UNIVERSITY OF CAPE COAST

ASSESSMENT OF THE PERFORMANCE OF WASTE STABILIZATION POND AT THE CAPE COAST TEACHING HOSPITAL IN GHANA

JANET MAWUNYO TORNYI

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BY

JANET MAWUNYO TORNYI

Thesis submitted to the Department of Environmental Science of the School of Biological Sciences, of the College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Environmental Science

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.. Date:..........................

Name: Janet Mawunyo Tornyi

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:................................... Date:.........................

Name: Professor Hugh Komla Akotoye

Co-Supervisor's Signature: .... Date:.........................

Name: Professor Frederick Ato Armah

ABSTRACT

In developing countries, hospital wastewater management is an issue of major concern. The purpose of the study was to evaluate the performance of the waste stabilization pond at the Cape Coast Teaching Hospital in Ghana. Wastewater samples were taken from the raw sewage (anaerobic pond) after screening. The process was repeated in both the facultative and maturation ponds, sequentially. Fifty four samples representing 18 samples each from the three stages of the waste stabilization treatment were analysed to evaluate the efficiency of the ponds over a period of six months. The selected parameters were analysed based on a well-established protocols. Descriptive and inferential statistics were used to determine the distribution and relationships among wastewater parameters measured in the stabilization ponds. The results showed that the final effluent values obtained for most of the parameters were within the acceptable limits of the Ghana Environmental Protection Agency. However, conductivity, TSS, turbidity, nitrate, phosphorus, magnesium and mercury levels were not compliant. The efficiency of the WSP for turbidity was 56.78%, TSS 71.96%, BOD 64.78%, magnesium 3.55%, total coliforms 34.48%, E.coli 53.53%, Iron 50.60%, manganese 75.40%, and cadmium 47.83%. The rest of the parameters exhibited negative values. Based on the low efficiency removal of some of the parameters, the effluent should be treated to prevent any possible pollution in the environment.

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DEDICATION

To my siblings and my parents Mr Johnson Gamedoagbao and Madam Regina Ganagodo

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LIST OF ABBREVIATIONS

APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UCC	University of Cape Coast
WSP	Waste Stabilization Ponds

CHAPTER ONE

INTRODUCTION

This chapter presents an overview of the thesis in terms of the background to the study and the statement of the research problem. The purpose and objectives of the study followed by the hypotheses that were formulated to guide this thesis are part of the chapter. This chapter also presents the significance of conducting the research work as well as the scope of the research work.

Background to the Study

Urbanization and rapid industrialization in many cities throughout the world have occurred as a result of an increase in human population. This situation has led to an increase in the discharge of domestic and industrial as well as hospital effluents into receiving water bodies (Massoud, Chami, Al-Hindi, & Alameddine, 2016). Wastewater released sometimes contain all sorts of chemical and biological pollutants which include nitrogen, phosphorus, heavy metals, detergents, pesticides, hydrocarbons, viruses, bacteria and protozoa. Chemicals such as heavy metals (Cd, Cr, Cu, Pb, Hg, Zn and Fe), metalloids (As) and biological pollutants if not treated properly may cause deleterious effects on organisms and the environment (Mansouri & Ebrahimpour, 2011; Akpor & Muchie, 2011; Nziku & Namkinga, 2013; Armah & Gyeabour, 2013; Armah, Quansah, & Luginaah, 2014). Heavy metals such as cadmium, chromium, copper, lead mercury, nickel, selenium, silver and zinc are toxic to wastewater treatment systems (Wissenschaftszentrum, 2005). These heavy metals are toxic to humans and other organisms, which may end up in surface water where they may influence the aquatic ecosystem and interfere with the food chain. Humans are particularly exposed to the drinking water, produced from surface water (Pauwels & Verstraete, 2006).

Wastewater from hospitals may constitute environmental potential contamination hazard due to chemical and microbiological characteristics of the effluent (Bohdziewicz & Sroka, 2005). According to Steven, Matt, & Rai (2008), wastewater effluents when released directly into the environment are responsible for the degradation of natural ecosystems and impacts may arise from an increase in nutrient loads leading to eutrophication, decreased levels of dissolved oxygen and releases of toxic substances, many of which can bioaccumulate and biomagnify in aquatic organisms (Morrison, Fatoki, Persson & Ekberg, 2001).

Currently, there are several techniques used to treat wastewater. These can be classified into two groups: conventional and non-conventional treatment techniques. The former has high-energy requirements whilst the latter is solely dependent on natural purification processes.

The conventional systems of wastewater treatment include trickling filters, activated sludge systems, bio-disc rotators and aerated lagoons. On the other hand, non-conventional systems, which are also called eco-technologies include constructed wetlands and waste stabilization ponds, WSPs (Nhapi & Gijzen, 2005). Out of the several technologies available, the recommended type for developing countries is the WSPs (Awuah, 2006). Several conventional wastewater management practices are not effective in the complete removal of antibiotics (Brown, 2011).

WSPs are biological treatment systems in which processes and operations are highly dependent on the environmental factors such as temperature, wind speed and light intensity that are highly variable and any given combination of these environmental parameters is usually unique to a given location (Gray, 2004).

WSPs are commonly used as efficient means of wastewater treatment relying on little technology and minimal regular maintenance. They generally consist of a series of ponds usually between 1 and 3m deep depending on the type of pond (Toumi, Nejmeddine, & Hamouri, 2000), namely anaerobic, facultative and maturation pond. The use of WSP in domestic applications is about 100 to 200 L per person per day, but the quantity for hospitals ranges from 400 to 1200 L per day per bed (Emmanuel, Perrodin, Keck, Blanchard, & Vermande, 2005).

Hospital wastewater normally contains several organic substances that are resistant to biological degradation and attended by low biodegradability ratio of biochemical oxygen demand (BOD_5) to chemical oxygen demand (COD) of 0.3, which shows a resistance toward conventional activated sludge biological treatment process (Kajitvichyanukul & Suntronvipart, 2006; Polar, 2007).

Studies have shown that the release of wastewater from hospitals is associated with an increase in the prevalence of antibiotic resistance (Elmanama, Elkichaoui, & Mohsen, 2006). Exposure even to low concentrations over long periods of time may result in selection and consequent spread of resistance to pharmaceuticals.

The general wastewater treatment methods depend on biological processes, principally bacteria feeding on organic material in the wastewater and most wastewater treatment plants are designed to remove biodegradable organic material, but not even low concentrations of synthetic pollutants (Karin, 2005). A study conducted in Thailand on hospitals where activated sludge and oxidation ditch were used, bacteria load exceed standard levels; pathogenic bacteria and parasites were found in two-thirds of the hospitals and heavy metals, namely lead, chromium and cadmium were also found in hospital effluents within an acceptable range (Danchaivijitr, Wongchanapai, Assanasen, & Jintanothaitavorn, 2005). A study conducted in Iran on seven hospitals revealed that activated sludge process, that is, secondary treatment was not effective in treating hospital wastewater (Mesdaghinia, Naddafi, Nabizadeh, Saeedi, & Zamanzadeh, 2009).

Waste stabilization ponds are the most important method of wastewater treatment in developing countries where sufficient land is normally available and where temperature is most favourable for their operation (Mara, 2003). If properly designed and operated, waste stabilization ponds (WSPs) can attain a 99.9% faecal coliform reduction and are capable of attaining l00% removal of helminths (USEPA, 2007). They are arranged in a series of anaerobic ponds, facultative pond and finally one or more maturation ponds, where anaerobic and facultative ponds are designed for BOD removal and maturation ponds are designed for faecal bacterial removal (Mara, 2003).

Some studies have been carried out in Ethiopia on solid waste management in hospitals but little or no previous data is available on wastewater.

It is, therefore, difficult to estimate the damage that wastewater from hospital has inflicted on human health and the environment. More so, observations indicate that, most health facilities have not put in place an organized management system to address Health Care Waste Management (HCWM) properly and where such a system was present, it did not meet the minimum requirements (Federal Ministry of Health, 2008).

Waste stabilization ponds have been used successfully and widely to treat municipal wastewater (Mara, 2003). Although the quality of hospital wastewater is similar to municipal wastewater, wastewater effluent from hospitals may contain non-metabolized pharmaceutical compounds, antibiotics, disinfectants, anaesthetics, radioactive elements, X-ray contrast agents and other persistent and dangerous compounds (Boillot, 2008; Carballa et al., 2004; Jolibois & Guerbet, 2005).

Statement of the Problem

Hospitals consume large volumes of water every day. The consumption of domestic water on the average is 100L per person per day, while that of hospitals varies from 400 to 1200L per bed per day (Dehghani & Azam, 2008) and this generates significant amounts of wastewater loaded with microorganisms, heavy metals, toxic chemicals, and radioactive elements. Such waste effluents could endanger public health and welfare if they are discharged into water bodies without treatment (Amouei et al., 2015). Wastewater could bring about skin diseases or enteric illnesses if it is not treated well before discharge into the environment. So far studies on the treatment of hospital wastewater by WSPs and their ability to remove various pollutants and pathogens are rather scanty especially in developing countries such as Ghana. Few experimental studies have focused on the full range of biological and chemical contaminants and their interactions in hospital wastewater. Majority of these experimental studies, the compounds analysed in wastewater were not necessarily the most important ones in terms of toxicity or impact on the environment and human health. This gap in the literature is a fundamental motivation for this thesis.

Purpose of the Study

The purpose of the study was to evaluate the performance of the waste stabilization pond at the Cape Coast Teaching Hospital. This hospital was selected because it is the largest in the Central Region of Ghana that provides tertiary patient care services. It is expected to exhibit highest standards in terms of environmental health.

Objectives

The objectives of the study were to:

1. Measure the various physicochemical parameters of the ponds (temperature, pH, electrical conductivity, total dissolved solids, total suspended solids, turbidity, biological oxygen demand, chemical oxygen demand, dissolved oxygen, sulphate, magnesium, nitrate, ammonia and phosphorus) and heavy metal (iron, manganese, lead, mercury, chromium and cadmium) concentrations in wastewater at various stages of treatment in the stabilization ponds.

2. Assess the microbiological characteristics (*E.coli*, total coliform and faecal coliform) of the wastewater in the stabilization ponds.
3. Determine the efficiency of removal of contaminants from the waste stabilization pond based on the physicochemical, heavy metals and microbiological characteristics of the influent and effluent.

Hypotheses

H_o: There is no significant difference in the physicochemical parameters and heavy metal concentrations in wastewater at the various stages of treatment in the waste stabilization ponds.

H_1: There is significant difference in the physicochemical and heavy metal concentration in wastewater at the various stages of treatment in the stabilization ponds.

H_o: There is no significant difference in the microbial loads of the wastewater at the various stages of treatment in the waste stabilization ponds.

H_1: There is significant difference in the microbial loads of the wastewater at the various stages of treatment in the waste stabilization ponds.

H_o: There is significant difference in determining the removal efficiency of contaminants from the waste stabilization pond based on the physicochemical, heavy metals and microbiological characteristics of the influent and effluent.

H_1: There is no significant difference in determining the removal efficiency of contaminants from the waste stabilization pond based on the physicochemical, heavy metals and microbiological characteristics of the influent and effluent.

Significance of the Study

Since the 1980s, data on the occurrence of pharmaceuticals in natural surface waters and the effluent of sewage treatment plants have been reported (Kummerer, Gartiser, Erbe, & Brinker, 1998). Stan and Linkerhager (1994) have measured pharmaceuticals in ground and drinking water. Humans are particularly exposed by the drinking water, produced from contaminated surface water (Pauwels & Verstraete, 2006). However, the significance of the research cannot be exaggerated. The results generated will contribute to the understanding of the physicochemical, heavy metals and biological quality wastewater in the waste stabilization pond at the Cape Coast Teaching Hospital. It will also provide baseline scientific data which could influence decision-making in wastewater treatment. The findings will provide useful information to guide policy formulation, implementation and evaluation for the hospital, Ghana health Service and other developmental organisations and NGOs interested in wastewater treatment. The results can also be used for both references for academic and wastewater quality monitoring purposes.

Delimitations

Delimitation is any factor within the researcher‘s control that may affect external validity, that is, the extent to which the findings of a study can be applied to individuals and settings beyond those that were studied (Gall, Borg & Gall, 2003 as cited in Wanjohi, 2014). The scope of this study was the treatment of hospital wastewater using waste stabilization pond at the Cape Coast Teaching Hospital. However, the three treatment stages of the waste stabilization pond were selected for this study. There are so many physico-chemical indicators of wastewater quality; heavy metal; microbial; however, the wastewater quality parameters for this research were delimited to 23 parameters. These included temperature, pH, conductivity, total dissolved solids, total suspended solids, turbidity, biological oxygen demand, chemical oxygen demand, dissolved oxygen, sulphate, chloride, magnesium, nitrate, ammonia and phosphorus. The heavy metals are iron, manganese, lead, mercury, chromium and cadmium. *E.coli*, total coliform and faecal coliform of the wastewater were also investigated. In all 54 samples were collected comprised of 18 samples from the anaerobic, facultative and maturation pond each from the stabilization pond. The Cape Coast Teaching Hospital was chosen because it is the largest in the Central Region of Ghana that provides tertiary patient care services.

Limitations of the Study

Hospital wastewater when not treated before being discharged into the environment can cause pollution. Humans are particularly exposed by the drinking water, produced from contaminated surface water. It would have been perfect for the sampling to cover the hospitals in the Cape Coast metropolis or at least the whole Central Region of Ghana. However, due to time and financial constraints 54 wastewater samples were taken once every month over a period of six months from November 2016 to April 2017 at the Cape Coast Teaching Hospital. The study should have run for at least 12 months in order to determine the seasonal variations, but because less than twelve months was available for the planning, design, data collection and analysis, and write-up this could not be achieved.

Definition of Terms

Biological Oxygen Demand (BOD): it is the amount of oxygen used by the organic and inorganic compounds which are oxidised by biological-oxidation effect in a certain condition (Yang, Liu & Yang, 2009).

Chemical Oxygen Demand (COD): this is the amount of oxygen consumed by the organic compounds and inorganic matter which were oxidised in wastewater (Yang, Liu & Yang, 2009).

Total dissolved solids (TDS): it is a measure of the minerals, metals, cations, anions, or salts that are dissolved in water (Bartram, & Balance 1996)

Total suspended solids (TSS): is a measure of the amount of all suspended particles in water (Branigan, 2013).

Parameter: specific characteristic of a sample that can quantitatively be measured.

Sample: portion of a large entity (i.e., population) whose measured quantity can represent the whole entity.

Dissolved oxygen (DO): it is a measure of the minerals, metals, cations, anions, or salts that are dissolved in water (Brant & Kauffman, 2011).

Waste stabilization ponds (WSP): Man-made earthen basins having low-cost, low-maintenance, highly efficient, entirely natural and highly sustainable which are used in treating wastewater (Khatri & Reddy, 2009).

Organisation of the Study

The thesis is systematically organised into six chapters. Chapter one so far has presented the background to the study, statement of the problem, purpose of the study, objectives of the study, hypotheses, and significance of the study. The chapter further considered the delimitation and the limitations of the study. Chapter two presents the literature review whilst chapter three focuses on the materials and methods. In chapter four, the results of the study are presented. The fifth chapter presents the discussion. In the final chapter, summary and conclusions of the study as well as the recommendations were made for policy makers and for further study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The purpose of this study was to evaluate the performance of the waste stabilization pond at the Cape Coast Teaching Hospital in the Central Region of Ghana. This chapter reviews current literature of related works gathered through published journals, articles and books. Among the topics covered include, overview and structure of the wastewater, hospital wastewater, hospital wastewater characteristics, various hospital departments and their operations that produce wastewater, impact of hospital wastewater on the environment, EPA hospital discharge guidelines, effect of hospital waste on public health, waste stabilization pond systems and effluent quality interms of physicochemical, microbial and heavy metal parameters or components of wastewater. Also, how the information can be used to predict quality of safety and healthcare delivery within the work environment will be considered in this chapter.

Wastewater

Wastewater may be defined as a combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments. Together with ground water, surface water and storm water (Maung & Htwe, 2014). Raschid-Sally and Jayakody (2009) also defined wastewater as “a combination of one or more of domestic effluent consisting of black water (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater); water from commercial establishments and institutions, including hospitals; industrial effluent, stormwater and other urban run-off; agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter".

Hospital wastewater

Hospital wastewater is waste generated from all activities of a hospital including medical and non-medical activities from the operating, emergency and first aid, laboratory, diagnosis, radiology, kitchen and laundry activities (Tewodros, 2015). As a result, hospitals generate hybrid wastewater comprising of domestic, industrial and effluents of medical research (Rezaee, Ansari, Khavanin, Sabzali, & Aryan, 2005). Hospital wastewater contains harmful pollutants, such as pathogenic microorganisms (bacteria, viruses), residual of medicine and laboratory chemicals (antibiotics, phenol, chloroform), toxic chemicals (Pb), and biodegradable organic material (proteins, fats, carbohydrates) (Mahvi, Rajabizadeh, Yousefi, Hosseini, & Ahmadian, 2009). Wastewater from health-care establishments is of a similar quality to urban wastewater, but may also contain various potentially hazardous components (Easa, Abdou, Mahmoud, & El-Meseiry, 2009).

Sarojini (2013) and Windfeld and Brooks (2015) stated that about 85% of 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 could range from 15% to 35% depending on the total amount of hospital waste generated (Babu, Parande, Rajalakshmi, Suriyakala, & Volga, 2009).

