperly disposed of in watercourses.

The findings revealed that the health care facilities had nitrate concentration which ranged from 0.73 mg/l to 424.95 mg/l .Health care facilities CC1, and CC3 wastewater shows high nitrate concentration of 429.95 mg/l and 152.6 mg/l respectively. This contrast the findings of Beyene & Redaie (2011) that had an average nitrate concentration from hospital wastewater of 25.25 mg/l.

Phosphorus is a nutrient used for organism growth. In natural wastewater it occurs in phosphate form. Its values ranged from 1.7 mg/l to 4.49 mg/l and more than the EPA acceptable value (EPA, 2012) (Figure 4.10). Its main source in the health care facilities were cleaning detergents (Gilmour *et al*., 2008). Health care facilities CC1,CC2,CC3, PH2,and SH Phorphorus values exceed the EPA guidelines (EPA, 2012).

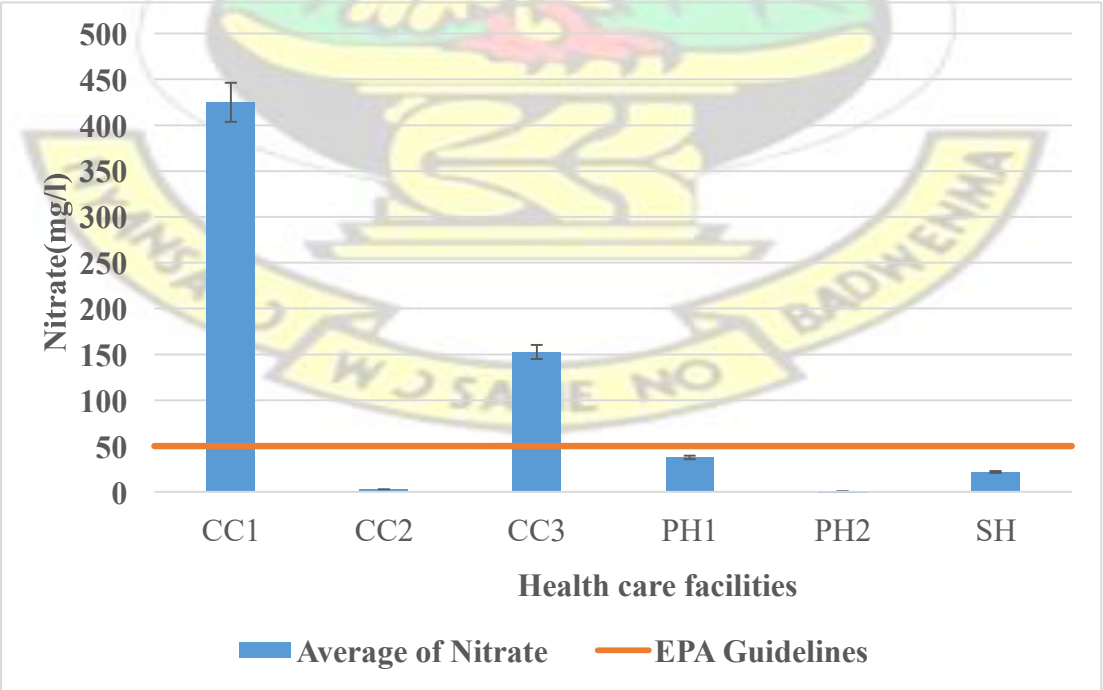

Figure 4.9: Average Nitrate values compared to Ghana EPA permissible values before discharge into water bodies

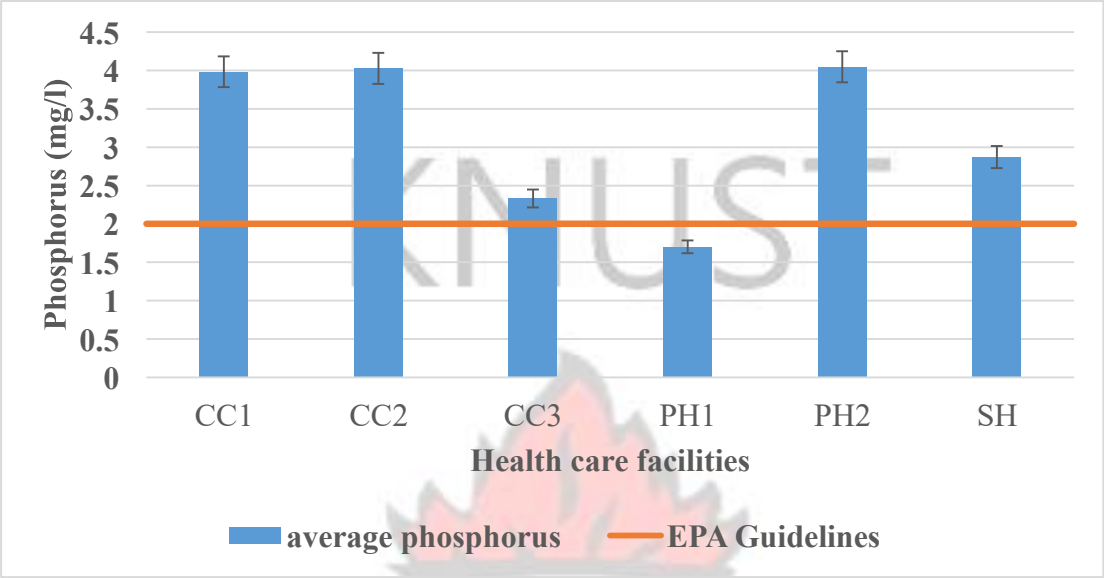

Figure 4.10: Average Phosphorus values compared to Ghana EPA permissible values before discharge into water bodies

4.6.3 Biological Parameters

4.6.3.1. Escherichia Coli concentration and Total coliform

There is a serious concern with regards to the high bacteriological content in the health care facilities wastewater, because they are easily transmitted. The Escherichia Coli number was very high compared to the EPA standards (EPA, 2012) (Figure 4.11) ranging between 52×10^4 and 52×10^6 MPN/100ml. The total coliform number was high and varied between 19.25 CFU/100 ml and 773.3 CFU/100 ml.

El-Gawad & Aly (2011) carried a study on hospital wastewater in Cairo, Egypt and obtained a very high number of total coliform 371×10^5 CFU/ml that exceeded the EPA standards being 400 CFU /ml (EPA, 2012). Salmonella species were counted even if there was no standard for it from the Ghana EPA. These organisms were of a great

concern because they are one major cause of typhoid fever through water use (El-Gawad & Aly, 2011).

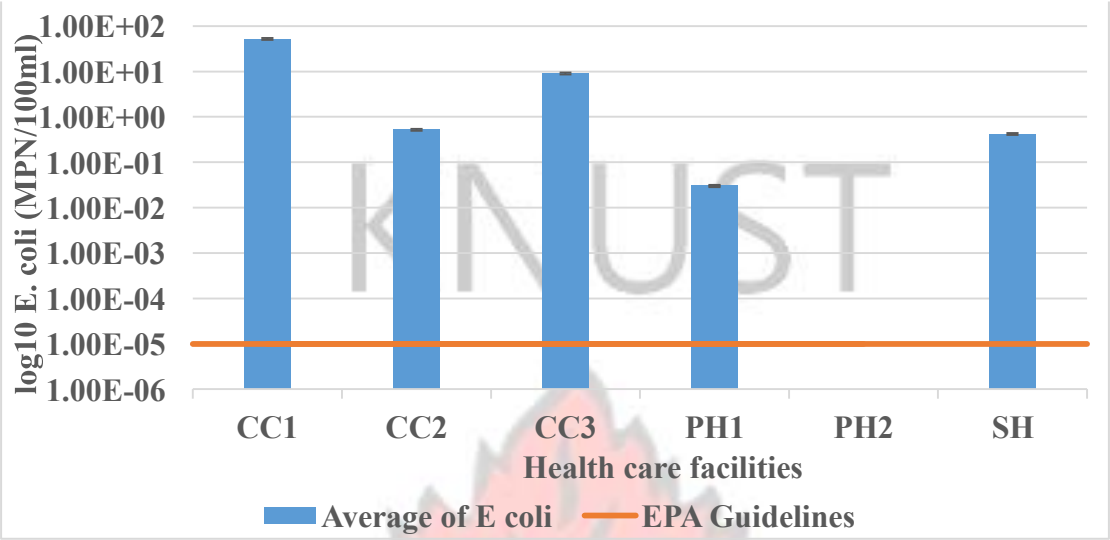

Figure 4.11: Average E coli species compared to Ghana EPA permissible values before discharge into water bodies

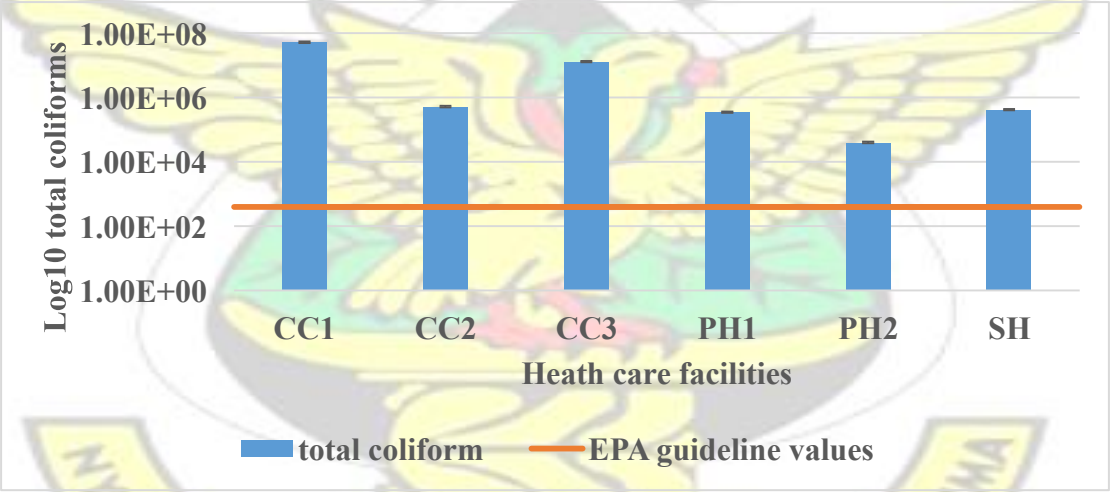

Figure 4.12: Average Total coliform species compared to Ghana EPA permissible values before discharge into water bodies

4.6.4 Presence of heavy metals

The presence of manganese (Mn), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), mercury (Hg), and iron (Fe) were analysed from the waste water effluent.

Traces of metals were found in hospital wastewater discharged. They were mainly from the cleaning activities, and from the devices used in the health facilities. Many of these metals are necessary for the growth of microbiological life if only in trace concentration, but if the required concentrations are exceeded, then it becomes toxic (Bai *et al*., 2010).

Bai *et al*. (2010) conducted a study on wastewater discharged from hospitals, households, and commercial establishments from Mysore City, Karnataka, India heavy metals such as lead, cadmium, chromium, iron, and zinc presence were tested. The average heavy metals concentrations obtained were 0 mg/l, 0.19 mg/l, 0.2 mg/l, 2.2 mg/l, and 0.27 mg/l respectively.

The study showed chromium concentration from all six health care facilities were ranging from 0 mg/l to 0.1 mg/l and were all within EPA acceptable limit 0.1 mg/l (EPA, 2012), the chromium concentration were within acceptable values (less than 0.1mg/l) (Figure 4.13).

The cadmium concentration for two health care establishments especially the CHPS compounds were above EPA acceptable levels (0.1 mg/l), PH1, PH2 and SH cadmium concentrations were within acceptable range (more than 0.1) (Figure 4.14). Chromium and cadmium sources could be plastic materials, batteries and laboratory.

Zinc, iron and manganese content of wastewater from all the health care facilities tested ranged between 0.052 mg/l to 0.128 mg/l, 0.284 mg/l to 1.5 mg/l, and 2.32 mg/l to 9.68 mg/l respectively lower than EPA guidelines values of 5 mg/l, 10mg/l and 2.5mg/l respectively (Figure 4.15, 4.16, 4.17). However the high iron content from CC1 might be explained by the use of borehole as source of water supply confirmed by

Nkansah *et al*. (2009) who investigated on the heavy metals contents of boreholes in Ghana found that iron content can range from 0.1 mg/l to 3.4 mg/l.

All the CHPS compounds CC1, CC2, and CC3 had boreholes as source of water supply while the hospitals were connected to GWCL. This could be an explanation for the high iron content from CHPS compounds wastewaters compared to the hospitals.

The wastewater from two health care facilities CC2, CC3 had average lead values of 0.189 mg/l and 0.137 mg/l higher than EPA permissible levels (Figure 4.18). This can be explained by the fact that boreholes were used as source of water supply in these facilities, and by the types of submersibles pumps used in ground water (Sa'eed and Mahmoud A.M, 2013). One out of six health care facilities CC1 had average mercury concentration of 0.014 mg/l higher than EPA permissible levels 0.005 mg/l (Figure 4.19). According to Omar (2011), wastewater from clinics laboratory might contain ionic mercury, and other heavy metals.

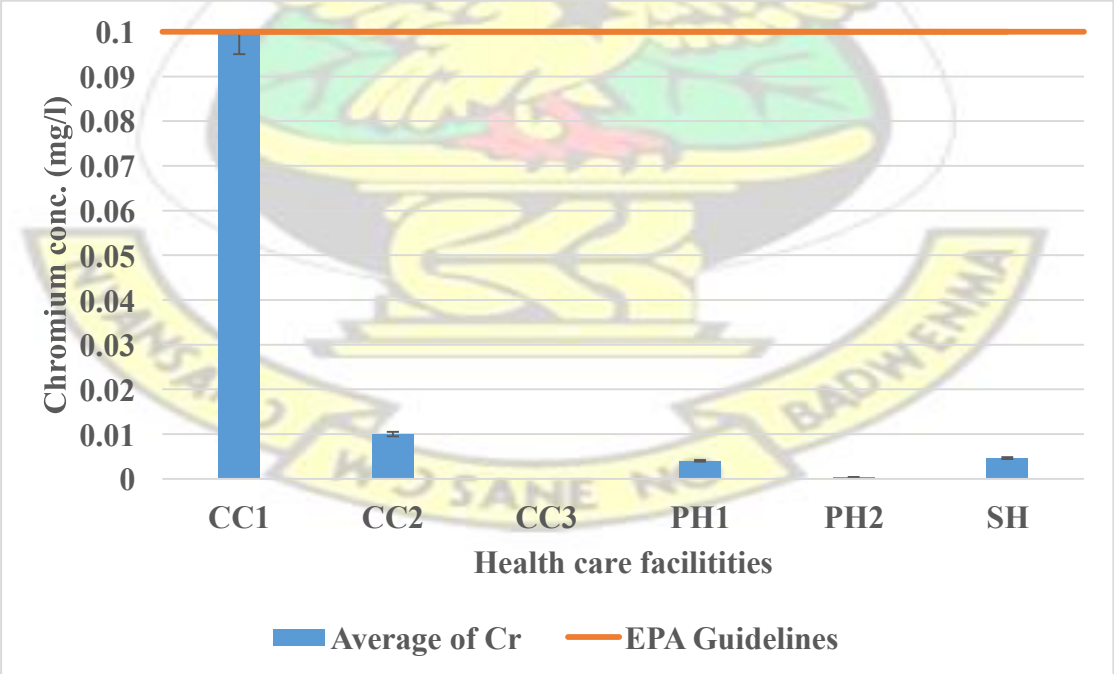

Figure 4.13: Average Cr concentrations values compared to Ghana EPA permissible values before discharge into water bodies