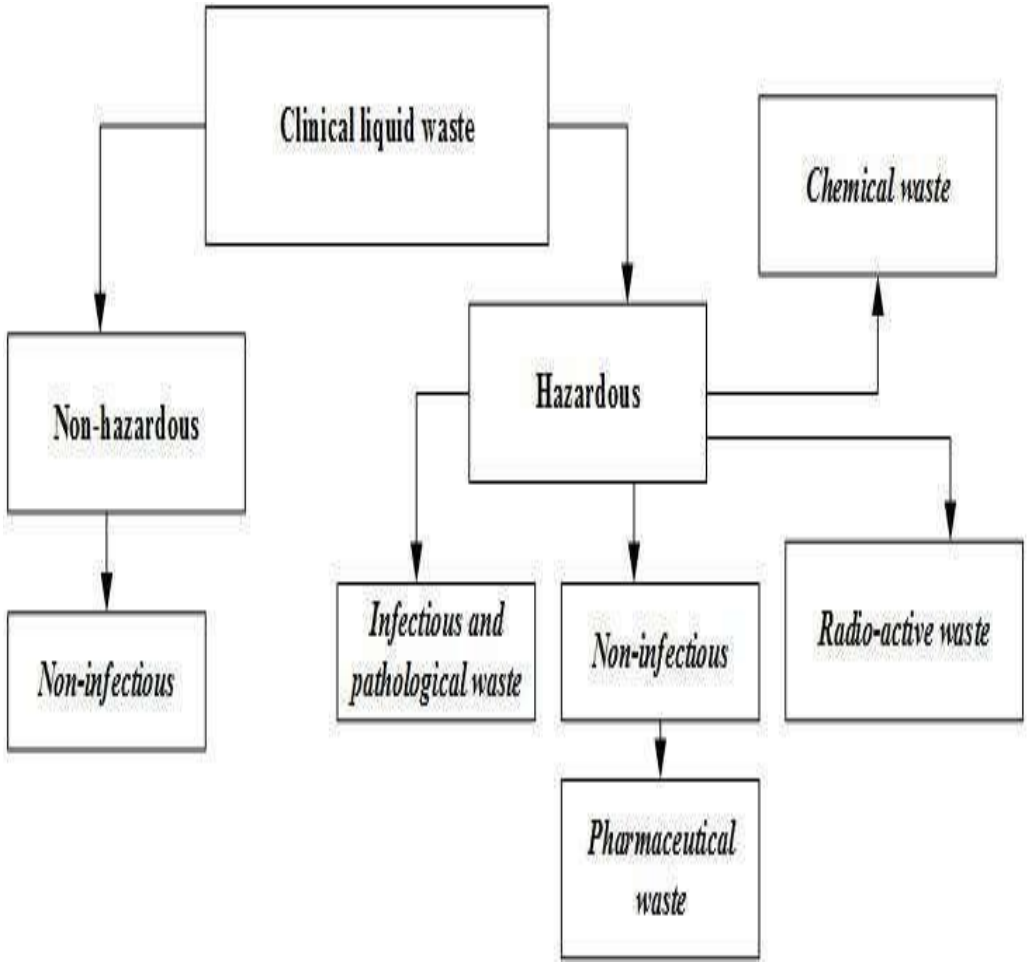

Figure 1: Clinical wastewater classification

Source: Wiafe, Nooni, Appiah, Nlasia, and Fianko, (2016)

Hospital wastewater characteristics

Just like many other industries, the healthcare facilities need to maintain hygienic standard at an optimal level so as to effectively look after the public's health. Owing to the poor immunity of patients together with the likelihood of harbouring pathogens sourced from patients of who may be suffering from various ailments, hospitals, in general, tend to use enormous amounts of disinfectants and detergents in order to eliminate pathogenic organisms (Leprat, 1988). These wastewaters typically contain large amounts of oxygen-consuming organic compounds, nutrients (e.g. nitrogen and phosphorus), low concentrations of persistent chemicals consequent from modern society's extensive use of detergents, insecticides, many chemicals, oils and metals all joining the wastewater streams through precipitation on city streets and grounds, and some industrial pollutants from the wastewater streams which are connected from industries to the municipal wastewater system (Halling-Sorensen et al., 1998).

Chan (2005) stated that hospital wastewater bearing the substances of infectious biological and hazardous chemical substances, does not just pose health hazards to human beings, but is also capable of causing irrevocable destructions and tremendous damages to nature. In fact, the hazardous impacts to various ecosystems start to take place as soon as the wastewater is discharged into the environment. In the midst of all types of natural environments, the aquatic arena, due to its initial contact with the hospital wastewater, is considered as the most affected and damaged area (Metcalf, 2003).

Infectious waste

Nwachukwu, Orji and Ugbogu (2013) defined infectious waste as waste suspected to contain pathogens such as bacteria, viruses, parasites, or fungi in adequate concentration to cause disease in susceptible hosts. Such category of waste include waste from laboratory work such as cultures, samples of stool and blood waste from surgical wards, and infectious diseases treatment units (Biswal, 2013). These infectious wastes are found in hospital wastewater which end up in water bodies as a study conducted in Sunyani Regional hospital recorded 7405 per L per day (Wiafe et al., 2016).

Pathological waste

Pathological waste consists of tissues, blood, and body fluids (Asante, Yanful, & Yaokumah, 2013). Pathological waste is mostly considered as a subdivision of infectious waste, although it may also include healthy body parts (Prüss, Giroult, & Rushbrook 1999). Studies have shown that pathological waste in clinical liquid waste in Sunyani Regional Hospital was 871 per L per day, which eventually goes into the natural environment (Wiafe et al., 2016).

Pharmaceutical waste

Pharmaceutical waste is generated from pharmacies, dispensaries or drug stores within health facilities. It includes spilt, expired, unused, contaminated pharmaceutical products such as drugs, and vaccines (Nwachukwu et al., 2013; El-Gawad & Aly, 2011).

There are significant amounts of chemicals and microbial agents in hospital wastewater. Many of these chemical compounds resist normal wastewater treatment. These usually end up in surface waters where they can influence the aquatic ecosystem and disturb the food chain (Pauwels & Verstraete, 2006).

Genotoxic waste

Nwachukwu et al. (2013) define genotoxic waste as waste highly hazardous and may have mutagenic, teratogenic, or carcinogenic tendencies that should be given special treatment. Vomit or urine from patients treated with cytotoxic drugs or antineoplastic drugs that are used in chemotherapy of cancer and are defined as a substance with the ability 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).

Chemical waste

Chemical waste is generated from hospitals containing discarded chemical substances such as laboratory reagents, disinfectants and solvents which are expired or no longer needed. Solid, liquid and gaseous chemicals and other cleaning materials from the hospital are normally seen in hospital wastewater (Hossain, Santhanam, Norulaini, & Omar, 2011).

Organic chemicals, inorganic chemicals and heavy metals

Organic chemicals are generated in health-care facilities and include disinfecting and cleaning solutions such as phenol-based chemicals used for scrubbing, perchlorethylene used in workshops and laundries as well as vacuum-pump oils used for vehicle engine on hospital premises (Acharya, Gokhale, & Joshi, 2014).

Inorganic chemicals consist mainly of acids and alkalis such as sulphuric, hydrochloric, nitric, and chromic acids, sodium hydroxide and ammonia solutions including oxidants, such as potassium permanganate ($KMnO_4$), and reducing agents such as sodium (Ibrahim, 2005).

Hospital wastewater with high heavy metal content represents a subclass of hazardous chemical waste, which is highly toxic. Mercury wastes are generated by spillage from broken clinical equipment such as thermometers and other chemicals used (Njiru, 2015).

Various Hospital Departments and Their Operations That Produce Wastewater

As hospital is one of the utmost important community services, the healthcare sector alone involves the usage of massive amounts of water for its effective operation (Kummerer, 2001).

Within a clinical or hospital setting, water is required in almost all areas including laundry, kitchen and other sanitary facilities (Jørgensen & Halling-Sørensen, 2000). The general maintenance and cleansing of the hospital environment and ward environments also utilize large amounts of chemicals. Such chemicals would as well be mixed into the sewage along with the hospital wastewater causing environmental hazards. Worse still, other facilities such as the hospital laboratories often require a lot of special chemicals in their pathological tests and investigations, not to mention chemical agents for cleaning and sterilizing special equipment. Such specific chemicals are often disposed of into the common drainage network and eventually get mixed into the communal sewage (Spellman, 2003).

Impact of Hospital Wastewater on Environment

Kumar, Mathur, Singh and Sharma (2014) reported that because of the infectious nature of hospital wastes, they are one of the most dangerous causes of environmental pollution. Effluents from hospital source contain antimicrobial residues which are being released into the environment, after patient intake and subsequent excretion. These residues are toxic in nature and when not properly treated before discharged into the environment can increase the risk of treatment complications and morbidity (Harris, Morris, Morris, Cormican, & Cummins, 2014).

The discharge of hospital wastewater into urban sewage without any preliminary treatment causes environmental problems, as these effluents find their way into the natural system (Magdaleno et al., 2014). Disinfectants in particular are often highly complex products or mixture of active substances. When such substances are disposed into sewage system after use, they may finally end up in surface and ground waters (Diallo, 2016).

Environmental Protection Agency Effluent Discharge Criteria of hospital wastewater

Table 1 lists the national guideline values for the quality of wastewater before discharging into inland water bodies such as lakes/dams, rivers and streams in Ghana (Ghana Environmental Protection Agency, 2012).

Generally, the guidelines values of developed countries are very strict because of the advanced technology adopted for wastewater treatment and the possible enforcement by the responsible agents. Nevertheless for the case of the developing countries including Ghana, explanation given by Hodgson and Larmie (1998) states that, the economy of the country makes it difficult to use high level technologies to treat domestic and industrial wastewater including hospital wastewater to achieve the strict guideline values adopted by the developed countries.

Table 1: *Ghana Environmental Protection Agency guidelines for hospital wastewater*

Parameter	Maximum permissible level before discharge
Temperature increase	< 3 ^{O}C above ambient
pH	6-9
BOD5 (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 (µS /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)

Effect of Hospital Waste on Public Health

Hospital wastes could be harmful to the ecological balance and public health. When pathological, radioactive, chemical, infectious, and pharmaceutical wastes, are untreated they could lead to outbreak of communicable diseases, diarrhea epidemics, water contamination, and radioactive pollution. Wastewater from hospital origin contain pollutants that are hazardous and require on-site treatment to prevent contaminating the city's sewage system and rivers (Gautam, Kumar, & Sabumon, 2007; Sun, Gu, & Wang, 2008).

One of the major concern regarding wastewater is the high content of enteric pathogens including bacteria, viruses, protozoa and helminthes, which can be easily transmitted through water. Wastewater from hospital where patients with enteric diseases are hospitalized, when not treated can get into environment and could lead to outbreak of diarrheal diseases (Amouei et al., 2015).

Transmission of disease through infectious waste is the greatest and most immediate threat of healthcare waste. If waste does not undergo treatment in a way that destroys the pathogenic organisms, dangerous amounts of microscopic disease producing agents such as viruses, bacteria, parasites or fungi will be found 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., 2013; Nwachukwu et al., 2013).

Hospital waste is potentially dangerous, since it can harbour pathogenic agents. Some of the pathogenic organisms are dangerous, because they may be resistant to treatment and possess high pathogenicity. Insufficient waste management will cause environmental pollution, odour nuisance, growth and multiplication of insects, rodents and worms which may lead to the transmission of diseases such as typhoid, cholera, hepatitis and AIDS through injuries from syringes and needles contaminated with human blood (Henry & Heinke, 1996). Really, some of the substances found in healthcare wastewaters are genotoxic and are suspected to be a possible cause of the cancers observed in the last decades. Therefore special care in handling genotoxic waste is essential; any discharge of such wastewater into the environment for long periods could have disastrous ecological consequences (Kumar, Mathur, Singh, & Sharma, 2014).

Medical wastewater has a high content of heavy metals which include excessive amounts of iron, manganese, aluminium, mercury, cadmium, or beryllium or semimetal as arsenic in medicine that can be poisonous and also cause a detrimental human or environmental effect (Singh, Gautam, Mishra, & Gupta, 2011). Exposure of heavy metals such as mercury, lead, arsenic, zinc, cadmium, manganese, chromium, copper, nickel, in wastewater can cause 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).

Waste Stabilization Pond Systems

Waste stabilization ponds are usually the most appropriate method of domestic and municipal wastewater treatment in developing countries, where the climate is most favourable for their operation. WSPs are man-made earthen with basins having low-cost, low-maintenance, highly efficient, entirely natural and highly sustainable. The only energy they use is direct solar energy, saving expenditure on electricity and more skilled operation (Khatri & Reddy, 2009). However, WSP requires more land than conventional electromechanical treatment processes such as activated sludge but land is an asset which increases in value with time. Natural biological and physical processes are used to treat wastewater to the required effluent standard. The quality of the discharged effluent depends on both the process design and the physical design of the WSP (Craggs, Green & Oswald, 1999). WSP technology offers important advantages and interesting possibilities when viewed in the light of sustainable energy and carbon management. WSP systems stand out as having significant advantages due to simple construction; low (or zero) operating energy requirements; and the potential for bio-energy generation through sunlight-powered by aerobic treatment and disinfection. Also energy may be cost-effectively produced as biogas from anaerobic ponds (Craggs et al., 1999). Conventional WSP requires little or no electrical energy for aerobic treatment as a result of algal photosynthesis (De-Garie, Crapper, Howe, Burke, & McCarthy, 2000).

Sunlight enables WSP to disinfect wastewaters very effectively without the need for any chemicals or electricity consumption. In addition, to the heat effects of solar irradiance on WSP treatment, incident irradiance to WSPs can influence treatment (Davies-Colley, Craggs, Park, & Nagels, 2005) because it has a strong influence on photosynthetic activity (Dermoun, Chaumont, Thebault, & Dauta, 1992).

WSPs have a relatively small carbon footprint considering the low-cost, energy production opportunities of anaerobic ponds and the potential of algae as a biofuel (Mara, 2004). The energy and carbon emission savings gained over electromechanical treatment systems are immense. Furthermore, WSP can be utilised as CO_2 scrubbers because algal photosynthesis consumes CO_2.

Each type of WSP carries out a unique function. Prior to treatment in the WSPs, the wastewater is first subjected to preliminary treatment (screening and grit removal) to remove large and heavy solids. Basically, primary treatment is carried out in anaerobic ponds, secondary treatment in facultative ponds, and tertiary treatment in maturation ponds. Anaerobic and facultative ponds are for the removal of organic matter (BOD) both soluble and suspended, *Vibrio cholerae* and helminth eggs. Maturation ponds are for the removal of faecal bacteria and nutrients (nitrogen and phosphorus). Anaerobic and facultative ponds are designed for BOD removal, while maturation ponds are designed to remove excreted pathogens. Well-designed WSPs, provided they are constructed and maintained properly and are not overloaded, will provide a high level of wastewater treatment for very many years. Other wastewater treatment processes can do this as well, of course, but not at the low cost of WSP, or with their simplicity (Craggs et al., 1999).

Waste Stabilization pond technology is the most cost effective wastewater treatment technology for the removal of pathogenic microorganisms. The treatment is achieved through natural disinfection mechanisms (Kamyotra & Bhardwaj, 2011).

Anaerobic ponds are commonly 2-5m deep. They are the smallest units in the series and are sized according to their volumetric organic loading (100 to 350g BOD5/m^3 day) depending on the design temperature. There is no dissolved oxygen present and the redox potential is negative. Anaerobic ponds work extremely well in warm climates. Around 60 % BOD5 removal at 20°C and over 70 % at 25°C can be achieved in a properly designed pond. Odour nuisance from anaerobic ponds, typically due to hydrogen sulphide, is a concern for design of anaerobic ponds. However, odour is not a problem provided that the anaerobic pond is properly designed and the sulphate concentration in the raw wastewater is less than 300 mg SO_4^{-2}/l (Gloyna, 1971). Facultative ponds follow anaerobic ponds in a WSP system. They are usually 1-2 m deep and are geometrically designed to have high length-to-width ratio (up to 10:1) to simulate a plug flow regime (Mara, Alabaster, Pearson, & Mills, 1992). They are designed for BOD removal on the basis of relatively low surface loading (100-400kg BOD/ha day) to permit the development of a healthy algal population as the oxygen for BOD removal is generated by algal photosynthesis. The algae give facultative ponds a dark green colour. Ponds may occasionally appear red or pink (especially when overloaded) due to the presence of anaerobic purple sulphide-oxidising photosynthetic bacteria (Khatri & Reddy, 2009).

Photosynthetic activity of the algae results in a diurnal variation of dissolved oxygen (DO) concentration and pH. DO concentration can rise to more than 20 mg/l i.e., highly supersaturated conditions and pH to more than 9.4, these are both important factors in the removal of faecal bacteria and viruses (Curtis, Mara & Silva, 1992). Ammonia and sulphide toxicity have been observed to be pH-dependent (Cooman, Gajardo, Nieto, Bornhardt, & Vidal, 2003). As the pH of a facultative pond increases, the unionized form of ammonia increases while sulphide production decreases. The effect of this toxicity is to inhibit algae growth and production and these mechanisms are thought to be self-sustaining (Khatri & Reddy, 2009). In primary facultative ponds BOD removal of about 70 % on an unfiltered basis and more than 90 % on a filtered basis can be achieved. Maturation ponds, used in series with facultative ponds are usually 1−1.5m deep and are geometrically designed to have a high length-to-width ratio (up to 10:1) to simulate a hydraulic plug flow regime (Mara et al., 1992). The primary function of maturation pond is to remove excreted pathogens to enable the practice of unrestricted crop irrigation.

Maturation ponds achieve only a small removal of BOD, but their contribution to nutrient (nitrogen and phosphorous) removal is significant (Kayombo, Mbwette, Katima, Ladegaard, & Jrgensen, 2004). The size and number of maturation ponds is governed mainly by the required bacteriological quality of the final effluent. Treatment efficiency of waste stabilization pond systems is often compromised by poor hydraulic design. Problems such as hydraulic short-circuiting are prevalent in many ponds. Improved hydraulic design can reduce the concentration of pollutants that escape treatment and thereby improve the water quality of the receiving environment. Pond hydraulic behaviour is influenced by the inlet/outlet configuration, baffles and wind, but design information relating to these factors is still very limited (Shilton & Harrison, 2003).