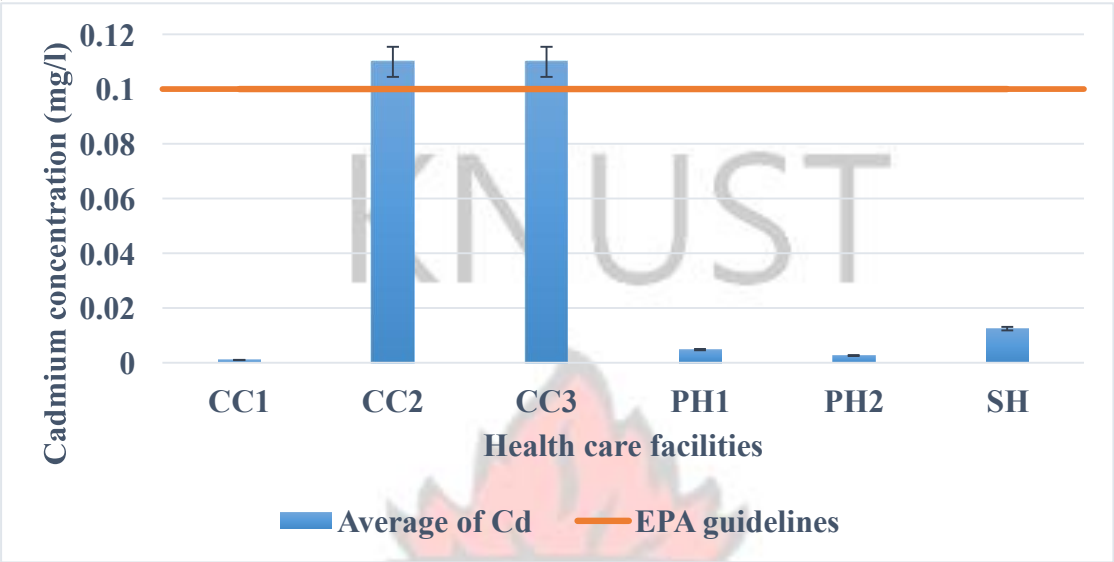

Figure 4.14: Average Cd concentrations values compared to Ghana EPA permissible values before discharge into water bodies

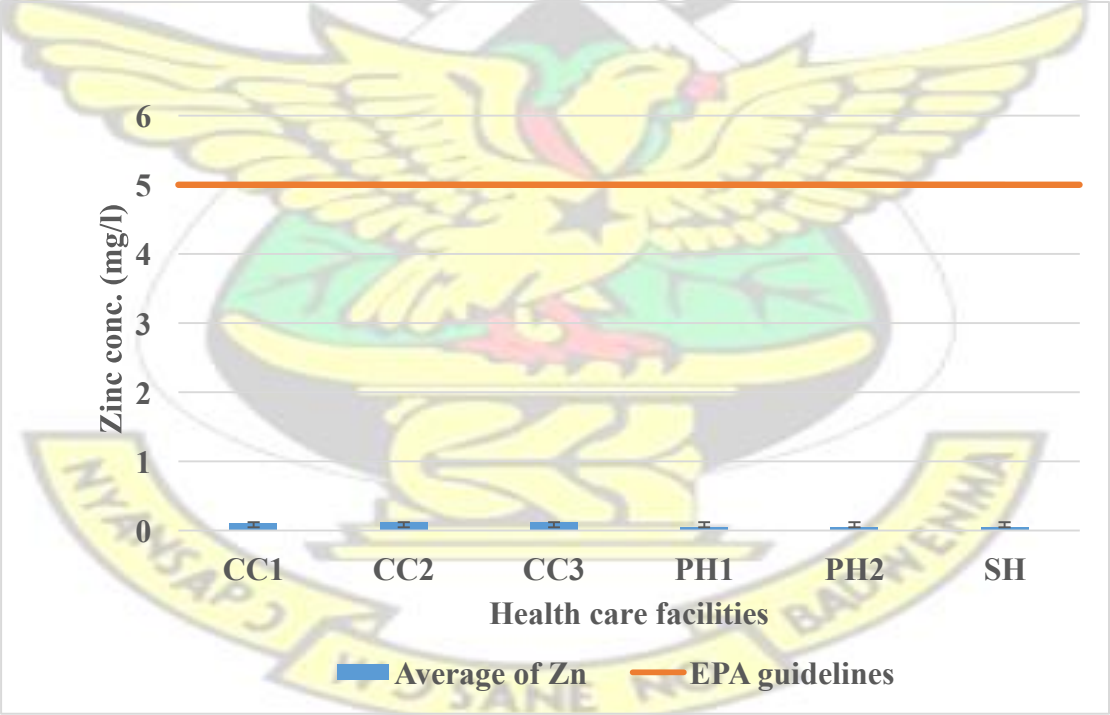

Figure 4.15: Average Zn concentrations values compared to Ghana EPA permissible values before discharge into water bodies

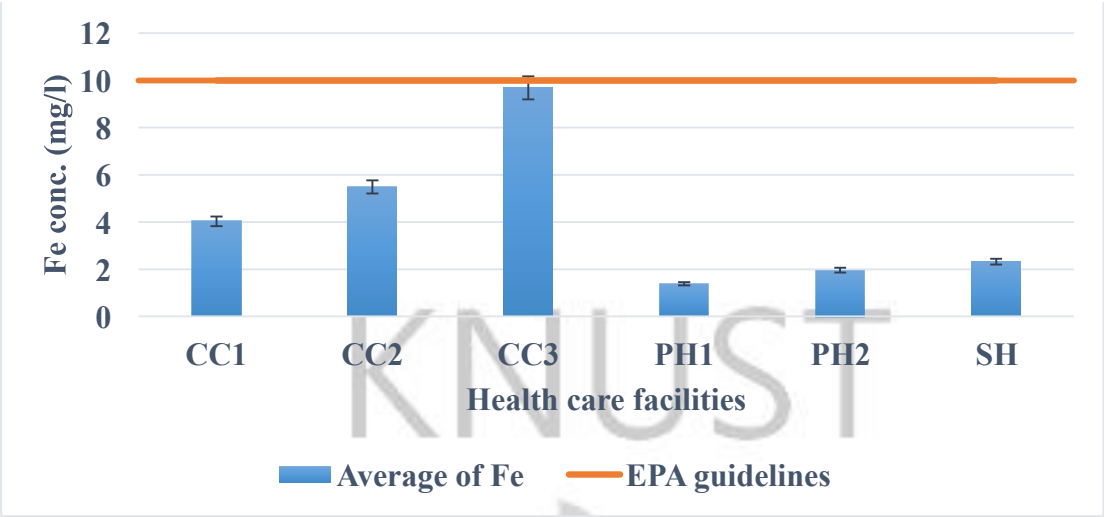

Figure 4.16: Average Fe concentration values compared to Ghana EPA permissible values before discharge into water bodies