Shilton and Harrison (2003) reviewed guidelines for the improved hydraulic design of WSPs and reported that, inlet design can have a significant influence on the flow regime in a pond. Poorly considered positioning of the inlet and the outlet configuration can create hydraulic short-circuiting problems. Extensive testing undertaken on a wide range of baffle configurations showed how short stub baffles could provide improvements similar to longer "traditional" baffle designs and offer significant savings in construction costs.

Waste stabilization ponds (WSP) are now regarded as the method of first choice for the treatment of wastewater in many parts of the world. WSPs are very widely used for small rural communities (Boutin, Vachon, & Racault 1987; Bucksteeg, 1987). In developing countries and especially in tropical regions sewage treatment by WSPs has been considered an ideal way of using natural processes to improve sewage effluents. Many characteristics make WSP substantially different from other treatment technologies. Waste stabilisation pond effluents bring additional benefits since the algae they contain add organic content to soil and improve soil structure and its water holding capacity. Waste Stabilisation Ponds (WSP) have high concentration of total suspended solids (TSS) in their effluent. These solids comprise suspended algal cells as their constituents. These algae can impose serious constraints for some potential areas of effluent reuse like agricultural applications (Saidam, Ramadan, & Butler, 1995). Treated wastewater is a reliable water resource, especially for periodic droughts and in arid areas.

Naddafi, Jaafarzadeh and Mokhtari (2004) investigated the full scale application of stabilization ponds effluent of southern Hovaizeh Wastewater Treatment Plant located in Khuzestan Province for irrigation use to assess the health effects and feasibility of crop irrigation. Two experimental plots, each of about 0.5 ha were constructed. One of the plots was irrigated by stabilization pond effluent and the other by Nisan River water. Basic parameters for both the plots, such as, type of cultivated crops, amount of fertilizer used and lack of soil contamination were similar. The only difference was the type of water applied for irrigation. Results showed the growth rate and quality of crops were increased by using stabilization pond effluent in comparison with Nissan River water. Potential of natural treatment systems for the reclamation of domestic sewage in irrigated agriculture was studied by Kim, Giokas, Lee, and Paraskevas (2006). Various systems consisting of waste stabilization ponds, shallow algal ponds and water hyacinth ponds were operated in parallel, series or mixed arrangement in order to find the optimum setting that enables efficient effluent quality to be reused for agricultural purposes. The results indicate that waste stabilization ponds were very efficient for wastewater treatment, achieving an effluent quality to be used for restricted irrigation. However, coliform numbers were not always consistent with the proposed guidelines. To cope with the problem, a modified configuration employing water hyacinth ponds as the final pond was proposed. Routine monitoring of the quality of final effluent of a pond system permits a regular assessment to be made of whether the effluent is complying with the local discharge or reuse standards (Mara, 1997).

The evaluation of pond performance and behaviour is extremely useful as it provides information on how under loaded or overloaded the system work. Thus how much, if any of the loading on the system can be safely increased as the community it serves expands, or whether further ponds (in parallel or in series) are required. It also indicates how the design of future pond installations in the region might be improved to take account of local conditions. A full evaluation of the performance of a WSP system is a time consuming and expensive process, it is the only means by which pond designs can be optimized for local conditions (Mara, 1997).

Design of Waste Stabilization Pond

The required and accepted quality of discharged wastewater is characterized by effluent limits. Hence, prior to design, these limits must be known since they will be used as the water quality design objectives. The general standards for the discharge of treated wastewaters into inland surface waters are given in the Environment Protection Rules (Central Pollution Control Board [CPCB], 1996). The most important of these for WSP design are: BOD 30 mg/l (non-filtered), suspended solids 100 mg/l and Total N 100 mg N/L.

Kayombo et al. (2004) list the most important input design parameters of WSP as temperature, net evaporation, design flow, per capita BOD and faecal coli form concentration. Helminth eggs are required if the effluent is to be reused for restricted crop irrigation. Shilton and Harrison (2003) observed that poor hydraulic design reduces the theoretical hydraulic retention time due to short-circuiting and the formation of dead spaces. This results in incomplete removal of the wastewater pollutants. The resulting treated effluent then fails to meet the required standards. It has been observed that BOD removal in an anaerobic pond is directly proportional to pond temperature (Miguel & Mara, 2004).

Mara and Pearson (1986) proposed the relationship between design temperature and design BOD removal for anaerobic ponds. It can be concluded that the performance of a WSP system depends on robust process and physical design methods. The process design should assume a realistic hydraulic flow regime that can be achieved by the physical design.

Design Principles for Anaerobic Ponds

An empirical approach is the recommended method for designing anaerobic ponds. Such ponds are normally designed based on permissible volumetric organic loading rate (v) expressed in g/m3.d of BOD (Kayombo et al., 2004) and the proposed permissible volumetric organic loading rates should be within a range of 100-400 g/m^3.d to ensure that anaerobic ponds function as intended. Volumetric organic loading rate of less than 100 g/m^3.d can cause anoxic reactions in anaerobic ponds. The upper limit of 400 $g/m^3.d$ is established to avoid the risk of odour produced by hydrogen sulphide gas (H_2S).

Table 2 lists suitable design volumetric organic loading rates for various temperatures ranges. Here the design temperature is the mean temperature of the coldest month.

Table 2: *Design values of permissible volumetric BOD loadings and percent removal in anaerobic ponds at various temperature*

Temperature (^{O}C)	Volumetric loading ($g/m^3.d$)	BOD removal (%)
<10	100	40
10-20	20T-100	2T+20
20-25	10T+ 100	2T+20
>25	350	70

T = temperature, °C.

Source: Mara, (1997); Mara and Pearson, (1986).

Depths of anaerobic ponds are kept high (3.5-5.0m) in order to guarantee the predominance of anaerobic conditions. Anaerobic ponds are square or slightly rectangular. Which receives the highest organic loading and is normally lacking oxygen due to high BOD concentrations entering the system (Mara & Pearson, 1998). The removal of BOD is achieved by settling, acidogenesis, acetogenesis, and methanogenesis (Sah, Rousseau, & Hooijmans, 2012). The major problem of anaerobic ponds are the odour and the increase in ammonia and sulphide concentrations caused by the anaerobic processes (Mara & Pearson; Crites, Middlebrooks & Reed, 2006). Besides BOD, COD and Suspended Solids removal, anaerobic pond is efficient in the removal of Vibrio cholerae due to their high sulphide concentrations (Mara, Pearson, Oragui, Arridge, & Silva, 2001).

The chemical reactions occurring in the anaerobic ponds can be represented by the following equations (Crites et al., 2006).

$5(CH_2O)_x \rightarrow (CH_2O)_x + 2CH_3COOH + \text{Energy}$

$2CH_3COOH + 2NH_4HCO_3 \rightarrow 2CH_2COONH_4 + 2H_2O + 2CO_2$

$2CH_3COONH_4 + 2H_2O \rightarrow 2CH_2 + 2NH_4HCO_3$

A properly designed anaerobic pond can achieve around 60% BOD removal at 20° C and one-day hydraulic retention time is sufficient for wastewater with a BOD of up to 300 mg/l and temperatures higher than 20° C (Mara, 2003).

Design of Facultative Ponds

The design of facultative ponds focuses on BOD removal. Mara (1997) described how the design of facultative ponds is currently based on rational and empirical approaches. The empirical design approach is based on correlating performance data of existing WSP. The rational design approach models the ponds performance by using kinetic theories of biochemical reactions in association with the hydraulic flow regime.

Design of Maturation Ponds for Coliform Removal

The design of maturation ponds is based on bacterial decay. Faecal bacteria, protozoa and viruses die off with time because of unfavourable environment in the pond. Main factors causing removal are sedimentation, scarcity of food, predators, ultra-violet light. The main parameter to be considered in bacterial die-off in ponds is retention time as well as temperature, high pH (>9), and high UV Light irradiance together with significant amount of dissolved oxygen (Hamzeh & Ponce, 2007) which is generally used to design a pond series for faecal coliform removal (Mara & Pearson, 1998). This assumes that faecal coliform removal can be reasonably well represented by a first-order kinetic model in a completely mixed reactor.

Effluent Quality

Effluent quality is used to describe the physical, chemical, and biological characteristics of wastewater usually in respect to its suitability for various uses. These characteristics are often influenced by substances which dissolve or suspend in wastewater. Human activities directly influence wastewater quality and indirectly from particulate, dissolved, and volatile material sources which may eventually enter a water body. The quality of wastewater, therefore is closely linked to wastewater reuse because there are numerous measures for wastewater quality (Chapman, 1996).

Physical Characteristics

The physical characteristics of wastewater include particle size distribution, turbidity, colour, taste, temperature, conductivity, specific gravity and odor (Crittenden, Trussell, Hand, Howe, & Tchobanoglous, 2012). Others include suspended solids, total dissolved solids, settleable solids and total chemical solids. These characteristics are used to assess the reuse potential of wastewater and to determine the most suitable type of operation and processes for its treatment (Gutterres & de Aquim, 2013).

pH

The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body (Chapman, 1996). The pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH scale runs from 0 to 14 (i.e. very acidic to very alkaline), with pH 7 representing a neutral condition. At a given temperature, pH (or the hydrogen ion activity) indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution (Chapman).

All organisms have an optimal pH range within which they thrive best. Although some bacteria are known to grow at pH 3.0 or perhaps in even more acid media, most species have an optimum range between pH 6.0 and 8.5. A few bacteria are known which prefer alkaline media of pH 8.5 (Esrey, Potash, Robe, & Shiff, 1991). Moreover, optimum pH for the growth of nitrifying bacteria is in the range 8.0 to 9.0, with pH levels below 7.0 causing a substantial reduction in nitrification activity (Quist, 2004). Levels of pH greater than 9.0 are effective in pathogen removal (Curtis, 1990).

Temperature

The temperature of the wastewater is very important because it affects chemical dissolutions and reaction rates (El-Mouhty & Gad, 2014). Temperature change affect the solubility of oxygen, solubility of the chemicals in wastewater treatment to increases and can cause microbial action to be more effective.

However, if temperatures are low, microbial activity is slow and more chemicals will be required for treatment (Drinan & Whiting, 2001).

The metabolic rate of aquatic organisms is related to temperature, and in warm waters, respiration rates increase leading to increased oxygen consumption and increased decomposition of organic matter (Chapman, 1996). Increased temperature also decreases the solubility in water of gases, such as O_2, CO_2, N_2, CH_4 etc. (Chapman). The optimum temperature for bacterial activity is in the range of 25 to 35°C. According to Kagya (2011), high temperature is suitable for removal of wastewater constituents such as nitrogen through volatilisation.

Odour

Water odour is usually the result of labile, volatile organic compounds and may be produced by decaying organic matter. Human wastes can create odours, either directly or as a result of stimulating biological activity. Usually, the presence of odour suggests higher than normal biological activity although it does not automatically indicate the presence of harmful substances (Chapman, 1996).

Turbidity

Turbidity is an expression of the optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (Pan, Ho, Tsutsui, & Takahashi, 2001). Turbidity is caused by suspended and colloidal particulate matter such as clay, silt, and finely divided organic and inorganic matter, plankton and other microscopic organisms (Chapman, 1996). The most reliable method for determination of turbidity employs the principle of nephelometry (i.e. light scattering by suspended particles) by means of a turbidity meter which gives values in Nephelometric Turbidity Units i.e. NTU (Chapman).

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current (Chapman, 1996). The determination of electrical conductivity provides a rapid and convenient way of estimating the concentrations of dissolved ions. Conductivity increases as the concentration of ions increases, since electrical current is transported by ions in solution (Smedley, Edmunds, West, Gardner, & Pelig-Ba, 1995). Conductivity is expressed as microsiemens per centimetre ($\mu S\ cm^{-1}$) and, for a given water body, is related to the concentrations of total dissolved solids and major ions (Chapman). Conductivity could be used as a measure of total dissolved solids (Faure, 1998) as well as a measure of salinity in water (Kesse, 1985).

Total Suspended Solids

Total Suspended Solids (TSS) is a measure of the amount of all suspended particles in water that will not pass through a glass fiber filter without an organic binder (Branigan, 2013). The suspended solids are a collection of organic and inorganic materials of various sizes and density. TSS can also be categorized into settleable and nonsettleable components, where settleability is a function of particle size (mass), flow and turbulence. High TSS in water is an indication of poor water quality (Chapman, 1996). Total suspended solids test results are used routinely to assess the performance of conventional treatment processes and the need for further effluent filtration for reuse applications (Tchobanoglous, Burton & Stensel, 2003).

Total Dissolved Solids (TDS) and Salinity

TDS are a measurement of inorganic salts, organic matter and other dissolved materials in water and wastewater which are commonly correlated with electrical conductivity (EC). TDS consist of inorganic salts and small amounts of organic matter that are dissolved in water. Clay particles and colloidal iron and manganese oxides and silica, fine enough to pass through a 0.45 micrometer filter membrane can also contribute to total dissolved solids. Total dissolved solids comprise sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), sulphate (SO_4^{2}), bicarbonate (HCO_3^{2-}), carbonate (CO_3^{2-}), silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate (National Health and Medical Research Council, 2004).

Salinity is an indication of the concentration of dissolved salts in a body of water. The ions responsible for salinity include the major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and the major anions (CO_3^{2-} and HCO_3^{2-}, SO_4^{2-}, and Cl^-). The level of salinity in aquatic systems is important to aquatic plants and animals as species can survive only within certain salinity ranges (Friedl, Teodoru, & Wehrli, 2004).

Chemical Characteristics

Chemical parameters associated with the organic content of wastewater include ammonia, nitrate and nitrite, phosphorus, calcium, magnesium, sulphate, dissolved oxygen, chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Inorganic chemical parameters include salinity, hardness, pH, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulphates, sulphides, nitrates and phosphates (Wong, Moganaragi, & Atiqah, 2015).

Nitrogen compounds

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Plants and micro-organisms convert inorganic nitrogen to organic forms. In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO_3^-) and nitrite (NO_2^-), the ammonium ion (NH_4^+) and molecular nitrogen (N_2) (Chapman, 1996). 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 (Spellman, 2014).

Ammonia

Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere (Chapman, 1996). It is also discharged into water bodies as a component of municipal or community waste. At certain pH levels, high concentrations of ammonia (NH3) are toxic to aquatic life and, therefore, detrimental to the ecological balance of water bodies (Chapman).

Nitrate and nitrite

The nitrate ion NO_3^- is the common form of combined nitrogen found in natural waters and nitrate in wastewater indicates that the wastewater has been stabilized with respect to oxygen demand. It may be biochemically reduced to nitrite (NO_2^-) by denitrification processes, usually under anaerobic conditions. The nitrite ion is rapidly oxidised to nitrate. Natural sources of nitrate to surface waters include igneous rocks, land drainage and plant and animal debris. Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth and decay (Chapman, 1996).

Phosphorus compounds

In natural waters and in wastewaters, phosphorus occurs mostly as dissolved orthophosphates and polyphosphates, and organically bound phosphates. Changes between these forms occur continuously due to decomposition and synthesis of organically bound forms and oxidised inorganic forms (Chapman, 1996).

Phosphorus is also a primary macronutrient that is essential to the growth of plants and other biological organisms but large quantities can cause algae blooms. Phosphorous sources in wastewater include phosphates from detergents (Abhilash, Srikantaswamy, Kumar, & Kiran, 2014), weathering of phosphorus-bearing rocks and the decomposition of organic matter (Chapman, 1996).

High concentrations of phosphates can indicate the presence of pollution and are largely responsible for eutrophic conditions. Phosphorus concentrations are usually determined as orthophosphates, total inorganic phosphate or total phosphorus i.e. organically combined phosphorus and all phosphates (Chapman, 1996).

Calcium

Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates. The salts of calcium, together with those of magnesium, are responsible for the hardness of water. Industrial, as well as water and wastewater treatment processes also contribute calcium to surface waters. Calcium is an essential element for all organisms and is incorporated into the shells of many aquatic invertebrates, as well as the bones of vertebrates (Chapman, 1996).

Magnesium

Magnesium is common in natural waters and wastewater as Mg^{2+}, and along with calcium, is a main contributor to water hardness. Magnesium arises principally from the weathering of rocks containing ferromagnesium minerals and from some carbonate rocks. Magnesium occurs in many organometallic compounds and in organic matter, since it is an essential element for living organisms (Chapman, 1996).

Sulphate

Sulphate is naturally present in surface waters as SO_4^{2+}. It is the stable, oxidised form of sulphur and is readily soluble in water and in wastewater (with the exception of lead, barium and strontium sulphates which precipitate). Industrial discharges and atmospheric precipitation can also add significant amounts of sulphate to surface waters. Sulphate can be used as an oxygen source by bacteria which convert it to hydrogen sulphide (H_2S, HS-) under anaerobic conditions (Chapman, 1996).

Dissolved oxygen (DO)

Determination of DO concentrations is a fundamental part of a water quality assessment since oxygen is involved in, or influences, nearly all chemical and biological processes within water bodies. Concentrations below 5mg/l may adversely affect the functioning and survival of biological communities and below 2mg/l may lead to the death of most fish. The measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic substances and the level of self-purification of water and wastewater. Its determination is also used in the measurement of biochemical oxygen demand, BOD (Chapman, 1996).

Chemical Oxygen Demand, (COD)

The chemical oxygen demand is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate (Chapman, 1996). COD measures biodegradable and non-biodegradable organic matter of wastewaters (Riffat, 2012). The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants (Chapman).