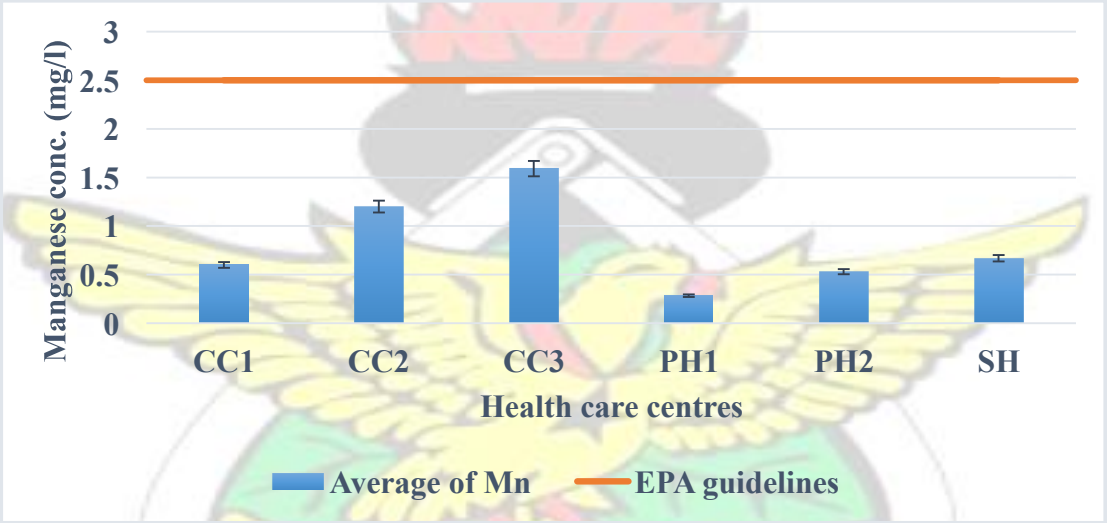

Figure 4.17: Average Mn concentrations values compared to Ghana EPA permissible values before discharge into water bodies

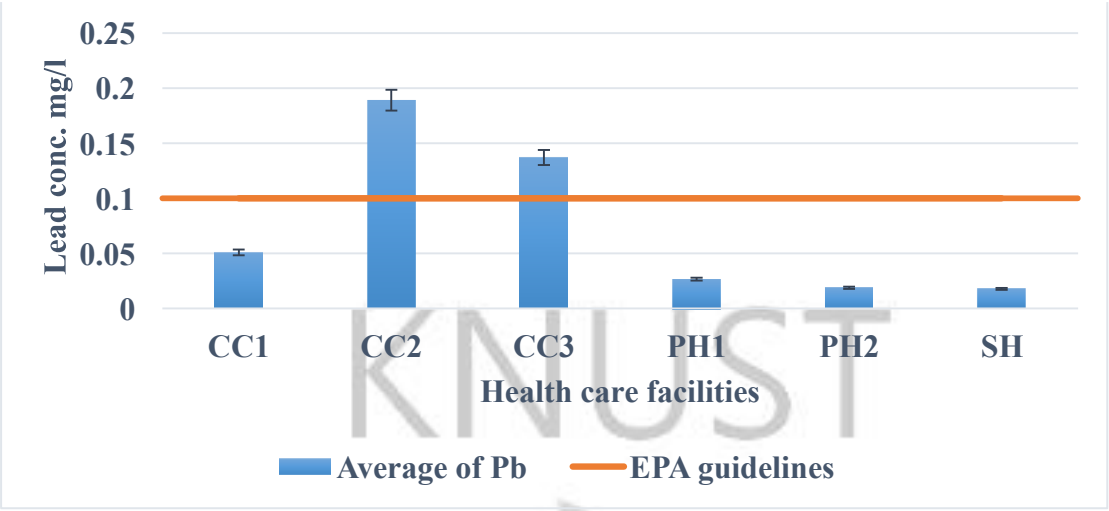

Figure 4.18: Average Pb concentrations values to Ghana EPA permissible values before discharge into water bodies

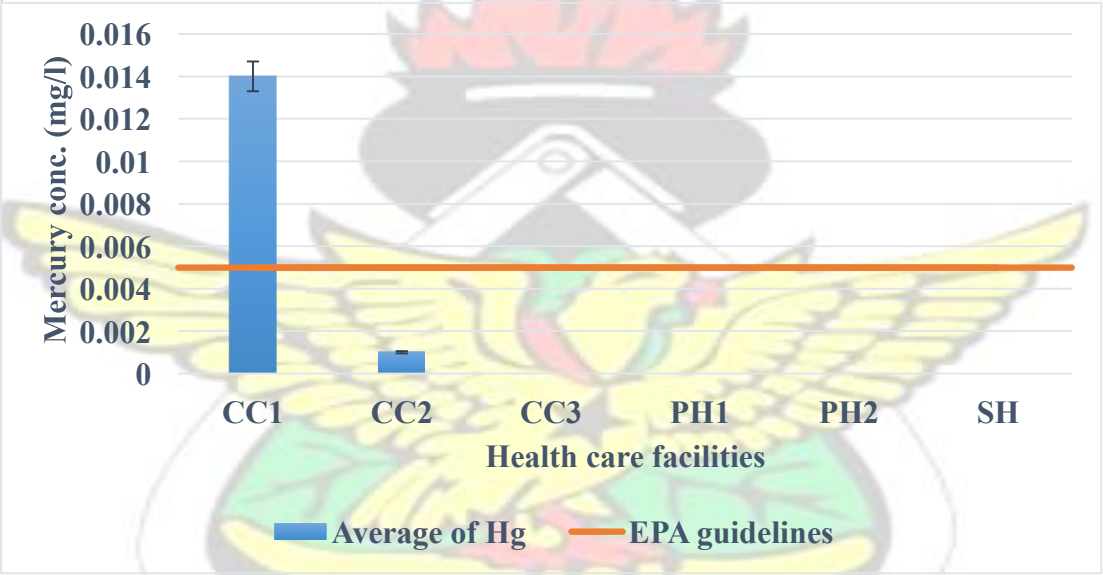

Figure 4.19: Average Hg concentrations values compared to Ghana EPA permissible values before discharge into water bodies

4.6.5 Contaminants load

In wastewater many particles become dissolved (Buitendijks *et al.*, 2009).

High TSS load (g/ day) was observed especially from health care facilities PH1, PH2, SH that discharged high volume of wastewater (Figure 4.20).

The BOD test was developed as a test for the effect of discharge on the river's water quality (Buitendijks *et al.*, 2009). High BOD and COD loads were obtained from health care facilities PH1, PH2, and SH wastewater with a significant variation, the CHPS compounds CC1, CC2, and CC3 had relatively low BOD and COD load (Figure 4.21).

Phosphorus is one of the most common nutrient monitored in wastewater effluents due to its role as limiting nutrient in eutrophication of marine and freshwater environments respectively (Buitendijks *et al.,* 2009), and is a very essential nutrient to biological metabolism. Phosphorus sources include cleaning detergents, chemicals, and insecticides, however excessive discharge into aquatic environment can result in excessive algae growth, oxygen depletion in water bodies, impacting aquatic life (Tjandraatmadja *et al*., 2010).

Highest sulphate and nitrate loads were detected in wastewater from health care facility PH1. Phosphorus and Manganese loads were almost nil from all wastewater discharged (Figure 4.21).

Zinc and lead loads were high in wastewater discharged from PH1, PH2 and SH, while very low loads of iron, mercury and cadmium were observed from all the health care facilities (Figure 4.22). These microelements depending on their concentrations can promote or inhibit plant development and impact aquatic life, on the other hand can be carcinogenic when inhaled or ingested by human beings (Tjandraatmadja *et al*., 2010).

Various compounds of organic matter containing materials can be measured in two simple parameters, biochemical oxygen demand and chemical oxygen demand as BOD, COD, however BOD/COD ratio describes the biodegradability level of materials by

which organic matter containing wastewater is readily broken down in the environment (Ganjar & Sarwoko, 2010).

BOD/COD ratio from the six health care facilities ranged from 0.03 to 0.52.

According to Ganjar & Sarwoko (2010), the acceptable zone for BOD/COD ratio ranges from 0 to 0.1 while the biodegradability zone ranges from 0.1 to 1. However two health care facilities CC1 and SH were within the acceptable range (BOD/COD ratio less than 0.1) and four (04) within the biodegradability range (0.1 to 1) (Figure 4.23).