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic microorganisms present in the sample to oxidise the organic matter to a stable inorganic form (Chapman, 1996). By measuring the initial concentration of a sample and the concentration after five days of incubation at 20 ^{O}C, the BOD5 can be determined (Greenberg, Clesceri, & Eaton, 1992). BOD measurements are usually lower than COD measurements. Unpolluted waters typically have BOD values of 2 mg l^{-1} O_2 or less, whereas raw sewage has a BOD of about 600 mg l^{-1} O_2. Treated sewage effluents have BOD values ranging from 20 to 100 mg l^{-1} O_2 depending on the level of treatment applied (Chapman).

Heavy Metals

The ability of a water body to support aquatic life, as well as its suitability for other uses depends on many trace elements. Some heavy metals (Mn, Zn and Cu) present in trace concentrations are important for the physiological functions of living tissue and regulate many biochemical processes. The same metals, however, discharged into natural waters at increased concentrations in sewage, industrial effluents or from mining operations can have severe toxicological effects on humans and the aquatic ecosystem (Chapman, 1996).

Heavy metals are a group of metals with density greater than 5g/cm_3 (Lewinsky, 2007). In water they are harmful in relatively small amounts and are classified as toxic metals while other metals are categorized as nontoxic because they are not harmful (Duruibe, Ogwuegbu, & Egwurugwu, 2007; Tchounwou, Yedjou, Patlolla, & Sutton, 2012). The toxicity of metals in water depends on the degree of oxidation of a given metal ion together with the forms in which it occurs. In natural waters other than groundwater, heavy metal sources include dissolution from natural deposits, discharges from laboratories (preservatives), dental department, thermometers, and sphygmomanometers (US EPA, 2006).

In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these metals. Also, human exposure has risen dramatically as a result of an exponential increase of their use in various industrial, agricultural, domestic and technological applications (Bradl, 2005).

Many of these metals are necessary for growth of organisms but only in trace concentrations. If the required concentrations are exceeded they can become toxic and thus impede the potential beneficial uses (Bai, Srikantaswamy, & Shivakumar, 2010).

Table 3 is the selected heavy metals indicating their sources in the environment, their effect on human and permissible level required in the environment.

Table 3: *Selected of heavy metals, their major sources, effect on human health and permissible levels*

Pollutants	Major sources	Effect on human health	Permissible level (mg/l)
Cadmium	Pesticides, fungicides, metal smellers	Bronchitis, dermatitis, poisoning	0.06
Lead	Paint, pesticide, smoking, automobile emission, mining, burning of coal	Mental retardation in children, developmental delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and, acute or chronic damage to the nervous system, epilepticus, liver, kidney, gastrointestinal damage	0.1
Manganese	Welding, fuel addition, ferromanganese production	Inhalation or contact causes damage to central nervous system	0.26
Mercury	Pesticides, batteries, paper industry	Tremors, gingivitis, minor psychological changes, acrodynia characterized by pink hands and feet, spontaneous abortion, damage to nervous system, protoplasm Poisoning	0.1
Chromium	Mines, mineral sources	Damage to the nervous system, fatigue, irritability	0.05

Adapted from Singh, Gautam, Mishra, & Gupta (2011)

Biological Characteristics

Wastewater contains a wide range of micro-organisms specially bacteria, viruses and protozoa. The majority is harmless and can be used in biological sewage treatment, but sewage also contains pathogenic microorganisms, which are excreted in large numbers by sick individuals and a symptomic carriers (Abdel-Raouf, Al-Homaidan, & Ibraheem, 2012). Bacteria which cause cholera, typhoid and tuberculosis; viruses which cause infectious hepatitis; protozoa which cause dysentery and the eggs of parasitic worms are all found in sewage (Shaaban, Haroun, & Ibraheem, 2004).

The presence of indicator organisms are often used to predict the level of faecal contamination (and pathogens) in water resources (Gilbride, Lee, & Beaudette, 2006). The indicator organisms presently used for monitoring the efficiency of wastewater treatment facilities and surface water resources in developing countries are total coliforms, faecal coliforms, or *Escherichia coli* (Ashbolt, Grabow, & Snozzi, 2001).

Total coliforms

Total coliforms are Gram-negative, oxidase-negative, non-spore forming rods that ferment lactose with gas production at 35–37 ^{O}C, after 48 hours, in a medium with bile salts and detergents (Cabral, 2010). Total coliforms can provide basic information on contamination of water samples, but they are not an index of faecal pollution (Gibson, Opryszko, Schissler, Guo, & Schwab, 2011).

Faecal Coliform

Faecal coliform bacteria are the most commonly used indicators of faecal pollution in water. Faecal coliform bacteria are present in the digestive tract and faeces of all warm-blooded animals (Harwood, Butler, Parrish, & Wagner, 1999). The presence of faecal coliform indicates that the water source may be contaminated with faecal matter and the presence of other pathogenic organisms.

However, even this group includes some species that can have a non-faecal origin in wastewater (Tallon, Magajna, Lofranco, & Leung, 2005).

Escherichia coli

E.coli is the best coliform indicator of faecal contamination from human and animal wastes (Spellman, 2014). *E.coli*'s presence is more representative of faecal pollution because it is present in higher numbers in faecal material and is rarely found in the absence of faecal pollution (WHO, 2011).

CHAPTER THREE

RESEARCH METHODS

This chapter presents the various methods and techniques employed in data collection and analysis. The content of this chapter includes the description of the research design used, study area, design of the stabilization pond, data collection procedure and laboratory procedures employed to analyse each variable and description of how the data collected from the field and other sources were analyzed and presented.

Research Design

Completely randomized design was employed as the experimental design in collecting data on the physicochemical, heavy metal and microbiological parameters. Before and after design was used. Wastewater samples were collected from each of the treatment stages once in a month in order to examine trend and efficiency of the various stages of the pond. The assumption underlying the choice of this design is that, samples would be drawn from homogenous population (Yu, 2012).

Study Area

Location of the study Area

The study was conducted at the Cape Coast Teaching Hospital in the Cape Coast Metropolis of Ghana. The hospital receives an average of 300 patients per day. The only management practice undertaken was the clearing of weeds around the various ponds. The metropolis is bounded to the south by the Gulf of Guinea, to the west by Komenda Edina Eguafo Abrem Municipality, to the east by Abura Asebu Kwamankese District, and to the north by Twifu Heman Lower Denkyira District. It is located on longitude 1° 15ˈW and latitude 5^{O} 06ˈN. It occupies an Area of approximately 122 square kilometres, with the farthest point at Brabedze located about 17 km from Cape Coast, the Central Regional capital (Ghana Statistical Service, 2013). Figure 2 is the map of Cape Coast metropolitan assembly.

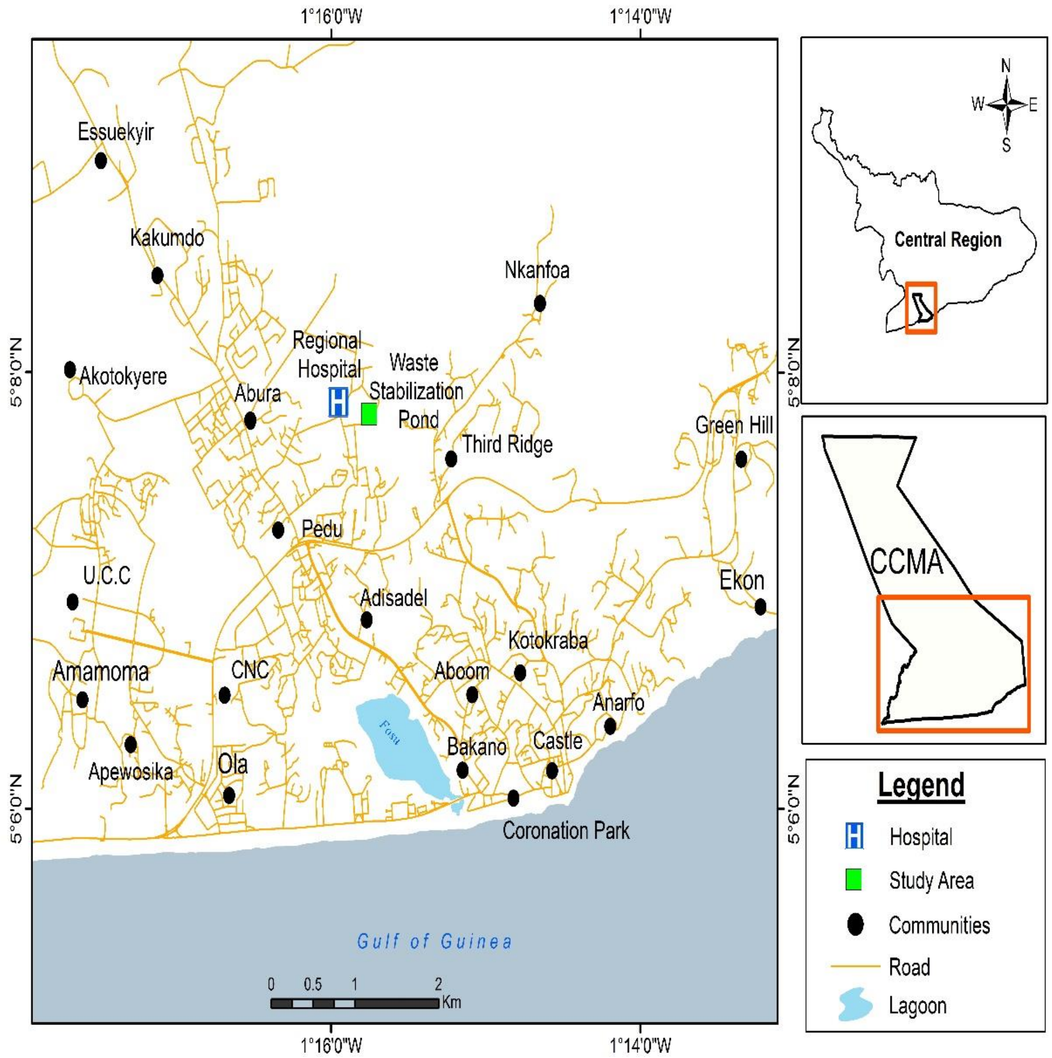

Figure 2: Map of the study area and location of the stabilization pond

Source: University of Cape Coast, Department of Geography

Relief and Drainage

The landscape of the Cape Coast Metropolis is generally undulating with batholiths as a dominant feature. The rock type of the metropolis is of the Birimian formation and consists of schist and introduced granites and pegmatite. The hills are generally overlain by sandy and clayey silts while the valleys are overlain by clayey gravel with lateritic soils exposed in a number of areas. In between the batholiths and the few hills are valleys of various shapes, some occupied by rivers and streams including the Kakum, the major steam in the metropolis. It is the main source of water for domestic and industrial purposes. Many of the minor streams end up in wetlands, with the largest draining into the Fosu Lagoon at Bakaano. The landscape in the northern parts of the metropolis is however, generally low-lying and is suitable for crop cultivation (Ghana Statistical Service, 2013).

Climate

The Cape Coast Metropolis experiences high temperatures throughout the year. The hottest months are February and March, just before the main rainy season, while the coolest months are June, July and August. The variability in climate in the Metropolis is influenced more by rainfall than temperature. The metropolis has a double maximal rainfall months are April, May, June, July and October, with annual rainfall total between 750 and 1,000mm (Ghana Statistical Service, 2013).

Vegetation

The present vegetation of the metropolis consists of shrubs of about 1.5m high, grasses and a few scattered trees. The original vegetation of dense scrub, which the rainfall supported, has been replaced by secondary vegetation as a result of clearing for farming, charcoal burning, bush fires and other human activities. Presently, trees are less dense in the area compared with the interior forest areas. The northern parts of the metropolis are an exception to what has been described above. In these areas, secondary forest can be found, and has survived mainly due to lower population densities and relatively little disturbance of the ecosystem (Ghana Statistical Service, 2013).

Design of the Stabilization Pond

The study was conducted on the Cape Coast Teaching Hospital's wastewater treatment plant (stabilization ponds) (Figure 3). The waste stabilization pond was constructed to help in the storage, treatment and disposal of liquid waste generated in the hospital and to ensure good environmental health. The ponds at Cape Coast Teaching Hospital were constructed and commissioned in 1996. The dimensions of the treatment facility is 150m × 120m. Wastewater generated are channelled into the stabilization pond for treatment before they are released into the environment.

The waste stabilization pond consists of three treatment ponds, namely primary anaerobic, facultative and maturation ponds. The facultative and maturation ponds are serially connected basins with sand embankments. The anaerobic pond has three inlet points, representing influents. The sewage enters a retention chamber of the pond and then flows by gravity into the pond through two inlet points. The third inlet also flows by gravity. Physical and visible objects in wastewater such as rags, plastics, tissues, etc. are removed from the raw sewage by a screen in chamber before entering the first pond. The second pond which is the facultative pond serves as facultative and maturation treatment sections before the final effluent is released into the environment.

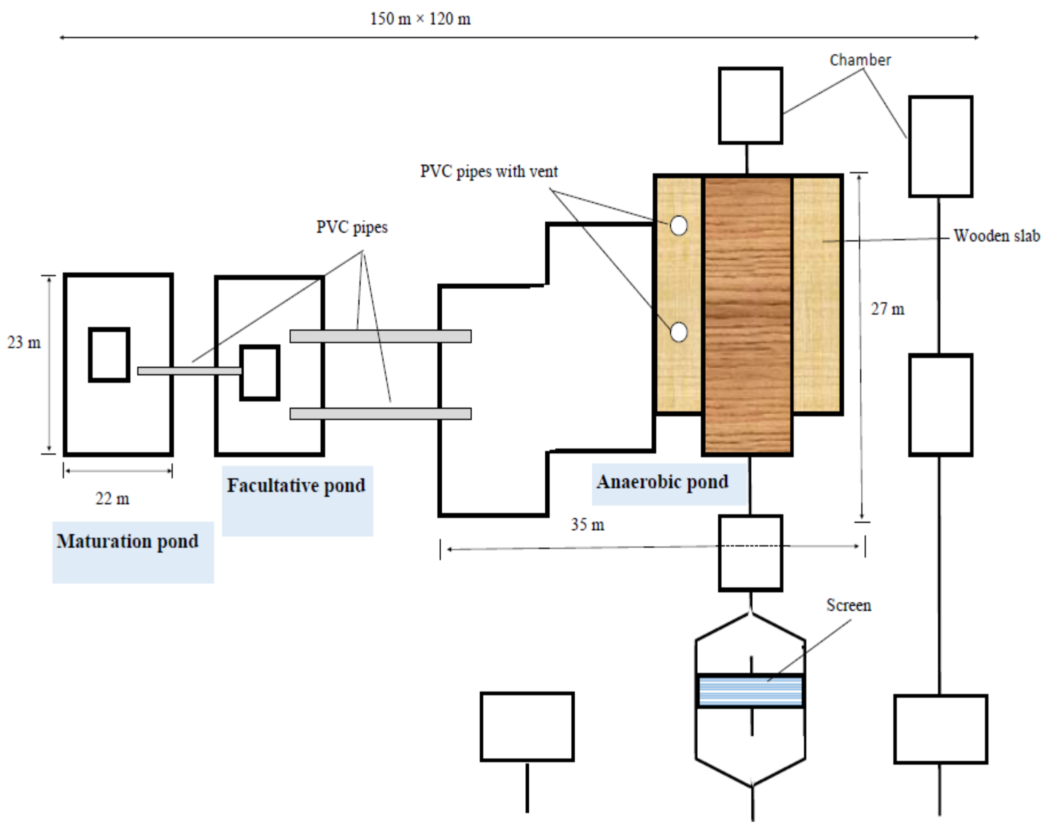

Figure 3: Schematic diagram of the stabilization pond

Data Collection

To assess the treatment performance of the Cape Coast Teaching Hospital waste stabilization pond, wastewater samples were collected from the raw sewage (anaerobic pond) after screening. The process was repeated in both the facultative and maturation ponds. The samples were taken to the laboratory for analysis. The analyses comprised of the removal efficiency of physicochemical parameters, heavy metal concentration as wells as microbial content. The physicochemical parameters included temperature, pH, conductivity, turbidity, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids, total dissolved solids, nitrate, nitrite, ammonia, phosphorus and microbiological parameters, namely total coliform, faecal coliform and *E. coli*.

Sampling Procedure

Sampling was done monthly starting in November, 2016 to April, 2017. Wastewater sampling and analysis was conducted once primarily to determine the concentration of selected physicochemical parameters, trace metals and microbial concentrations in each pond and also determine the overall efficiency of the whole treatment system.

Pre-treated plastic bottles were used for the collection of wastewater samples. Wastewater samples were taken at three different spots in each of the ponds on each sampling day. Wastewater samples obtained from each of the ponds; namely anaerobic, facultative and maturation ponds were bulked together to form three composite samples. The samples were immediately preserved in an ice-chest and transported to the laboratories of the Ghana Atomic Energy Commission (GAEC) in Accra for analysis of the physicochemical parameters while the microbial analysis was carried out at the Department of Laboratory Technology of the University of Cape Coast.

In all, 54 samples representing 18 composites, with 9 samples each of the wastewater from the three stages of the waste stabilization treatment; anaerobic, facultative and maturation ponds were analyzed to evaluate the efficiency of the ponds.

Procedures for Laboratory Analysis

Test for physicochemical parameters in wastewater

Temperature

The temperature was measured with a WTW (Xylem Analytics, Germany) pH meter, pH 523 Instrument. The cap of the probe was removed and the probe was rinsed with distilled water before dipping it in the sample to about 3 to 4cm and reading allowed to stabilize. The temperature was then recorded.

pH

Apparatus

WTW (Xylem Analytics, Germany) pH meter, pH 523 Instrument was used together with the temperature probe for the pH measurement.