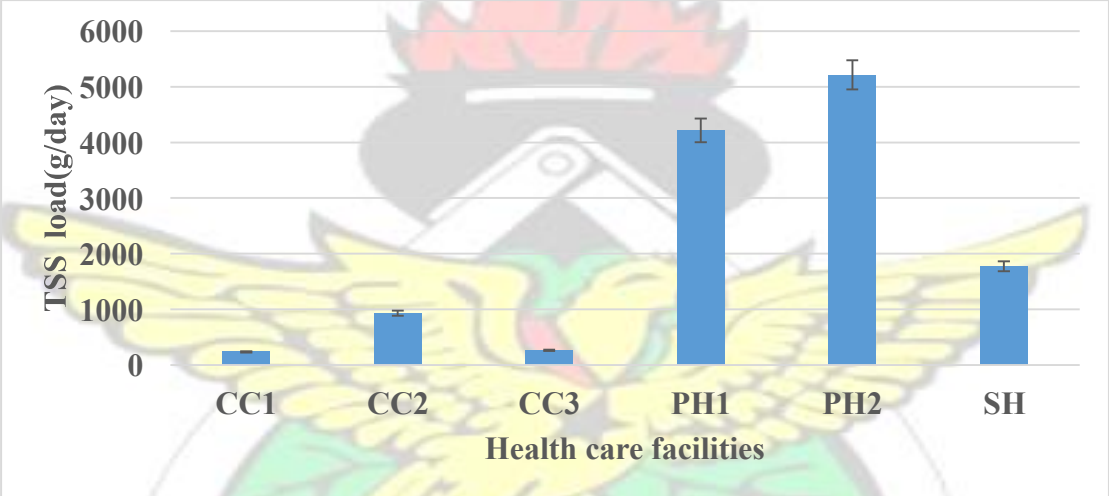

Figure 4.20: TSS load in the six health care facilities wastewater discharged

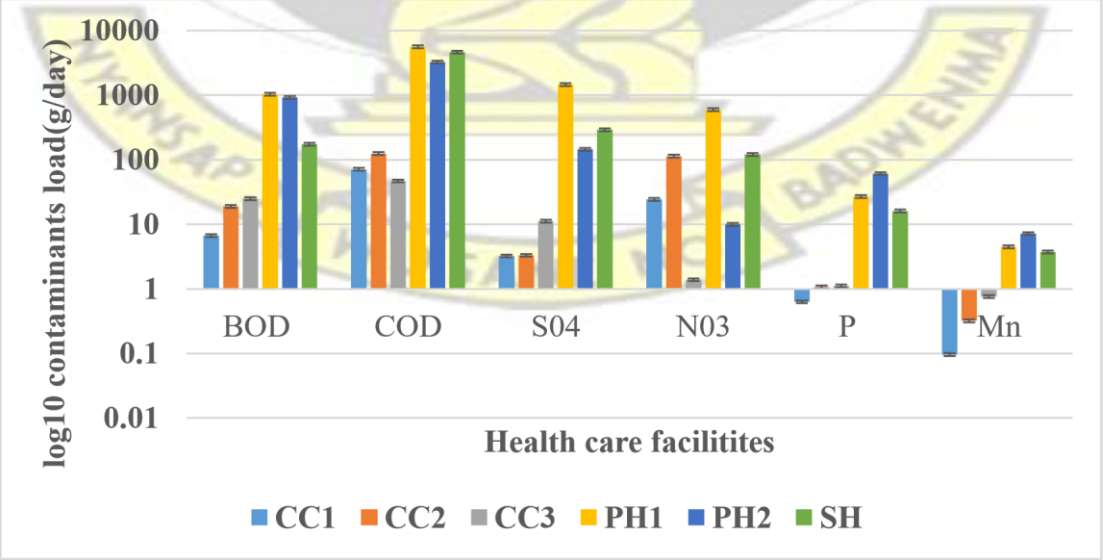

Figure 4.21: BOD, COD, SO4, NO3, P and Mn loads in the six health care facilities wastewater discharged

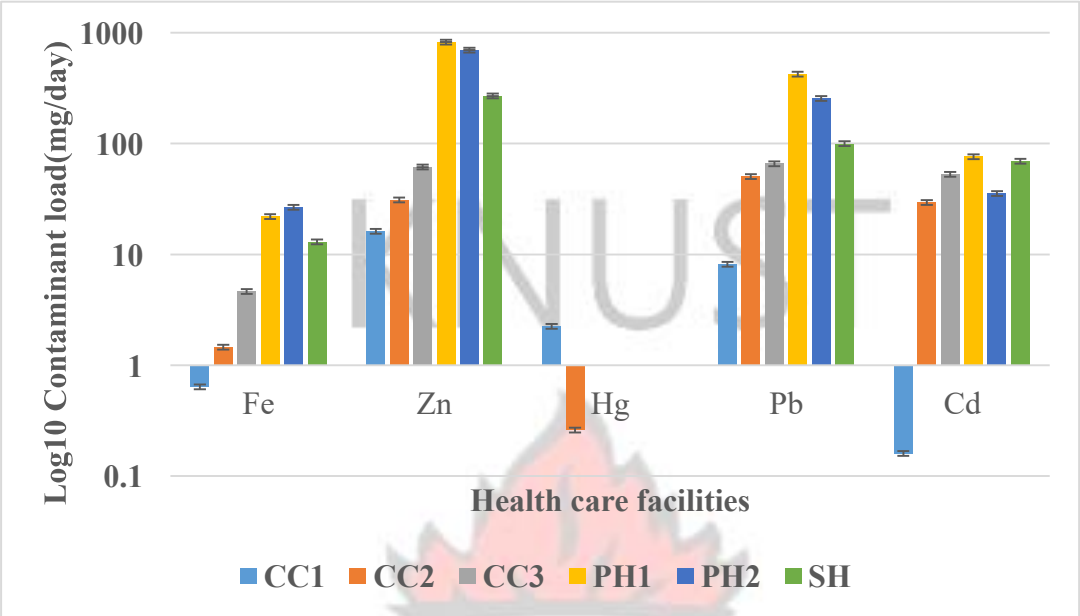

Figure 4.22: Fe, Zn, Hg, Pb, and Cd loads in the six health care facilities wastewater discharged

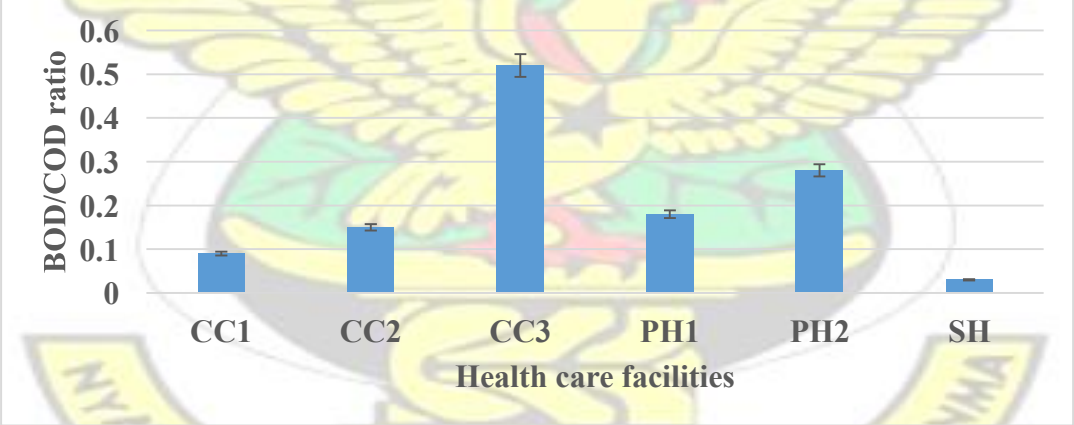

Figure 4.23: BOD/COD ratio in the six health care facilities wastewater discharged

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From this study, it could be concluded that:

- There are poor and inefficient management of wastewater in community health care centres and hospitals.
- The main sources of wastewater generation from the hospitals are labour wards, laboratories, and theatres.
- One health care facility (CC3) out of six studied treated and properly disposed of its wastewater into a soakaway pit. The other five clinical waste were disposed of into drains.
- The water consumption for CHPS compounds CC1, CC2, CC3 ranges between 200 litres/day to 600 litres/day and discharged between 160 to 480 litres/day of wastewater, also hospitals PH1, PH2 and SH water consumption varies from 7,000 litres/day to 19,800 litres/ day while discharged ranged from 5,600 litres/day to 15,840 litres/ day.
- The laboratory analysis results showed that most of the chemicals, heavy metals and microbiological parameters in the discharge wastewater were above Ghana EPA guideline values. The average values of BOD_5 ranged between 41.77 mg/l and 70.9 mg/l, while the COD values ranged from 98 mg/l to 466 mg/l which exceeded Ghana EPA guideline values.