Principles of method

pH was measured with a pH meter and a combination electrode (a set of glass electrode and reference electrode). The electrode was first calibrated against pH buffers 7 and 4 or 9 to adjust the response of the glass electrode. The electrode was then immersed in the test solution where a change in potential (in mV), was set up between the glass electrode and the solution. Since the potential cannot be measured directly, the change in potential in the glass electrode compared with reference electrode (that is, at constant potential) was measured. The potential was converted into pH units by the tip of the glass electrode that was sensitive to pH changes.

Procedure

The electrode was connected to the pH meter and the system was calibrated using the pH buffers. The electrode was withdrawn and rinsed with deionised water. It was dipped in the sample, stirred and reading allowed to stabilize.

Conductivity

Apparatus

Conductivity meter Lovibond senso direct con 200, Conductivity Cell (probe) Type PCM/141

Principle

At constant temperature, the electrical conductivity of a given water sample is a function of its concentration of ions. The probe is sensitive to the ionic charges in the solution. A factor that controls the current carrying of the water sample helps the meter provide a direct reading of the conductivity of the test sample.

Procedure

The conductivity cell was connected to the conductivity meter and the cell was rinsed thoroughly with distilled water and then a portion of the sample. The cell was inserted into the well shaken sample and the conductivity value read on the display after the value had stabilized (American Public Health Association [APHA], 1995).

Turbidity by Nephelometric Method

Apparatus

Turbidity meter with sample cell: HACH Model - 2100P Turbidity meter

Principle

It is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light the higher the turbidity.

Procedure

The sample was shaken vigorously and poured into the clean sample cell to at least 2/3 full. Using the range knob an appropriate range was selected. When the red light was shown, the next range is selected. The stable turbidity reading was recorded and the reading obtained for the turbidity of the sample in Nephelometric Turbidity Units (NTU) (APHA, 1995).

Biochemical Oxygen Demand (BOD_5) Dilution method

Principle

BOD determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, polluted waters and effluents. The method consists of the determination of dissolved oxygen (DO) concentration before and after incubation at 20 ^{O}C for 5 days. The BOD is then calculated from the initial and final DO.

Procedure

Wastewater samples collected are diluted with aerated distilled water and incubated at 20 ^{O}C for 5 days. Dissolved oxygen (DO) concentration is measured before and after incubation. The BOD is calculated from the difference between the initial and final dissolved oxygen.

An amount of 2 ml $MnSO_4$ followed by 2 ml Alkali-Iodide-Azide solution was added to the day one (DO) sample in BOD bottle. The bottle was corked carefully to exclude air bubbles and shaken thoroughly by inverting several times. Precipitate was allowed to settle. After precipitate has settled, 2 ml conc. H_2SO_4 was added. The bottle was corked again and inverted several times to dissolve the precipitate which gives an intense yellow colour. 100 ml of solution was titrated with $Na_2S_2O_3$ to a pale yellow colour. 1 ml of starch was added as indicator. The titration was continued to the first disappearance of the blue colour.

Calculation

BOD_5, (mg/l) = (D1-D2)/P

Where

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

D2 = DO of sample after 5 day incubation at 20 ^{O}C, mg/l

P = Decimal volumetric fraction of sample used (APHA, 1995).

Chemical Oxygen Demand (COD) Closed tube reflux method

Principle

Most organic matter is oxidized by boiling a mixture of chromic and silver catalyst in strong sulphuric acid. The sample is refluxed in strongly acid solution with a known excess potassium dichromate. After digestion, the remaining unreduced potassium dichromate is titrated with Ferrous Ammonium Sulphate (FAS) to determine the amount of dichromate consumed and the oxidizable matter is calculated in terms of oxygen equivalent.

Procedure

Culture tubes and caps were washed with 20% H_2SO_4 before used to prevent contamination. Sample was placed in culture tubes and digestion solution added. Sulphuric acid reagent was carefully run down inside of vessel to form an acid layer under the sample-digestion solution layer. Tubes were tightly capped and inverted several times to mix completely. Tubes were placed in block digester preheated to 150 ^{O}C, and refluxed for 2hrs behind a protective shield. They were cooled to room temperature in a test tube rack. Culture tube caps were removed and small TFE-covered magnetic stirrer added, followed by 1 to 2 drops Ferroin indicator. Stirring was done rapidly while titrating with standard 0.1M FAS. The end point is a sharp colour change from blue green to reddish brown. In the same manner, a blank containing reagents and a volume of distilled water equal to that of the sample was refluxed and titrated. Calculation:

$$\text{COD mg } O_2/l = \frac{(A-B)\times M\times 8000}{V}$$

Where

A = volume of FAS used for blank, ml

B = volume of FAS used for sample, ml

M = molarity of FAS

V = volume of sample

8000 = milli equivalent of oxygen (8) x 1000 ml/L (APHA, 1995).

Total Suspended Solids (TSS) By Gravimetric method

Principle

A well-mixed sample is filtered through a weighed standard glass-fibre filter. The residue that is retained on the filter is dried to a constant weight at 105 ^{O}C. The increase in weight of the filter represents the total suspended solids.

Procedure

A filtering apparatus and a glass-fibre filter were assembled and suction was begun. The filter was soaked with a small volume of reagent grade water to seat it. Water sample was stirred, with a magnetic stirrer, to obtain a more uniform or homogenous particle size. Whilst stirring, a measured volume was poured in to measuring cylinder and onto the seated glass-fibre filter. The filter was washed with three successive 10 ml volumes of reagent grade water. Complete drainage was allowed between washings. Suction was continued for about three minutes after filtration was complete. The filter was carefully removed from filtration apparatus and transferred onto an aluminium weighing dish. It was dried for at least 1hour at 103 to 105 ^{O}C in an oven and then cooled in a desiccator to balance temperature and weighed. The cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained.

Calculations

TSS (mg/l) = (A-B) × (1000)/sample vol. (ml)

Where

A = weight of filter + dried residue (mg)

B = weight of filter (mg) (APHA, 1995).

Total Dissolved Solids (TDS) By Gravimetric Method

Principle

The sample is filtered and the filtrate evaporated on a water bath. The residue left after evaporation is dried to a constant weight in an oven at 105 ^{O}C. The increase in weight over that of the empty dish is the weight of the TDS.

Procedure

Water sample was stirred with a magnetic stirrer and a measured volume (100 ml) was transferred onto a glass-fibre filter using a measuring cylinder and vacuum applied. The glass-fibre filter was washed with three successive 10 ml volumes of reagent grade water, allowing complete drainage between washings, and suction continued for about three minutes after filtration. Total filtrate (with washings) was transferred into a weighed evaporating dish and evaporated to dryness on a steam bath. The evaporated sample was dried for at least 1hour in an oven at 180 ± 2 ^{O}C. It was then cooled in a desecrator to balance temperature and weigh. The cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained.

Calculations

TDS (mg/l) = (A-B) × (1000)/sample vol. (ml)

Where

A = weight of dried residue + dish (mg)

B = weight of dish (mg) (APHA, 1995).

Nitrate- Nitrogen (NO_3-N) By Hydrazine Reduction method

Principle

Nitrate is reduced to nitrite with hydrazine sulphate. The nitrite ion originally present, plus reduced nitrate ion is determined by diazotization with sulphanilamide and coupling with N-(1-naphthly-)–ethylenediamine dihydrochloride to form a highly coloured azo dye which is measured spectrophotometrically. The apparatus used was the 6705 UV/VIS Spectrophotometer Jen Way

Procedure

10 ml of the sample or an aliquot was transferred into a test tube.1.0 ml of 0.3MNaOH was added and mixed gently1.0 ml of reducing mixture was added and mixed gently. It was heated at 60 ^{O}C for 10min in a water bath. It was cooled to room temperature and 1.0 ml of colour developing reagent added. It was shaken to mix and absorbance read at 520nm (APHA, 1995).

Phosphate (PO_4-P) By Stannous Chloride method

Molybdophosphoric acid is formed and reduced by stannous chloride to intensely coloured molybdenum blue. The absorbances of the molybdenum blue at a wavelength of 690nm are proportional to the concentration of the phosphate in sample.

Procedure

100 ml sample free from colour and turbidity, 1 drop of phenolphthalein indicator was added. 4 ml of molybdate reagent and 1 was added to the sample. 10 drops of stannous chloride reagent was added with thorough mixing. After 10 minutes, but before 12 minutes, absorbance was measured at wavelength of 690nm on the spectrophotometer. The spectrophotometer was zeroed with a blank solution (this solution was prepared in the same way as samples except that instead of 100 ml sample, 100 ml distilled water was used).

Ammonia-Nitrogen (NH_4-N) By Direct Nesslerization

The method is based on the calorimetric determination of nessler's reagent. The yellow to brown colour produced by the Nessler–ammonia reaction absorbs strongly in the range of 400 to 425 nm when a 1 cm light path is used.

Procedure

1-5ml wastewater sample was pipetted and dilute to the 50ml mark with ammonia-free water two drops of Rochelle salt solution was added to the diluted sample. It was mixed well and 2 ml of Nessler's reagent added blank was prepared (50 ml of ammonia-free water plus 5drops Rochelle salt and 2 ml Nessler's reagent). Samples were allowed to stand for 10 minutes for colour development and their absorbance determined using the UV/VIS spectrophotometer at a wavelength of 410nm using a 1cm light path cuvette. The spectrophotometer was zeroed with the blank solution (APHA, 1995).

Sulphate By Turbidimeteric method

Sulphate ion (SO_4^{2-}) was precipitated in an acetic acid medium with barium chloride ($BaCl_2$) to form barium sulphate ($BaSO_4$) crystals of uniform size. Light absorbance of the $BaSO_4$ suspension was measured by a photometer and SO_4^{2-} concentration was determined by comparison of the reading with a standard curve.

Silica in excess of 500 mg/l interfere and in waters containing large quantities of organic material it was not be possible to precipitate $BaSO_4$ satisfactorily.

In potable waters, there are no ions other than SO_4^{2-}that will form insoluble compounds with barium under strongly acid conditions. Determination was made at room temperature; variation over a range of 10 ^{O}C will not cause appreciable error. Minimum detectable concentration: Approximately 1mg SO_4^{2-}/L.

Barium chloride, $BaCl_2$, crystals, 20 to 30 mesh in standardization, and uniform turbidity is produced with this mesh range and the appropriate buffer. Standard sulphate solution in 1) or 2) below; 1.00 ml=100µg SO_4 (100 mg/l). Dilute 10.4 ml standard 0.0200N H_2SO_4 titrant specified in alkalinity, section 2320B.3c, to 100 ml with distilled water. Dissolve 0.1479 g anhydrous Na_2SO_4, in distilled water and dilute to 1000 ml (100 mg/l).

Procedure

Formation of barium sulphate turbidity: 100 ml of the sample was measured into a 250 ml erlenmeyer flask. 20 ml buffer solution was added and mix in a stirring apparatus. While stirring, a spoonful of $BaCl_2$ crystals was added and the timing began immediately. It was stirred for 60 ± 2 seconds at a constant speed.

Measurement of barium sulphate turbidity: After the stirring period has ended, the solution was poured into absorption cell of photometer and measure turbidity at 5 ± 0.5 min.

Preparation of calibration curve: SO_4^{2-} concentration was estimated in the sample by comparing turbidity reading with a calibration curve prepared by carrying SO_4^{2-} standard through the entire procedure. Space standards at 5 mg/l increments in the 0 to 40 mg/l SO_4^{2-} range. Above 40 mg/l, accuracy decreases and $BaSO_4$ suspensions lose stability. Reliability of calibration curve was checked by running a standard with every three samples.

Correction for sample colour and turbidity: For the correct sample colour and turbidity blanks were run which $BaCl_2$ was not added.

Calculation:

$$\text{mg } SO_4^{2-}/L = \frac{mgSO_4^{2-} \times 1000}{mL\ sample} \quad \text{(APHA, 1995).}$$

Chloride by Argentometric method

Principle

In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride is precipitated quantitatively before red silver chromate is formed.

Potassium chromate indicator solution: dissolve 50g K_2CrO_4 in a little distilled water. Add $AgNO_3$ solution until a definite red precipitate is formed. Let stand 12h, filter, and dilute to 1L with distilled water.

Standard silver nitrate titrant, 0.0141M (0.0141N): dissolve ardize against by sodium chloride by the procedure described below; 1.00 ml= 500 µg Cl^- store in a brown bottle.

Aluminium hydroxide suspension: dissolve 125 g aluminium potassium sulphate or aluminium ammonium sulphate, $AIK(SO_4)_2 \cdot 12H_2O$ or $AlNH_4(SO_4)_2 \cdot 12H_2O$, in 1 L distilled water. Warm to 60 ^{O}C and add 55 ml conc. ammonium hydroxide (NH_4OH) slowly with stirring. Let stand about 1 h, transfer to a large bottle and wash precipitate by successive additions, with thorough mixing and decanting with distilled water, until free from chloride. When freshly prepared, the suspension occupies a volume of approximately 1 L. Phenolphthalein indicator solution, Sodium hydroxide, NaOH, 1 N, Sulfuric acid, H_2SO_4 1N and Hydrogen peroxide, H_2O_2, 30%.

Procedure

The samples were directly titrated in a pH range of 7 to 10. The sample was adjusted pH to 7 to 10 with H_2SO_4. For adjustment, preferably a pH meter was used with a non-chloride-type reference electrode. 2 to 3 drops of K_2CrO_4 indicator solution was added. It was titrated with standard $AgNO_3$ titrant to a pinkish yellow end point. It was consistent in end point recognition.

Standardize $AgNO_3$ titrant and establish reagent blank value were used in the titration method outlined above. A blank of 0.2 to 0.3 ml is usual.

$$\text{mg cl-/L} = \frac{(A-B)\times M\times 35450}{mL\ sample}$$

Where

A= ml titration for sample

B= ml titration for blank and

M= normality of $AgNO_3$ (APHA, 1995).

Test for Heavy Metals

Principles of acid digestion

Heavy metal traces was analysed using the acid digestion method. This technique is usually accomplished by exposing a sample to a strong acid and under moderate temperature which leads to a thermal decomposition of the sample and the solubility of heavy metals in solution, it is possible to quantify the sample through elemental techniques.

The reagents used were 67% of concentrated hydrochloric acid (HCl) and 65-67% of concentrated nitric acid (HNO_3).

The following apparatus were used: 150 ml of measuring cylinder, 100 ml of borosilicate beaker, test tube, fume chamber, clean film and hot plate, a 3 ml dropper and wash bottle for the metal analysis.

Hot plate digestion on water sample

Forty grams of the wastewater sample was taken into a 100 ml borosilicate beaker. 5 ml aqua regia was added in the ratio of 4.5 ml conc. HCl to 0.5 ml conc. HNO_3 in the fume chamber. The beaker was covered with a cling film, placed on the hot plate and digested for 3 hours at a temperature of 45°C. After the acid digestion, the sample was transferred into a 100 ml measuring cylinder. A distilled water was used to top it up to the 30 ml mark. The digestate was then assayed for the presence of Iron (Fe), Manganese (Mn), Calcium (Ca), Lead (Pb), Mercury (Hg), Cadmium (Cd), Chromium (Cr) and Magnesium (Mg) using

VARIAN AA 240FS-Atomic Absorption Spectrometer in an acetylene-air flame. The whole content was then transferred into a test tube for AAS analysis.

Reference standards used for the elements of interest, blanks and duplicates of samples were digested the same conditions as the samples. These served as internal positive controls.

Reference standards used were from FLUKA ANALYTICAL, Sigma-Aldrich Chemie GmbH, and product of Switzerland.

Quality control and quality assurance (QC/QA):

The following Quality Control and Quality Assurance techniques were used during the analysis: Blanks, Duplicates and Standards. During sample preparation they were check for contamination, check the reproducibility of the method used and lastly the efficiency of the equipment used was also checked.

Recommended instrument parameters

The Atomic Absorption and Working Conditions of the heavy metal parameters selected are in the appendix A.

Test for Microbial Parameters

Escherichia coli, Total and Faecal coliform

All samples were collected into sterilized plastic containers before noon and transported to the Department of Laboratory Technology for processing within 24 hours of collection. Using the Ghana Standards Authority standards, the samples were analyzed for Total Coliforms (TC), Fecal Coliforms (FC), and *Escherichia coli* (EC), using the pour plate method.

Preparation of eosin methylene blue agar and peptone water

Eosin Methylene Blue agar (Levine)-CM0069 [Oxoid Ltd., Hampshire, England] and Peptone Water-CM0009 [Oxoid Ltd., Hampshire, England] were prepared according to the manufacturer's instructions and sterilized at 121 ^{O}C for 15 min.

Enumeration of total and faecal coliform

The samples were shaken vigorously and area around the top of the bottle was wiped with clean tissue soaked with 70% ethanol. Samples were diluted serially in sterile phosphate-buffered saline (pH 7.3) to the 10^{-2} dilution. Two duplicate of each serially diluted sample were plated on Eosin Methylene Blue agar. The plates were inverted and incubated at 37 ^{O}C for 24 hrs to observe for TC and the other plates were incubated at 44 ^{O}C for 24 hrs to observe for FC. All pink, purple, black and green metallic sheen colonies were counted and an average of duplicate samples were recorded as TC and FC counts/ml (cfu/ml), respectively for the sample.

Identification and enumeration of E. coli.

Each of the presumptive colonies (green metallic sheen colonies on the FC plates) were sub-cultured in 10 ml of peptone water for biochemical testing. Each colony was grown in peptone water and incubated at 44 ^{O}C for 24 hrs. A drop of Kovac's reagent was added to the tube of peptone water. All the tubes showing a red ring colour development after gentle agitation indicated the presence of indole and recorded as a confirmation of *E. coli.* All colonies of that morphological type were enumerated.

Data Analysis

The data obtained after laboratory procedures were subjected to statistical analysis using Microsoft Word (2010) and Microsoft Excel (2010) for tabular and graphical presentations. Excel together with Statistical Package for Social Sciences (SPSS), version 21 was also used for statistical analyses. Data values on water parameters were compared with standard values of the Ghana EPA.