  Phosphorus average values ranged from 1.7 mg/l to 4.49 mg/l and more than the EPA acceptable value, high Nitrate concentration varying from 29 mg/l to 424.95 mg/l also exceeding the standard limit. *E. Coli* numbers were very high compared to the EPA standards and ranged between 52×10^4 MPN/100ml and 52×10^6 MPN/100ml. Cadmium concentration, Lead and Mercury concentrations were beyond EPA acceptable values especially for the CHPS compounds.

The causes of this actual waste water management situation in the hospitals are

- Non applicability of the Ghana EPA waste (solid and liquid) regulatory framework especially for the wastewater, more emphasize has been put on the solid waste management neglecting the wastewater management
- Lack of training on waste water management for the health care facilities workers

5.2 Recommendations

Clinical wastewater can be a major pollution source and its improper management exposes communities to epidemic diseases and also environmental pollution risks.

From the study the following recommendations were made:

- The regulatory bodies such as EPA should enforce laws on liquid waste treatment facilities for hospitals.
- Dangerous waste should never be released into sewers or septic tanks, but use less toxic alternatives if possible.
- The drains in which hospitals liquid waste is discharged into should be covered.
- All body fluids from patients from all wards should be disinfected with chlorine solution to reduce the bacteriological and viral load before disposal into the sink or drain.
- Hospital sewage should not be discharged into natural water bodies that are used to irrigate fruits or vegetable crops, to produce drinking water, or for recreational purposes in order to protect human health.

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APPENDICES

Appendix A: Analytical Methods Used in Research

a) Parameters measured in-situ: Temperature, pH, TDS and EC Apparatus

PC 300 Waterproof Handheld pH/Conductivity/TDS/Temperature meter

Procedure

A digital reading appears upon inserting the probes into the sample indicating first the values of pH and temperature. The sample is stirred and the digital reading allowed

stabilize before recording. The “MODE” button which allows switching to other parameters was then used to read the values of TDS and EC.

b) Total Suspended Solids (TSS)

Gravimetric method

Apparatus

- 1 µm pore-size Watman glass fibre filter paper(GF/C)
- Petri dish
- Desiccator
- Oven
- Balance scale

Procedure

50mL of a well-mixed sample was filtered through a weighed standard glass-fiber filter paper. The residue retained on the filter was then dried in an oven at 103 to 105 ^{O}C for 1 hour. It was then cooled in a dessicator and weighed. The increase in weight of the filter represents the total suspended solids.

Calculation

The TSS was computed for using the formula below:

mg total suspended solids = (A - B) × 1000/ sample volume

A = weight of filter + dried residue, mg, and B
= weight of filter, mg.

c) Turbidity Principle

For water to be aesthetically accepted its clarity must be ensured. Presence of suspended matter such as silt, clay, organic and inorganic matter and microorganisms in water affect the clarity of it and give rise to turbidity in the water. Furthermore floating particulates could easily hide bacteria as the bacteria attaches itself to the particles, making it difficult to eliminate the bacteria, after adding a disinfectant. Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in straight lines through the sample. Whereas most suspended matter scatter light waves, optically black particles such as activated carbon adsorb light and increased turbidity readings.

Apparatus

5 ml sample dispenser

Measuring cylinder

Turbidimeter (HANNA TURBIDIMETER HI 93414)

Procedure

1) Measure 5ml of the sample and dilute in 20 ml of distilled water and pour an aliquot of 10 ml with the measuring cylinder and pour into the sample cell.

2) Clean the surface of the sample cell carefully with tissue paper.

3) Place the sample cell into the instrument light cabinet and cover with the light shield.

4) Read the turbidity.

5) Remove the light shield and sample cell and clean cell after emptying the sample.

d) Five day Biochemical Oxygen Demand (BOD5)

Dilution method

Principle

The biochemical oxygen demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters. It is computed from the initial and final DO of a sample after incubating at 20 °C for five days.

Procedure

A known volume of the sample was poured into a 300ml BOD bottle and mixed with dilution water until it overflowed and then stoppered. Another standard 300mL BOD bottle was filled with dilution water to represent the blank. The initial dissolved oxygen concentrations of the blank and diluted sample were determined using a DO meter. Both bottles were stored at 20 °C in the incubator for five days. After 5 days the amount of dissolved oxygen remaining in the samples were measured with a DO meter.

Calculation

The 5-day BOD was computed using the equation below:

BOD= (D1 – D2) /P

*D*1 = DO of diluted sample immediately after preparation, mg/L, *D*2 = DO of diluted sample after 5 day incubation at 20 °C, mg/L, *P* = decimal volumetric fraction of sample used.

e) Chemical Oxygen Demand (COD)

Open Reflux method

Principle

A boiling mixture of chromic and sulphuric acids oxidises most types of organic matter. In this method, a sample is refluxed in strongly acid solution with a known excess of

potassium dichromate ($K_2Cr_2O_7$). After digestion, the remaining unreduced $K_2Cr_2O_7$ is titrated with ferrous ammonium sulphate to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter is calculated in terms of oxygen equivalent.

Procedure

1g of $HgSO_4$ was transferred into the reflux flask followed by a known volume (10mL) of the sample and mixed. 10mL of 0.0417M $K_2Cr_2O_7$ solution was also added to the flask and mixed. 20mL of conc. H_2SO_4 was added slowly to the flask whiles simultaneously cooling the outside of the flask under running water after which 1mL of silver sulphate solution was added. The procedure was repeated for the same volume of distilled water as the blank. The solution was then boiled under reflux for 2 hours after which 45mL of distilled water was added and subsequently cooled under running water. 2 to 3 drops of ferroin indicator was added after which a light blue/green colour appeared. The residual solution was titrated with 0.1M Ferrous Ammonium Sulphate (FAS) solution to reddish brown endpoint. The COD was calculated using the formula below:

$$\text{COD as mg } O_2/L = ((A - B) \times M \times 8000)$$

Where:

A = mL FAS used for blank,
B = mL FAS used for sample,

M = molarity of FAS (0.1M)

8000 = milliequivalent weight of oxygen × 1000 mL/L.

f) Total coliforms, E. coli and Salmonella

Membrane filter technique using Chromocult Coliform Agar

Principle

Chromocult Coliform Agar determines the presence or absence of coliform bacteria, E. coli, and salmonella in water. A water sample is passed through the membrane that retains the bacteria. Following filtration, the membrane containing bacterial cells is placed on the media and incubated at 36 ± 1 °C for 24 ± 1 h. Salmon to red colonies are recorded as coliforms. In contrast, dark-blue to violet colonies are recorded as E. coli. And green to turquoise colonies are counted as salmonella. Salmon to red, darkblue to violet and tuiquoise colonies are recorded as total coliforms.

Procedure

In this method, an appropriate volume (1mL) of the wastewater sample was added to a known volume of dilution water (99mL). Four serial dilutions with 99mL dilution of dilution water and 1mL of the resulting solutions were performed and the final solution was filtered through a sterile micro pore filter by suction, thereby capturing any coliforms. With the aid of sterile forceps, the filter membrane was placed aseptically and rolled onto the Chromocult Coliform Agar in a Petri dish. The dish was inverted, closed and incubated at 35 °C.