The choice of data analysis depends on the way the data were collected. Experimental designs such as the completely randomized design and analysis of variance (ANOVA). In these classical designs, replicates are usually equal, in other words, the sample sizes are equal for all treatments. Therefore, in order to assess whether the levels of physical and chemical parameters of the stabilization pond Kruskal-Wallis test was also used to test for significant differences in the parameters across the ponds and months. The use of this test was occasioned by the fact that the values came from independent populations with unequal variances and were not normally distributed (Bluman, 2004). Pearson Correlation was employed to establish the relationship between quality of the wastewater from the stabilization pond, using the SPSS software and Microsoft Excel. The values obtained were used to evaluate the efficiency of the waste stabilization system.

CHAPTER FOUR

RESULTS

Introduction

Results obtained from the treatment process monitoring and performance evaluation analysis of the Waste Stabilization Pond at the Cape Coast Teaching Hospital in the Central Region of Ghana are presented in this chapter. The performance evaluation analysis used the data obtained from the monitoring of the WSP at three different components of the WSP namely; anaerobic, facultative and maturation ponds for six month period (i.e. from November 2016 to April 2017). The data obtained from the monitoring is given in the Appendices of this thesis. All removal efficiency calculations for the period are given in Table 11.

Physical Parameters of Wastewater in the Stabilization Ponds

Table 4 shows the descriptive statistics of physical parameters of wastewater sampled from anaerobic, facultative and maturation ponds. The parameters were measured on monthly basis over a period of six months at the waste stabilization ponds (WSP). The physical parameters measured included pH, temperature, conductivity, total dissolved solids, total suspended solids and turbidity.

pH

The Mean pH values recorded throughout the study period ranged from 7.12 to 8.11 with an average of 7.72 (Table 4). Generally, pond 1C recorded the lowest value in November 2016 and pond 3C recorded the highest value. It was negatively skewed that showed a symmetric distribution and had a negative kurtosis. ANOVA test for mean showed significant difference among the three stages of the ponds (p <0.05).

Conductivity

In terms of conductivity, the mean recorded was 1693.2 µS/cm. The minimum and maximum conductivity values also ranged from 716 µS/cm to 2320 µS/cm for the six months long study (Table 4). Pond 1A recorded the lowest value in November 2016 and the same pond recorded the highest value in December 2016. The distribution of conductivity during the study showed negative skewness with a positive kurtosis value of .445. The conductivity levels of the three ponds revealed no significant variation (p >0.05) in the treatments.

Total Dissolved Solids

Total dissolved solids concentrations ranged from 394 to 1153 mg/l with mean total dissolved solids value of 848.3 mg/l (Table 4). Generally the lowest value was recorded in pond 1A in November 2016 and the highest in the same pond in December 2016. TDS also showed a negative skewness with a positive kurtosis value of .312. ANOVA test of difference among means showed that, total dissolved solids readings recorded in the three stages of the pond appeared to be the same (p > 0.05).

Total Suspended Solids

Regarding the total suspended solids (TSS), the mean recorded was 96.06mg/l. The minimum and maximum TSS values were 0 to 578 mg/l for the six months long study (Table 4). Pond 3A, in December 2016, recorded the lowest value while pond 1A, in January 2017, recorded the highest value. The TSS levels of the three ponds revealed a significant variation ($p < 0.05$) in the treatments. TSS was right skewed and had a positive value greater of 2.907 and also a positive kurtosis value of 10.718.

Table 4: *Physical Parameters of the Wastewater Samples from Stabilization Pond.*

Parameter	Mean	Skewness	Kurtosis	Minimum	Maximum
pH	7.7254	-.782	-.176	7.12	8.11
Temperature	26.254	-.013	.771	23.7	28.1
Conductivity	1693.22	-.608	.445	716	2320
TDS	848.26	-.615	.312	394	1153
TSS	96.06	2.907	10.718	0	578
Turbidity	107.37	1.991	5.024	30	397

Source: Analysed data from the laboratory, November 2016-April, 2017.

Temperature

The minimum and maximum temperature values ranged from 23.7 to 28.1 ^{O}C with mean value of 26.2 ^{O}C. Temperature recorded fluctuated over the study period (Figure 4). Peak and the lowest temperatures were recorded in pond 3A in December 2016 and pond 1A in February 2017, respectively. Temperature was negatively skewed and had a positive kurtosis value of (.771). Test of difference among the mean temperature values of the three ponds however showed significant difference among the various treatments of the pond ($p>0.05$).

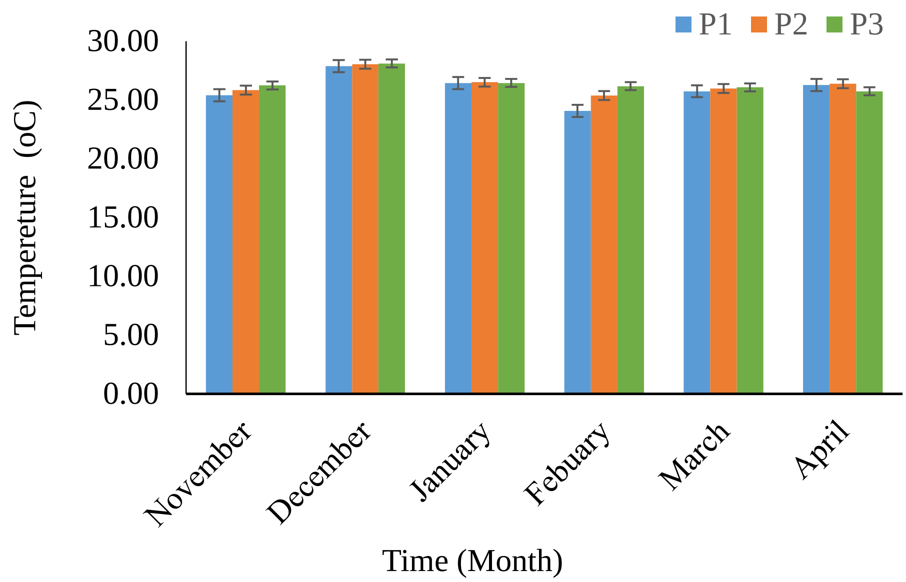

Figure 4: Mean Temperature values recorded over a six month period at waste stabilization pond.

Turbidity

Turbidity values ranged from 30 to 397 NTU with mean recorded of 107.37 NTU. Turbidity values recorded fluctuated over the study period as the highest value was recorded in pond 1B in November and the lowest in pond 3B in December 2016 (Figure 6). Test of difference among the mean temperature values of the three ponds however showed significant difference among the various treatment of the pond ($p < 0.05$). Turbidity was right skewed and had a positive value of 1.991 and also a positive kurtosis value of 5.024.

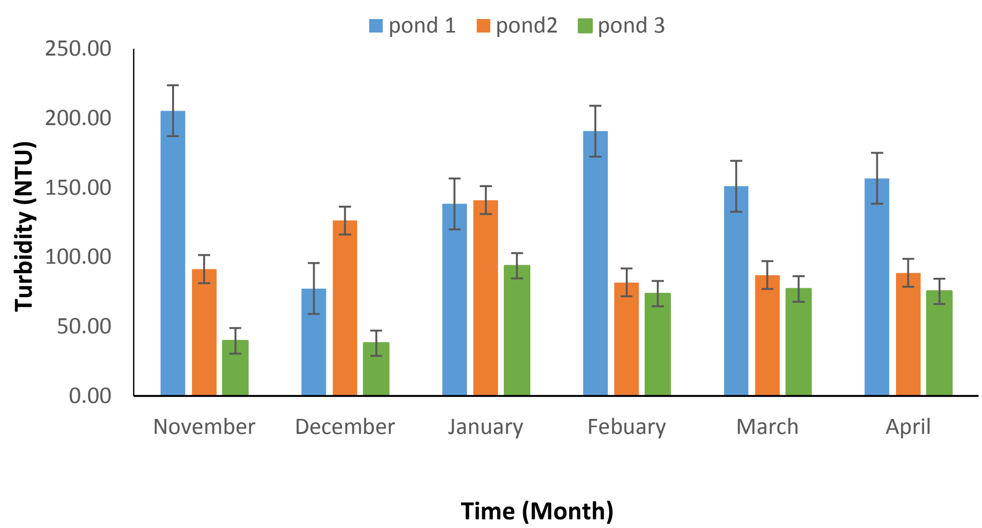

Figure 5: *Mean Turbidity values recorded over a six month period.*

Chemical Parameters of Wastewater in the Stabilization Ponds

Dissolved Oxygen (DO)

The dissolved oxygen levels ranged from 0.20 to 3.25 mg/l with a mean of 1.16 mg/l (Table 5). The highest value was recorded in pond 3B and the lowest in pond 1B in December 2016. ANOVA test of difference among means showed that, dissolved oxygen readings recorded in the three stages of the pond appeared not to be significant ($p > 0.05$). The values recorded for DO was right skewed and had a positive value of 1.020 and also a negative kurtosis value (-.053).

Biological Oxygen Demand (BOD)

BOD levels ranged from 0.03 to 3.25 mg/l with a mean load of 0.60 mg/l for the six months long study (Table 5). The highest value recorded was in pond 3B in December 2016 as the lowest value recorded was in pond 1B in November 2016. The BOD levels of the three ponds revealed no significant variation ($p >$

0.05) in the treatments. BOD was right skewed and had a positive value of 2.244 and also a positive kurtosis value of 4.322.

Ammonia

The ammonia concentration ranged from 0.001 to 0.686 mg/l with a mean value of 0.172 mg/l for the study period (Table 5). The highest ammonia value was recorded in pond 3C in February 2017 and the lowest was in pond 1A in November 2016. ANOVA test of difference among means showed that, ammonia readings recorded in the three stages of the pond appeared not to be significant ($p > 0.05$). In terms of distribution ammonia had a positive value that was right skewed and also had a positive value for kurtosis (.181).

Phosphorus

The phosphorus concentration of ranged from 0.001 to 0.114 mg/l with a mean concentration of 0.031 mg/l for stabilization pond for the six period (Table 5). Phosphorus recorded the highest value in pond 3B in February 2017 and the lowest in pond 1B in November 2016. The variations across the ponds were not significant as the ($p > 0.05$). Phosphorus had a positive value (1.479) that was right skewed and also had a positive value for kurtosis (1.311).

Chloride

Chloride concentration ranged from 107.8 to 377.8 mg/l with a total chloride concentration mean of 244.5 mg/l for the pond during the study period (Table 5). The mean chloride concentration test of difference among means showed that, chloride readings recorded in the three stages of the pond appeared not to be significant ($p > 0.05$). Generally the highest value of chloride was recorded in pond 1A in December 2016 and the lowest also in the same pond in

March 2017. The distribution of chloride showed a negative skewness and a positive kurtosis value of .605.

Nitrate

The minimum and maximum nitrate values ranged from 0.005 to 8.97 mg/l with mean recorded at 1.54 mg/l. Nitrate recordings fluctuated over the study period (Table 5). The highest value was recorded in pond 3C in December 2016 and the lowest was in pond 1A in November 2016. The mean nitrate values of the three ponds, however showed no significant difference among the various treatment stages of the pond ($p > 0.05$). Nitrate had a positive value (1.993) that was right skewed and also had a positive value for kurtosis (2.624).

Sulphate

Considering the sulphate concentration, the minimum value recorded was 1.02 mg/l and the maximum value was 44.3 mg/l while the mean value was 11.6 mg/l (Table 5). Throughout the study period sulphate concentrations fluctuated. It recorded the highest value in pond 3A in December 2016 and the lowest in pond 2B November 2016. ANOVA test of difference among means showed that, sulphate readings recorded in the three stages of the pond appeared not to be significant ($p > 0.05$). Sulphate had a positive value (1.570) that was right skewed and also had a positive value for kurtosis (1.992).

Calcium

Calcium level in the wastewater generally ranged from 18 to 40mg/l while the mean value was 28.5 mg/l with respect to monthly variations for the study period (Table 5). Throughout the study, pond 1C in January 2017 recorded the highest value as pond 1A also recorded the lowest value in February 2017. The mean calcium values recorded in the three stages of the pond indicated that, there were no significant difference ($p > 0.05$). The values of calcium showed a right skewness and a negative kurtosis value of -.801.

Magnesium

Magnesium concentration ranged from 7.3 to 15.7 mg/l with a total magnesium concentration mean of 10.7 mg/l for the pond during the study period (Table 5). As the highest value was recorded in pond 1C in March 2017 and the lowest in pond 1A in February 2017. The mean magnesium readings recorded in the three stages of the pond appeared not to be significant ($p > 0.05$). Magnesium had a positive value of .655 that was right skewed and also had a positive value for kurtosis (.113).

Table 5: *Chemical Parameters of the Wastewater Samples from Stabilization Pond.*

Parameter	Mean	Skewness	Kurtosis	Minimum	Maximum
NH_3	.172759	1.315	.181	.0010	.6860
Cl	244.599444	-.969	.605	107.8800	377.8800
NO_3-N	1.546722	1.993	2.624	.0050	8.9700
PO_4	.031815	1.479	1.311	.0010	.1140
SO_4	11.654204	1.570	1.992	1.0250	44.3500
DO	1.164259	1.020	-.053	.2000	3.2500
COD	73.1313	.939	-.140	56.88	107.44
BOD	.602593	2.244	4.322	.0300	3.2500
Ca	28.497222	.351	-.801	18.3500	40.0000
Mg	10.725556	.655	.113	7.3400	15.7100

Source: Analysed data from the laboratory, November 2016-April, 2017.

Chemical Oxygen Demand (COD)

The COD levels ranged from 56.88 to 107.44 mg/l with a mean value 73.13 mg/l for the six month period. The test of differences among the COD levels of the three ponds indicated a significant variation ($p < 0.05$). COD levels fluctuated over the study period (Figure 5) as the highest value was recorded in November 2016 in the pond 2B and the lowest in pond 1A in February 2017. COD had a positive skewness value of .939 and had a negative kurtosis (-.140).

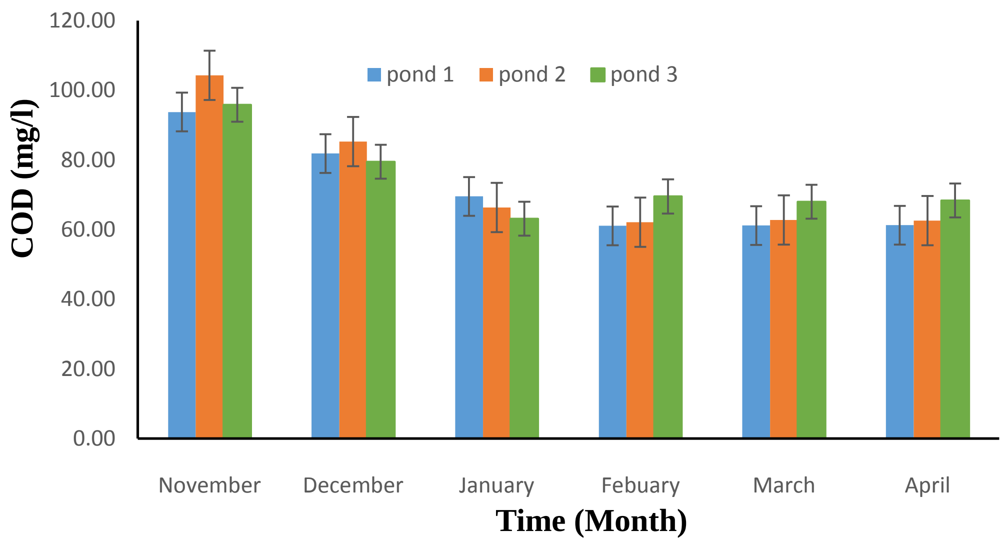

Figure 6: Mean Chemical Oxygen Demand (COD) values recorded over a six month period.

Heavy Metal concentrations in the Stabilization Ponds

Iron

The iron values of the wastewater measured ranged from 0.063 to 1.34 mg/l as the total iron concentration mean of the wastewater was 0.30 mg/l for the six month period (Table 6). The minimum value was recorded in pond 2B in December 2016 and the maximum value was also recorded in pond 1B in January

2017. The mean iron values of the three ponds however showed significant difference among the various treatment of the pond ($p < 0.05$). Iron had a positive value of 2.406 that was right skewed and also had a positive value for kurtosis (5.143).

Manganese

Regarding manganese content measured in the wastewater, it was realised that the minimum value recorded was 0.007 mg/l in pond 2B in November 2016 and the maximum was 1.68 mg/l in pond 1B in December 2016 as the overall mean was 0.09 mg/l (Table 6). The test of ANOVA among the means of manganese in the three ponds were significant ($p < 0.001$). Manganese had a positive value (6.247) that was right skewed and also had a positive value for kurtosis (42.113).

Lead

The lead values of the wastewater measured ranged from 0.001 to 0.015 mg/l as the total lead concentration mean of the wastewater was 0.001 mg/l for the six month period (Table 6). The minimum value was recorded almost in the various ponds except pond 3C which recorded the highest value in November 2016. The mean lead values of the three ponds however did not indicate any significant difference among the various treatment of the pond ($p>0.05$). Lead had a positive value (4.705) that was right skewed and also had a positive value for kurtosis (23.588).

Cadmium

Cadmium values of the wastewater measured from the stabilization pond ranged from 0.002 mg/l to 0.006 mg/l as the total cadmium concentration mean of the wastewater was 0.003 mg/l for the six month period (Table 6). Generally, Pond 3 recorded the minimum value throughout the study and the maximum was recorded in pond 1B in November and December 2016. The mean cadmium values of the three ponds however did not show any significant difference among the various treatment of the pond ($p > 0.05$). Calcium had a positive value (.888) that was right skewed and also had a positive value for kurtosis (.263).