After 24 hours of incubation, the number of Salmon to red colonies is recorded as coliforms by visual examination whiles dark-blue to violet colonies are recorded as *E. coli*. The sum of these two colonies is recorded as total coliforms.

g) Analysis for heavy metals (Cd, Pb, Zn, Fe) Atomic Absorption Spectrophotometry Analysis

Acidification of the water samples was done immediately the water was sampled. A 1 ml concentrated HNO3 was added to 300 ml of the samples. This was done to preserve the water samples and as an initial step to bring the particulate metals into solution form (APHA, 2005).The samples were then covered tightly and transported to the laboratory for further treatment.

The samples were thoroughly mixed by shaking and 100 ml transferred into a conical flask. A 10 ml concentrated HNO3 and a few boiling chips were added (APHA,

2005), the mixture was then heated until the volume was reduced to about 30-40 ml and complete digestion was indicated by a clear solution. Contents were washed down with double distilled water and then filtered. The filtrate was transferred into 100 ml volumetric flask and topped up to the 100ml mark with double distilled water prior transfer into washed plastic containers and stored at 4 $^{\circ}$C, ready for AAS analysis.

AAS 220 model was used in determining the total Cd, Zn, Fe and Pb concentration in the previously digested samples. The acetylene gas and compressor were fixed and compressor turned on and the liquid trap blown to rid of any liquid trapped. The Extractor was turned on and the AAS 220 power turned on (AOAC, 2006). The capillary tube and nebulizer block were cleaned with cleansing wire and opening of the burner cleaned with an alignment card. The worksheet of the AAS software on the attached computer was opened and the hollow cathode lamp inserted in the lamp holder. The lamp was turned on; ray from cathode aligned to hit target area of the alignment card for optimal light throughput, then the machine was ignited. The capillary was placed in a 10 ml graduated cylinder containing deionized water and aspiration rate measured, and set to 6 ml per minute. The analytical blank was prepared, and a series of calibration solutions of known amounts of analytes element (standards) were made.

The blank and standards were atomized in turn and their responses measured. A calibration graph was plotted for each of the solutions, after which the sample solutions were atomized and measured. Cd, Fe, Zn, and Pb concentrations from the sample solution was determined from the calibration, based on the absorbance obtained for the unknown (AOAC, 2006).

k) Determination of Phosphorus as Phosphate Ion ($PO4^{-3}$) Principle

Ammonium Molybdate and Potassium Anumonyl Tatrate (PAT) reacts with phosphate ions in strong acidic medium to form a complex. By reduction with ascorbic acid, an intense blue colour is formed which is measured on the spectrophometer.

Procedure

1 part of H2SO4 in % part of distilled water was diluted to 250 ml

2 ml of 6M H2SO4 was added in 25 ml of each sample followed by adding powder pillows of K2SO4.

Samples were heated for 30 minutes and 2 ml of NaOH solution reagent was added and topped up with distilled water to the 25 ml mark.

Phosphate 3 reagent was added to 10 ml of each sample for 3 minutes, samples were placed in the photometer and phosphate concentrations were determined.

Appendix B: Effluents In situ measurement

Table B1: In situ measurement from CHPS effluent

Location	pH	Temperature (°C)	Conductivity (µS/cm)	Turbidity (NTU)	TDS (mg/l)
CC1	7.26	28.4	452	323	320
CC1	8.1	27.9	535	208	384
CC1	7.55	30.1	429	80	305
CC1	7.49	28.9	355	180	361

CC1	7.2	29.1	6.18	106	436
CC2	7.1	28.5	264	200	185
CC2	7.9	28.5	506.9	287.8	403.85
CC2	8.2	28.7	938	130	672
CC2	8.65	27.7	820	658	305
CC2	7.8	28.9	6.42	163	454
CC3	8.1	30.71	93.1	16.8	66
CC3	6.75	30.1	134.8	48.6	94.2
CC3	6.51	29.6	81.3	45.7	58.5
CC3	6.9	29.8	90.2	20.8	65.9
CC3	7.34	30.45	116.1	53.3	80

Table B2: In situ measurement from Hospitals effluent

Location	**pH**	**Temperature (°C)**	**Conductivity (µS/cm)**	**Turbidity (NTU)**	**TDS (mg/l)**
PH1	12.3	28.5	265	25.1	180
PH1	8.2	29.7	333	40.9	291
PH1	8.1	30.1	528	205	380
PH1	9.3	29	430	103	318
PH1	8.65	29.8	585	145	418
PH2	8.08	26	582	339.3	415
PH2	8.55	27.8	817	91.5	572
PH2	8.45	27.2	1059	124	759
PH2	8.22	26.8	758	215	528
PH2	8.4	27.2	882	154	536
SH	9.26	30.1	456	30.1	319
SH	10.3	29.8	1080	578.7	740
SH	8.75	28.7	530	71.9	370
SH	9.2	29	947	351	522
SH	9.6	30.1	431	101	430

Appendix C: Effluents Laboratory analyse results

Table C1: Chemical and Microbiological Laboratory results CHPS compounds effluents

Location	TSS (mg/l)	BOD (mg/l)	COD (mg/l)	SO_4(mg/l)	NO_3(mg/l)	PO_4 (mg/l)	P (mg/l)	E coli (MPN/100ml)	Salmonella(MPN/100 ml)	Non Fecal Coliform (MPN/100 ml)
CC1	250	92.53	608	2	14.8	22.4	4.50	4.00E+06	5.00E+06	4.80E+07
CC1	153.1	7.46	784	8	22.1	12.2	2.44	1.40E+07	3.00E+06	
CC1	600	61.19	160	6	97.8	3.89	0.77			1.00E+04
CC1	1500	42	444.8	20.3	153	20	4	9.00E+06	4.00E+06	1.60E+07
CC1	4930	5.91	224	65	476	41.1	8.22			2.00E+04
CC2	1000	191	336	3	4.9	9.6	1.92		1.00E+04	9.60E+05
CC2	350	70.95	465.8	12	425	20.1	4.02	5.20E+07	1.50E+04	4.80E+05
CC2	90	2.98	1152	42	0	12.2	2.44	5.20E+07	2.00E+04	
CC2	598	43.28	256	4.6	162	40.4	8.09			2.60E+05
CC2	780	46.26	120	0	72	18.2	3.65			2.20E+05
CC3	600	8.95	30	65	5.6	21.8	4.36			6.00E+05
CC3	550	92.53	64	2	0	9.74	1.94	5.20E+05		1.34E+07
CC3	500	81.8	200	3	3.1	3.41	0.68			8.73E+06
CC3	65	5.85	71	16	2.2	9.7	1.94			7.14E+06
CC3	440	65	124	31	3.6	13.6	2.72	5.10E+05		7.99E+06

Table C2: Chemical and Microbiological Laboratory results from Hospitals effluent

Location	TSS (mg/l)	BOD (mg/l)	COD (mg/l)	SO_4 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	P (mg/l)	E coli (MPN/100 ml)	Salmonella (MPN/100 ml)	Non Fecal Coliform (MPN/100 ml)
PH1	53.5	4.95	96	44	0.9	4.79	0.958	4.00E+04		1.08E+06
PH1	10	98.8	88	42	0.9	3.96	0.792	4.00E+04	1.50E+05	9.40E+05
PH1	150	42.5	752	84	123.7	21.73	4.346	1.00E+04		6.00E+05
PH1	300	115	355	93	37.5	8.6	1.69	3.00E+04	3.10E+05	8.40E+05
PH1	37	64.9	480	198	24.9	3.55	0.71		4.90E+05	7.40E+05
PH2	200	47.7611	192	32	2.1	19.39	3.878			2.00E+04
PH2	605	107.4626	184	0	0	22.42	4.484		4.00E+04	1.08E+06
PH2	359	49.2537	344	0	0.1	25.53	5.106			5.00E+04
PH2	501	53.9	295	11	1.1	24.2	4.84		6.00E+04	4.00E+04
PH2	317	82.5	185	8.5	0.5	20.7	4.14		2.00E+04	3.50E+05
SH	550	4.171045	528	63	10.3	3.32	0.664			2.00E+07
SH	500	68.20896	1512	28	0	29.2	5.84	4.20E+05		3.54E+07
SH	100	20.895	456	65	54.6	10.53	2.106		1.00E+04	4.47E+07
SH	410	15.7	915	43	11.7	17.2	3.44	5.70E+05		3.80E+07
SH	50	46.5	750	61	31.6	11.5	2.3	2.70E+05	3.00E+04	2.80E+07

Table C3: Heavy metals results from CHPS compounds and Hospitals effluents

Health care facilities	Avg. pH	Avg. Temperature (∘C)	Avg. Turbidity (NTU)	Avg. Conductivity (us/cm)	Avg. TDS (ppm)	Avg. of TSS(mg/l)
CC1	7.5275	28.875	179.25	355.545	361.25	148.33
CC2	7.9375	28.45	287.75	507.105	404	349.25
CC3	7.12	30.1367	37.0333	103.06667	72.9	550
PH1	9.3125	29.525	104	427.75	317.25	266.2
PH2	8.36	27	184.9333	819.3333	582	383.3
SH	9.4367	29.5333	226.9	688.6667	476.3333	316.7

Table C4: average physical parameters experimental results

Health care facilities	Mn (mg/l)	Fe (mg/l)	Cr (mg/l)	Cd (mg/l)	Pb (mg/l)	Zn (mg/l)	Hg (mg/l)
CC1	0.6	4.03	0.1	0.001	0.051	0.101	0.014
CC2	1.2	5.49	0.01	0.11	0.189	0.116	0.001
CC3	1.59	9.68	Trace	0.11	0.137	0.128	Trace
PH1	0.09	1.45	Trace	0.009	0.011	0.025	Trace
PH1	0.07	1.39	Trace	0.001	0.063	0.026	Trace
PH1	0.2	1.44	Trace	0.001	0.017	0.069	Trace
PH1	0.16	1.2	0.01	0.005	0.029	0.071	Trace
PH1	0.9	1.45	Trace	0.008	0.0139	0.069	Trace
PH2	0.55	2.43	Trace	0.002	0.016	0.062	Trace
PH2	0.83	1.37	Trace	0.001	0.02	0.052	Trace
PH2	0.45	1.17	Trace	0.004	0.018	0.075	Trace
PH2	0.42	2.44	0.001	0.004	0.022	0.0129	Trace
PH2	0.4	2.39	Trace	0.002	0.018	0.055	Trace
SH	0.8	2.5	0.001	0.01	0.004	0.054	Trace
SH	0.61	2.1	Trace	0.02	0.024	0.012	Trace
SH	0.72	2.27	0.001	0.01	0.002	0.052	Trace
SH	0.52	2.25	0.01	0.011	0.025	0.06	Trace
SH	0.69	2.49	0.001	0.011	0.034	0.062	Trace

Table C5: average chemical parameters experimental results

Health care facilities	Avg. of BOD(mg O2/l)	Avg. of COD (mg O2/l)	Avg. of SO_4 (mg/l)	Avg. of NO_3 (mg/l)	Avg. of PO_4 (mg/l)	Avg. of P (mg/l)
CC1	41.77	444	20.25	152.6	19.92	3.98
CC2	70.89	466	12.4	424.95	20.13	4.02
CC3	50.74	98	23.33	2.9	11.66	2.33
PH1	65.31	354	92	37.6	8.50	1.70
PH2	68.16	240	10.66	0.73	22.44	4.49
SH	31.09	832	52	21.63	14.35	2.87

Table C6: average heavy metals results

Health care facilities	Avg. of Mn conc. (mg/l)	Avg. of Cr conc. (mg/l)	Avg. of Cd conc. (mg/l)	Avg. of Pb conc. (mg/l)	Avg. of Zn conc. (mg/l)	Avg. of Hg conc. (mg/l)	Avg. of Fe conc. (mg/l)
CC1	0.6	0.1	0.001	0.051	0.101	0.014	4.03
CC2	1.2	0.01	0.11	0.189	0.116	0.001	5.49
CC3	1.59	0	0.11	0.137	0.128	0	9.68
PH1	0.284	0.004	0.0048	0.027	0.052	0	1.386
PH2	0.53	0.0004	0.0026	0.018	0.051	0	1.96
SH	0.668	0.0046	0.0124	0.018	0.048	0	2.322

Table C7: biological parameters experimental results

Health care facilities	Avg. of E coli(MPN/100ml)	Avg. of Salmonella(MPN/100ml)	Avg. of Non Fecal Coliform(MPN/100ml)
CC1	9.00E+06	4.00E+06	1.60E+07
CC2	5.20E+07	1.50E+04	4.80E+05
CC3	5.20E+05	0.00E+00	7.56E+06
PH1	3.00E+04	3.20E+05	8.40E+05
PH2	0.00E+00	4.00E+04	3.83E+05

SH	4.20E+05	0.00E+00	3.34E+07

Table C8: contaminants load

Health care facilities	BOD (g/day)	COD (g/day)	SO_4 (g/day)	NO_3 (g/day)	P (g/day)	Mn (g/day)	Fe(mg/day)	Zn(mg/day)	Hg(mg/l)	Pb (mg/day)	Cd(mg/day)	BOD/COD ratio
CC1	6.68	71.04	3.24	24.41	0.63	0.096	0.64	16.16	2.24	8.16	0.16	0.09
CC2	18.94	124.51	3.31	113.54	1.07	0.32	1.46	30.99	0.26	50.5	29.39	0.15
CC3	24.94	47.04	11.2	1.39	1.11	0.76	4.64	61.44	0	65.76	52.8	0.52
PH1	1037.55	5607.36	1457.28	595.58	26.95	4.49	21.95	823.68	0	424.19	76.03	0.18
PH2	926.96	3264	145.06	9.97	61.05	7.2	26.65	698.77	0	255.68	35.36	0.28
SH	174.11	4659.2	291.2	121.14	16.07	3.74	13	268.8	0	99.68	69.44	0.03

Appendix D: Health care facilities data

Table D1: Water consumption in hospitals

Health facilities / month	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEPT.	NOV.	DEC.
PH1 (cubic meter)	588	452	950	651	923	448	773	459	139	497	646
PH2 (cubic meter)	768	985	139	113	162	445	738.5	535	380	505	730
SH (cubic meter)	588	452	950	651	923	448	773	459	139	497	646

Table D2: Health care facilities codes, categorization and services

Health care facilities Codes	Ownership	Type	Different units
CC1	Government	CHPS Compounds	Family planning unit, OPD unit, dispensary, Child welfare, labour ward, laboratory, eye clinic
CC2	Government	CHPS Compounds	Family planning unit, OPD unit, labour ward,
CC3	Government	CHPS Compounds	OPD unit, dispensary, labour ward
PH1	Government	Primary Hospital	OPD unit, dispensary, paediatric unit, labour ward, laboratory, theatre, eye clinic, dental unit, X-ray unit, lying in wards
PH2	Government	Primary Hospital	OPD unit, dispensary, paediatric unit, labour ward, laboratory, theatre, eye clinic, dental unit, X-ray unit, lying in wards
SH	Private hospital	Primary Hospital	OPD unit, pharmacy, Child welfare, labour ward, laboratory, laundry, kitchen, lying in wards

Table D3: Health care facilities statistical data

Health care facilities	Number of beds	Number of daily Out patients	Number of workers
CC1	4	2	15
CC2	9	4	7
CC3	14	85	36
PH1	130	350	233

PH2	128	220	205
SH	30	212	55

Appendix E: List of Plates

Plate H1.A: Health care centre PH2 Wastewater discharge into a drain

Plate H1.B: Health care CC1 Wastewater discharge into a drain

Plate H1.C: Health care centre CC3 wastewater collection chamber

Plate H2.A: wastewater samples characterization