Mercury

Mercury values in the wastewater measured from the stabilization pond ranged from 0.002 to 0.008 mg/l as the mean total mercury concentration of the wastewater was 0.005 mg/l for the six month period (Table 6). Pond 1B recorded the maximum value in December 2016 and the minimum value was recorded in pond 2C in November 2016. The mean mercury values of the three ponds did not show any significant difference among the various treatments of the pond ($p > 0.05$). The values of mercury showed a right skewness and a negative kurtosis value (-.452).

Table 6: *Heavy metals of Wastewater Samples from Stabilization Pond.*

Parameter	Mean	Skewness	Kurtosis	Minimum	Maximum
Fe	.300222	2.406	5.143	.0630	1.3400
Mn	.093944	6.247	42.113	.0070	1.6800
Pb	.001630	4.705	23.588	.0010	.0150
Cd	.003056	.888	.263	.0020	.0060
Hg	.005130	-.452	.885	.0020	.0080

Source: Analysed data from the laboratory, November 2016-April, 2017.

Microbial Loading in Hospital Waste Stabilization Ponds

Faecal coliform

The faecal coliform is one of the parameters that is very important in the wastewater treatment as the recorded values ranged from 0.00 to 41000 CFU/100ml and recorded a total mean of 9896.30 CFU/100ml for the study period (Table 7). In December 2016, the lowest value was recorded in pond 1B and pond 3A also recorded the highest value in March 2017. The mean faecal coliform values of the three ponds did not show any significant difference among the various treatments of the pond ($p < 0.001$). Faecal coliform had a positive value (1.503) that was right skewed and also had a positive value for kurtosis (2.739).

Total coliform

Total coliform is one of the parameters that is very important in wastewater treatment as the recorded values ranged from 0.00 to 67000 CFU/100 ml and recorded a total mean of 10318.52 CFU/100 ml for the study period (Table 7). The mean total coliform values of the three ponds did not show any significant difference among the various treatments of the pond ($p > 0.05$). Pond 1A and 1B recorded low concentration in December 2016 and March 2017. However, the higher concentration was recorded in pond 2B in March 2017. Total coliform had a positive value (3.333) that was right skewed and also had a positive value for kurtosis (17.041).

Escherichia coli

Value of *escherichia coli* in the wastewater treatment plant ranged from 0.00 to 5200 CFU/100 ml with a total mean of 1485.19 CFU/100 ml for the study period (Table 7). The level of *E. coli* was low in pond 1A and B in December 2016 and also in pond 2B and 2C in March 2017. However, higher concentration was recorded in pond 1A in January 2017. The mean *escherichia coli* values of the three ponds did not show any significant difference among the various treatment of the pond ($p > 0.05$). *E. coli* had a positive value (.992) that was right skewed and also had a positive value for kurtosis (.593).

Table 7: *Microbial load in Wastewater Samples from Stabilization Pond*.

Parameter	Mean	Skewness	Kurtosis	Minimum	Maximum
Fecal Coliform	9896.30	1.503	2.739	0.00	41000
Total Coliform	10318.52	3.333	17.041	0.00	67000
E. coli	1485.19	.992	.593	0.00	5200

Source: Analysed data from the laboratory, November 2016-April, 2017.

Test of Hypothesis

Observing from Table 8 is non-parametric analysis of the data by Krustal-Wallis test. The data is a continuous variable but are not normally distributed based on non- parametric analysis. This is normally employed when the population from which the samples are selected is not normally distributed as well as testing hypothesis that do not involve specific population parameters. (Bluman, 2004).

The pH showed that there were spatial variabilities in the various ponds implying that, in the individual ponds pH varied throughout the study period. TSS indicated spatial variability in the individual ponds throughout the six month period. Considering turbidity, it was released that there were spatial variations of turbidity in the ponds during the period of study. The hypothesis test revealed that ammonia was spatially variable within ponds during the study period. Nitrate is one of the parameters that also showed a spatial variability for the six month period. More so, chloride showed spatial variability in the ponds during the study. Again, phosphate showed a spatial variability in the individual pond in the six month. The analysis conducted showed spatial variability of sulphate in the various ponds of treatment. Lastly, manganese and cadmium also showed spatial variability in the various ponds. However, temperature, conductivity, total suspended solids, dissolved oxygen, chemical oxygen demand, biological oxygen demand, iron, calcium, magnesium, lead, chromium, mercury, faecal coliform, total coliform and *Escherichia coli* did not show spatial variability in the various ponds.

Table 8: *Non-parametric test showing the spatial variability of the parameters.*

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of pH is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
2	The distribution of TEMPERATURE is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.296	Retain the null hypothesis.
3	The distribution of CONDUCTIVITY is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.096	Retain the null hypothesis.
4	The distribution of TOTAL DISSOLVED SOLIDS is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.072	Retain the null hypothesis.
5	The distribution of TSS is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
6	The distribution of Turbidity is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.002	Reject the null hypothesis.
7	The distribution of NH3 is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
8	The distribution of Cl is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.012	Reject the null hypothesis.
9	The distribution of NO3-N is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
10	The distribution of PO4 is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 8: continued

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of SO4 is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
12	The distribution of DO is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.146	Retain the null hypothesis.
13	The distribution of COD is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.367	Retain the null hypothesis.
14	The distribution of BOD is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.106	Retain the null hypothesis.
15	The distribution of Fe is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.271	Retain the null hypothesis.
16	The distribution of Mn is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
17	The distribution of Ca is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.798	Retain the null hypothesis.
18	The distribution of Mg is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.375	Retain the null hypothesis.
19	The distribution of Pb is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.060	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 8*: continued*

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
20	The distribution of Cr is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	1.000	Retain the null hypothesis.
21	The distribution of Cd is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
22	The distribution of Hg is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.316	Retain the null hypothesis.
23	The distribution of Fecal Coliform is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.562	Retain the null hypothesis.
24	The distribution of Total Coliform is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.076	Retain the null hypothesis.
25	The distribution of E. coli is the same across categories of Pond_number.	Independent-Samples Kruskal-Wallis Test	.081	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

The monthly variability of the hypothesis test shows how the parameters concentrations varied during the month**.** During the study period, pH showed temporal variability. Temperature values also indicated temporal variability in the months of the study. Conductivity also showed temporal variability in the months. In respect of total suspended solids, temporal variability in the months were detected during the study. Dissolved oxygen also showed a temporal variability in the month during the study period. Chemical oxygen demand showed monthly temporal variability for the six months. In terms of the biological oxygen demand, a temporal variability was shown monthly during the study. Relating to manganese, a temporal variability was shown in the months for the study period. Calcium also indicated a temporal variability in the months during the study period. Considering magnesium, temporal variability was shown. Lead values of the pond also showed temporal variability in the months. Mercury concentration showed temporal variability in months during the study period. Furthermore, faecal coliform and total coliform values showed temporal variability in the months of the period of the study. More so, total suspended solids, turbidity, ammonia, chloride, nitrate, phosphate, sulphate, iron, chromium, cadmium and *escherichia coli* were not temporal variable within the months during the study period (Table 9).

Table 9: *Non-parametric test showing the temporal variability of the parameters in the ponds.*

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of pH is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.030	Reject the null hypothesis.
2	The distribution of TEMPERATURE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
3	The distribution of CONDUCTIVITY is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
4	The distribution of TOTAL DISSOLVED SOLIDS is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
5	The distribution of TSS is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.099	Retain the null hypothesis.
6	The distribution of Turbidity is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.273	Retain the null hypothesis.
7	The distribution of NH3 is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.734	Retain the null hypothesis.
8	The distribution of Cl is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.140	Retain the null hypothesis.
9	The distribution of NO3-N is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.993	Retain the null hypothesis.
10	The distribution of PO4 is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.086	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 9: *Continued*

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The distribution of SO4 is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.602	Retain the null hypothesis.
12	The distribution of DO is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.002	Reject the null hypothesis.
13	The distribution of COD is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
14	The distribution of BOD is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
15	The distribution of Fe is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.118	Retain the null hypothesis.
16	The distribution of Mn is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
17	The distribution of Ca is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.010	Reject the null hypothesis.
18	The distribution of Mg is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.012	Reject the null hypothesis.
19	The distribution of Pb is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.002	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 9*: Continued*

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
20	The distribution of Cr is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	1.000	Retain the null hypothesis.
21	The distribution of Cd is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.602	Retain the null hypothesis.
22	The distribution of Hg is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.029	Reject the null hypothesis.
23	The distribution of Fecal Coliform is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
24	The distribution of Total Coliform is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.005	Reject the null hypothesis.
25	The distribution of E. coli is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.129	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Correlation Coefficient Analysis

The correlation coefficient for the parameters are presented in Table 10. Correlation relationship usually gives good information on the source and the direction of the relationship as well as the strength and weakness. Correlation is a measure of degree of linear relationship between two variables. It expresses the extent to which two variables vary together in same directions or opposite directions. Correlation coefficients reveal the magnitude and direction of the relationships (Khambete & Christian, 2014). A correlation has value ranging from -1 to 1 and good correlation normally ranks from 0.5 and above which are in bold face. Values that are closer to the absolute value 1 indicate that there is a strong positive linear relationship between the variables being correlated, whereas values closer to 0 indicate that there is no liner relationship between two variables under study. Total dissolved solids had a significant positive correlation with conductivity in the ponds which indicates a strong relation. Chloride correlated strongly with total dissolved solids and conductivity. Turbidity had a strong correlation with total suspended solids as nitrate with ammonia. Again, phosphorus correlated with ammonia as sulphate also correlated with ammonia, nitrate and phosphorus significantly. Biological oxygen demand correlated strongly with dissolved oxygen and temperature. Calcium had a correlation with both dissolved oxygen and manganese. Also, lead correlated with nitrate as magnesium with calcium significantly and total coliform with faecal coliform. The above parameters depict relationships which show the same source as the correlate with each other. However, turbidity inversely correlated strongly with pH as cadmium with ammonia which indicate a negative correlation. There was no variability of chromium in the various ponds because of that it was removed from the correlation coefficient table below.

Table 10: *Relationship between Physico-chemical parameters in the Stabilization Ponds.*

	pH	Temp	EC	TDS	TSS	Turb	NH_3	Cl	NO_3	PO_4	SO_4	DO	COD	BOD	Fe	Mn	Ca	Mg	Pb	Cd	Hg
pH	1																				
Temp	-0.191	1																			
EC	0.153	.405**	1																		
TDS	0.158	.394**	.999**	1																	
TSS	-.421**	-.311*	-.274*	-.284*	1																
Turb	-.643**	-.320*	-0.255	-0.262	.745**	1															
NH_3	.426**	0.13	-0.036	-0.041	-.339*	-.391**	1														
Cl	.272*	0.2	.660**	.668**	-.304*	-.281*	0.201	1													
NO_3-N	.387**	0.116	-0.009	-0.014	-0.262	-.290*	.873**	0.135	1												
PO_4	.393**	0.035	0.003	-0.006	-0.221	-.300*	.524**	.315*	0.241	1											
SO_4	.270*	0.157	-0.062	-0.074	-0.183	-.271*	.597**	0.108	.528**	.592**	1										
DO	0.17	.448**	0.234	0.221	-.403**	-.380**	0.206	-0.044	0.192	0.143	0.218	1									
COD	-0.19	0.249	-.314*	-.316*	-0.262	-0.155	0.076	-0.237	0.049	-0.161	-0.114	.309*	1								
BOD	-0.1	.661**	.277*	0.262	-.316*	-0.241	0.179	0.028	0.153	0.139	0.219	.837**	0.238	1							
Fe	-.298*	-.279*	0.089	0.096	.434**	.495**	-0.236	0.096	-.287*	0.049	-0.209	-0.175	-0.184	-0.171	1						
Mn	-.351**	.372**	0.221	0.218	-0.053	-0.03	-0.152	0.09	-0.113	-0.124	-0.134	-0.036	0.097	0.119	-0.105	1					
Ca	0.001	.401**	0.163	0.163	-.484**	-.415**	-0.003	0.19	-0.018	-0.113	-0.044	.516**	.383**	.433**	-0.215	0.243	1				
Mg	0.076	.307*	0.208	0.213	-.482**	-.419**	-0.071	0.204	-0.075	-0.127	-0.113	.395**	0.198	.365**	-0.187	.277*	.932**	1			
Pb	-0.005	0.221	-0.137	-0.143	-0.213	-0.247	.460**	-0.126	.518**	-0.011	0.21	.316*	.325*	0.251	-0.154	-0.014	0.212	0.102	1		
Cd	-.468**	0.002	0.054	0.055	0.188	.366**	-.517**	-0.094	-.403**	-.448**	-.440**	-0.09	0.043	0.017	0.056	.510**	.282*	.349**	-0.238	1	
Hg	-0.088	-0.006	0.11	0.112	0.038	0.072	0.161	.354**	0.13	.274*	0.041	-0.254	-.377**	-0.114	0.208	.365**	-0.029	0.004	0.102	0.202	1
Fecal coli	0.125	-.273*	0.006	0.012	0.227	0.152	0.027	0.01	-0.011	0.103	0.057	-0.257	-.444**	-0.266	0.238	-0.204	-.275*	-0.153	-0.216	-0.006	0.028

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Efficiency of Cape Coast Regional Hospital Waste Stabilization Pond

Removal Efficiency of Physical Parameters

pH

pH influent samples analysed ranged from 7.12 to 7.99 with a mean value of 7.54. The effluent wastewater ranged from 7.65 to 8.11 and with a mean pH of 7.90. Table 11 is mean influent and mean effluent pH results of waste stabilization ponds and the Ghana EPA guidelines.

Temperature

The temperature of the raw sewage to the stabilization pond ranged from 23.73 to 28.00 ^{O}C with a mean of 25.96 ^{O}C, whilst the final effluent temperature ranged from 25.60 to 28.10 ^{O}C and the mean temperature was 26.46 ^{0}C indicating a slight drop compared to the influent temperature (Table 11).

Conductivity

The conductivity of the stabilization pond influent ranged from 716.0 to 2320 µS/cm with a mean of 1597.3 µS/cm. The conductivity of the final effluent was also between 1304.0 and 2140.0 µS/cm with a mean of 1682.9 µS/cm. The mean conductivity values for both the influent and the effluent were high. Table 11 is the mean influent and effluent conductivity results of the waste stabilization pond and Ghana EPA guideline values.

Turbidity

The influent turbidity values were between 58.00 and 397 NTU and the mean was 153.22 NTU. The final effluent turbidity ranged from 30.00 to 102.00 NTU with a mean of 66.22 NTU. The mean overall turbidity removal efficiency of the treatment ponds was 56.78%. Table 11 is the mean influent and effluent turbidity results and the EPA Ghana guidelines.

Total Dissolved Solids (TDS)

The TDS concentration of the influent wastewater ranged from 394.00 to 1153.00 mg/l with a mean value of 801.33 mg/l. The TDS levels of the final effluent ranged from 660.00 to 1067.00 mg/l with a mean of 841.33 mg/l. The mean overall TDS removal efficiency was calculated as -4.99%. The TDS results from the study were all low. Table 11 shows the mean influent and effluent and EPA Ghana guideline.

Total Suspended Solids

A mean value of 163.67 mg/l of influent rich in TSS was received into the waste stabilization ponds with levels ranging from 14.00 to 578.00 mg/l. The TSS of the treated effluent ranged from 0.00 to 69.00 mg/l with a mean value of 45.89 mg/l. The mean overall removal efficiency of the pond system was 71.96%. Table 11 shows the mean influent and the mean effluent of the stabilization pond and the Ghana EPA guideline values.

Biological Oxygen Demand (BOD)

The influent BOD levels ranged from 0.03 to 2.84 mg/l with a mean load of 0.50 mg/l whilst a mean load of 0.82 mg/l was discharged in the final effluent. The BOD levels of the effluent ranged from 0.18 to 3.25 mg/l as depicted in (Table 11). The mean overall BOD removal efficiency was -64.78%.

Chemical Oxygen Demand (COD)

The COD levels of the influent wastewater ranged from 56.88 to 97.96 mg/l with a mean value 71.44 mg/l, whilst the final effluent COD ranged from

56.88 to 97.96 mg/l with a mean value of 74.06 mg/l. The mean overall removal efficiency was -3.66% as shown in (Table 11).

Dissolved Oxygen (DO)

Dissolved oxygen for the influent ranged from 0.20 to 2.84mg/l and the mean was 1.09mg/l, while the range of the effluent was between 0.51 mg/l and 3.25 mg/l and the mean was 1.48mg/l for the six month period. The final effluent was slightly higher than the influent and the efficiency was -36.39 % in the Table 11.

Removal Efficiency of Chemical

Effluents with high nutrient levels can cause undesirable phytoplankton growth in the receiving water body. The study considered nitrate, ammonia, and phosphate concentrations to assess the nutrient content of the influent and effluent wastewater of the stabilization pond.

Nitrate

The mean influent concentration of nitrate was 0.03 mg/l and the nitrate levels ranged from 0.01 to 0.06mg/l. The effluent concentration of nitrate ranged from 0.54 to 8.97mg/l with a mean effluent concentration of 4.31 mg/l. The removal efficiency and Ghana EPA guideline in Table 11.

Ammonia

Free ammonia is formed as an initial product due to the decomposition of nitrogenous organic matter. The ammonia concentrations of the influent were between 0.00 and 0.02 mg/l with a mean value of 0.01 mg/l. The final effluent concentrations ranged from 0.05 to 0.69 mg/l with a mean concentration of 0.45

mg/l, this is slightly lower. Table 11 is the removal efficiency with the Ghana EPA guideline.

Phosphorus

The phosphate concentration of the influent ranged from 0.00 to 0.03 mg/l with a mean concentration of 0.02 mg/l whilst concentrations ranging from 0.02 to 0.11 mg/l with a mean value of 0.07 mg/l of the final effluent. The mean phosphate concentration of the final effluent was 0.07 mg/l. Table 11 is the removal efficiency with the Ghana EPA guideline.

Calcium

The calcium concentration of the influent ranged between 18.35 to 40.00 mg/l with a mean of 28.31mg/l, whilst the effluent ranged from 24.00 to 38.90 mg/l. The effluent mean for calcium during the study period was 28.50 Table 11. The calcium concentration was found to be lower and the efficiency removal was -0.65%.

Chloride

Chloride level of the wastewater influent range was from 107.88 to 377.88 mg/l with a mean of 213.85 mg/l and the effluent range was between 177.05 to 337.24 mg/l while the mean was 269.00 mg/l during the study period and overall efficiency removal was -25.79%. Table 11 is the results and the Ghana EPA guideline.

Sulphate

The concentration of sulphate for the influent ranged between 2.01 and 14.22 mg/l and the mean was 7.40. The effluent also ranged from 11.35 to 44.35

mg/l while the mean was 23.29 mg/l during the six month period. Sulphate concentration for the study period were low and removal efficiency was -214.01% as shown in Table 11.

Magnesium

Magnesium concentrations for the influent ranged from 7.34 to 15.71 mg/l with a mean of 10.83 mg/l, while the effluent also ranged from 8.75 to 13.99 mg/l and the mean value was 10.45 mg/l for the study period (Table 11). Magnesium values were high and the overall removal efficiency was 3.55%.

Removal Efficiency of Biological Parameters

Total Coliform (TC), Faecal Coliform (FC) and Escherichia Coli (E. coli)

The total coliform levels of the initial influent were between 0 and 26700 cfu/100 ml with a mean of 10133 cfu/100 ml while those of the final effluent were between 0 and 16500 cfu/100 ml with a mean of 6640 cfu/100 ml. The mean total coliform removal efficiency was determined to be 34.48% (Table 11).

The faecal coliform levels of the influent ranged from 0.00 to 29700 cfu/100 ml with a mean value of 10977 cfu /100 ml, while the faecal coliform levels of the final effluent range from 700 to 41000 cfu/100 ml with a mean of 9910 cfu/100 ml. The mean faecal coliform removal efficiency was 9.77% (Table 11).

The influent *E. coli* levels ranged between 0.00 and 5200 cfu/100 ml with mean value of 1888 cfu/100 ml, while the *E. coli* count of the final effluent range from 0.00 to 3000 cfu/100 ml with a mean of 878 cfu/100 ml. The mean overall *E. coli* removal efficiency was 53.53% in Table 11.

Table 11: *Removal efficiency of physical, chemical and biological parameters of wastewater from stabilization ponds.*

PARAMETER		INFLUENT			EFFLUENT			REMOVAL (%)	Ghana EPA STANDARD
	Unit	Mean ± SE	Min	Max	Mean ± SE	Min	Max		
pH		7.54 ± .07	7.12	7.99	7.90 ± .03	7.65	8.11		6.0 - 9.0
Temp	^{0}C	25.96 ± .28	23.70	28.00	26.46 ± .19	25.60	28.10		< 3 ^{O}C above ambient
Conductivity	µS/cm	1597.33± 110.48	716.00	2320.00	1682.94±58.16	1304.00	2140.00	-5.36	1500
TDS	mg/l	801.33 ± 53.75	394.00	1153.00	841.33 ± 28.05	660.00	1067.00	-4.99	1000
TSS	mg/l	163.67 ± 34.14	14.00	578.00	45.89 ± 5.66	0.00	69.00	71.96	50
Turbidity	NTU	153.22 ± 21.95	58.00	397.00	66.22 ± 5.08	30.00	102.00	56.78	75
NH_3	mg/l	0.01 ± .00	0.00	0.02	0.45 ± .05	0.05	0.69	-5210.39	1
Cl	mg/l	213.85 ± 18.91	107.88	377.88	269.00 ± 8.86	177.05	337.24	-25.79	250
NO_3N	mg/l	0.03 ± .00	0.01	0.06	4.31 ± .84	0.54	8.97	-15650.10	50
PO_4	mg/l	0.02 ± .00	0.00	0.03	0.07 ± .01	0.02	0.11	-268.01	10
SO_4	mg/l	7.40 ± .98	2.01	14.22	23.29 ± 2.44	11.35	44.35	-214.68	300
DO	mg/l	1.09 ± .19	0.20	2.84	1.48 ± .22	0.51	3.25	-36.39	
COD	mg/l	71.44 ± 3.11	56.88	97.96	74.06 ± 2.71	56.88	97.96	-3.66	250
BOD	mg/l	0.50 ± .16	0.03	2.84	0.82 ± .25	0.18	3.25	-64.78	50
Ca	mg/l	28.31 ± 1.96	18.35	40.00	28.50 ± 1.27	24.00	38.90	-0.65	200
Mg	mg/l	10.83 ± .72	7.34	15.71	10.45 ± .35	8.75	13.99	3.55	<1.0
TC	cfu/100ml	10133 ± 2033.33	0.00	26700	6640 ± 1123.17	0.00	16500	34.65	400
FC	cfu/100ml	10977 ± 1874.33	0.00	29700	9910 ± 2434.70	700	41000	9.77	400
E. coli	cfu/100ml	1888 ± 404.94	0.00	5200	878 ± 209.19	0.00	3000	53.53	10

Source: Analysed data from the laboratory, November 2016-April, 2017.

Removal Efficiency of heavy metal in the wastewater

The mean concentrations of heavy metal in the influent were 0.04, 0.001, 0.18, <0.002, <0.001 and 0.01 mg/l for Mn, Cd, Fe, Pb, Cr and Hg, respectively. The mean concentrations of heavy metal in the ponds were 0.18, <0.001, 0.48, <0.002, <0.001 and 0.01 mg/l for Mn, Cd, Fe, Pb, Cr and Hg, respectively. The composition of heavy metals in the wastewater ranged from 0.04 to 0.18 mg/l for Mn, 0 to <0.001 mg/l for Cd, 0.18 to 0.48 mg/l for Fe, <0.001 to <0.001 mg/l for Pb, <0.002 to <0.002 mg/l for Cr and 0.004 to 0.01 for Hg. Overall, heavy metal concentrations in the final effluent were in the following order: Fe > Mn > Hg > Pb > Cd > Cr as the efficiency removal for iron was 50.58%, manganese 75.35% and cadmium 47.83% in the (Table 12).

Table 12: *Removal efficiency of heavy metal in wastewater by stabilization pond.*

parameter		influent			Effluent			Removal (%)	GH EPA guideline
	Unit	Mean ± SE	Min	Max	Mean ± SE	Min	Max		
Fe	mg/l	0.48±.11	0.07	1.34	0.24±.04	0.08	0.55	50.58	10
Mn	mg/l	0.18±.09	0.02	1.68	0.04±.00	0.01	0.08	75.35	0.1
Pb	mg/l	0.00±.00	0.00	0.00	0.00±.00	0.00	0.02	-157.89	<0.1
Cr	mg/l	0.00±.00	0.00	0.00	0.00±.00	0.00	0.00	0.00	0.1
Cd	mg/l	0.00±.00	0.00	0.01	0.00±.00	0.00	0.00	47.83	<0.1
Hg	mg/l	0.01±.00	0.00	0.01	0.01±.00	0.00	0.01	-4.30	0.005

Source: Analysed data from the laboratory, *November 2016-April, 2017.*

CHAPTER FIVE

DISCUSSION

Introduction

This chapter discusses the findings of this research in context to similar studies in literature. Based on the order in which the results were presented in chapter four on the physicochemical, nutrient, heavy metal and microbial parameters in the stabilization pond, it will help draw conclusions from the findings in relation to objectives set for the research.

After a preliminary descriptive analysis revealed that the values were not drawn from a normally distributed population and the variances were not equal, non-parametric tests were used to analyse the data. The null hypothesis which stipulated all the ponds in terms of levels of physicochemical, nutrient, heavy metal and microbial parameters was assumed to be similar.

pH

The pH of the wastewater from the three ponds varied but not extensively for the six month period. The mean value compared favourably with a similar work done by Beyene and Redaie (2011) in Hawassa University Referral Hospital. The pH values during the study were within Ghana EPA pH range of 6 to 9, which agrees with Tchobanogolous, Burton and Stensel (2003) that the range is suitable for the existence of most biological life as it supports chemical and biological activities. The alkalinity of the effluent may be due to the presence of chemicals in soaps and detergents used for bathing, cleaning and washing from the hospital by Awuah and Abrokwah, (2008). Also, a similar study carried out by

Colmenarejoa et al. (2006) attributed increase in effluent pH compared to influent pH to decrease in dissolved CO_2 concentration through a reduction in the concentration of organic matter due to oxidation during the treatment.

Temperature

Generally, the temperature values recorded during the study revealed that the value of the effluent indicated a slightly drop in the mean influent temperature of the wastewater. The mean effluent temperature was within the EPA Ghana guideline of <3 °C above ambient temperature which ranged between 25.60 °C and 28.10 °C. The study revealed that temperature changes within the stabilization ponds were not statistically significant. Although some decreases were recorded this may have been as a result of the large surface area of the ponds and mixing due to wind velocity caused by trees planted at the embankment of the ponds.

A study conducted by Beyene and Redaie (2011) in Hawassa University Referral Hospital at Ethiopia indicated a decrease in temperature in the final effluent. This may have effect on the efficiency of organic matter removal and photosynthesis by algae. Mostly optimum temperatures for bacterial activities are in the range of 25 °C and 35 °C as ascribed by Tchobanoglous et al. (2003) which revealed that the Cape Coast Teaching Hospital Stabilization Pond supports bacterial activities.

Conductivity

Generally conductivity of wastewater is measured to obtain the ability of the water to conduct electrical current. The mean conductivity values of the stabilization pond influent and the effluent recorded were high and were not satisfactory as compared to the Ghana EPA guideline value. The mean overall removal efficiency was negative and this could be as a result of the effluent value been higher than the influent. However, according to a research conducted by Beyene and Redaie (2011) there was a decrease in the conductivity values of the effluent which had a positive removal percentage in Hawassa University Referral Hospital. The high value may be attributed to high concentrations of dissolved ions present in the raw sewage. However, a similar study conducted by Hodgson (2007) in Akosombo recorded low mean conductivity values. High conductivity indicates the presence of high inorganic dissolved salt such as chloride, sulphate, sodium, calcium and others sources which may come from natural deposition, industrial waste, fertilizer and other sources (Li, Zhou, & Zhao, 2010).

Turbidity

This study revealed that the effluent values were less as compared to the influent. This indicated that the pond was able to reduce the turbidity level in the final stage of treatment of the stabilization. The effluent turbidity was below the limit; hence satisfactory compared to the Ghana EPA guideline value of 75 NTU. Cape Coast Teaching Hospital had efficiency removal of 56.78% as a study conducted by Kagya (2011) reported mean overall turbidity removal efficiency of the treatment ponds of 69.78% at Juapong. Turbidity has a large effect on the penetration of light into the water column and therefore a lower turbidity increases the light effectiveness (Qin, Bliss, Barnes & FitzGerald, 1991; Curtis, Mara & Silva, 1992).

Total Suspended Solids

Considering the total suspended solid values of the pond in this study, the mean influent recorded a high value while the mean effluent recorded a low value. All the TSS concentrations of the samples measured were satisfactory compared to the Ghana EPA guideline. The high TSS concentrations of the influent could be attributed to erosion of the soils nearby and debris washed into the ponds caused by rain water. It could also be due to high nutrients. The overall TSS removal efficiency was 71.96% which was 11% lower as compared to Hodgson (2007) who reported TSS removal of 83.5% in a study at Akosombo, Ghana. Furthermore, studies conducted show TSS removal of 46.0% which was observed in treatment ponds in Akuse by Hodgson which was 25.96% lower than that of Cape Coast Teaching Hospital. A similar study in Hawassa University Referral hospital also recorded favourably similar result as the influent was higher than the effluent (Beyene & Redaie, 2011).

Total Dissolved Solids

The study revealed that the mean total dissolved solids values of the waste stabilization pond influent were lower as compared to the effluent. The measured concentration was low compared to the EPA guideline of 1000 mg/l and hence satisfactory. TDS is a measurement of inorganic salts, organic matter and other dissolved materials in water. The toxicity of TDS is influenced by increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions.

Kagya (2011), who conducted a study in Juapong on effluent quality of two wastewater treatment systems, also reported a value of 329.0 mg/l in the final effluent discharged into water bodies which was lower than the study at the Cape Coast Teaching Hospital. The efficiency removal was negative and this could be attributed to high concentrations of dissolved inorganic and organic molecules and ions present in the sewage effluent.

Chemical Oxygen Demand (COD)

COD test measures the oxygen demand of oxidizable pollutants of both organic and inorganic materials. The mean COD levels of the wastewater influent recorded was slightly lower than that of the effluent in this study. The mean overall removal efficiency was negative. The higher levels of COD was observed in the effluent compared to the influent of the stabilization as a study conducted by Beyene and Redaie (2011) had COD effluent value lower than the influent at Hawassa University Referral hospital at Ethiopia. Even though it was lower than the Ghana EPA levels of 250mg/l, continuous discharge of high COD effluent level will greatly impact receiving water body to some extent and this may have negative effects on the quality of the freshwater and subsequently cause harm to the aquatic life especially fish (Morrison et al., 2001).

Dissolved Oxygen (DO)

This study recorded a high dissolved oxygen for the influent while the effluent had a lower value for the six month period. The removal efficiency of DO was negative. The results of the level of DO in the final effluent imply that there is an addition of oxygen to the wastewater after treatment; therefore it is safe to discharge it into the receiving water body. The addition of oxygen to the wastewater reflects the name of the oxidation pond sometimes given to waste stabilisation ponds. Statistically, there was no significant difference between the DO levels in the raw sewage (influent) and the treated effluent ($p > 0.05$) as a study conducted by Adu-Ofori, Amfo-Otu and Hodgson (2014) contradicted with this study which showed a significant difference of DO levels at Akosombo waste stabilization pond.

Biological Oxygen Demand (BOD)

Effluents with high concentrations of BOD can cause depletion of natural oxygen resources which may lead to the development of septic conditions (Hodgson, 2000). Low BOD levels were observed in the influent while high effluent levels were also recorded. The BOD levels were favourable compared to the EPA Ghana guideline of 50 mg/l as they were low. Biological oxygen demand (BOD) and chemical oxygen demand (COD) are two of the most important biochemical parameters commonly used to examine wastewater quality since they reflect the organic load in wastewater (Uz, Turak, & Afsar, 2004; Huertasa Salgota, Hollenderb, Weberb & Dottb, 2008). The mean overall BOD removal efficiency was -64.78% was less as compared with other waste stabilization ponds which give BOD removal efficiencies greater than 70% (Arceivala, 1981; Hodgson, 2007). More so, a study conducted by Kagya (2011) at Juapong in the Volta Region of Ghana also reported a low mean load of 17.58 mg/l in the effluent and argued that the result of considerably, small amounts of organic materials available for biodegradation.

Ammonia

Mean ammonia concentration of the influent was lower than the effluent. Wastewaters with high nutrient levels can cause undesirable phytoplankton growth in the receiving water body (Hodgson, 2000). All the ammonia concentrations were less than the Ghana EPA guideline value. The mean ammonia concentration of the final effluent was found to be satisfactory compared to the EPA guideline value. Beyene and Redaie (2011) did a similar research involving hospital waste stabilization pond and had the influent being lower than the effluent.

Phosphorus

During the period of study, the phosphorus concentration was found to be less than the Ghana EPA guideline value but phosphorus mean concentration was low for the influent whilst the effluent was high. The removal efficiency of phosphorus was also low, which shows that the algae growth in the pond has added extra nutrient to the final effluent. Phosphorus is the one of the plant nutrient that can trigger plant growth when introduced into an aquatic environment (Nkegbe, Emongor & Koorapetsi, 2005). As stated by Nkegbe et al. that concentration of 0.01 mg/l phosphorus can cause eutrophication.

In a study by Beyene and Redaie (2011) in Hawassa University Referal Hospital at Ethiopia the phosphorus effluent value lower than the influent which was rather opposite in the case of this study.

Nitrate

Nitrate in water is the end product of the aerobic stabilization of organic nitrogen and may enter the environment through run offs from agricultural lands or in treated effluents from wastewater plants. The study showed that nitrate concentrations increased dramatically compared to that of the influent. A study by Nkegbe et al., (2005) suggested that high nitrate concentration may be due to the fact that more organic matter was broken down to oxides and nitrate. All the nitrate concentrations were less than the Ghana EPA guideline value.

A research conducted by Fosu (2009) on KNUST treatment plant recorded a concentration of nitrate in the final effluent (10.83 mg/l) that was low and within the acceptable limit which was higher than the study at the Cape Coast Teaching Hospital.

Chloride

The mean effluent chloride value was slightly higher than the Ghana EPA guideline value during the study period. Beyene and Redaie (2011) also obtained a chloride value in effluent lower than the influent in a Hospital Hawassa at Ethiopia, while the study conducted in Cape Coast Teaching Hospital had the effluent higher than the influent.

Chloride in wastewater from hospital comes as a result of extensive use of detergents and sterilizers in hospitals (Al-Ajlouni, Shakhatreh, Al-Ibraheem, &

Jawarneh, 2013). It is also noted that the difference in the concentration of the additive chloride cause a difference in the portions of the concentration of chloride.

A study by Singh, Mishra, and Mishra, (2013) showed chloride values in a hospital wastewater at Lucknow ranged between 7.9 and 8.5 mg/l and the study at the Cape Coast Teaching Hospital had higher chloride value.

Sulphate

The mean concentration of sulphate for the effluent dramatically increased more than the influent instead of decrease during the six-month period as Sulphate concentration at the Cape Coast Teaching Hospital was lower than the Ghana EPA guideline. A study had sulphate concentrations ranging from 35.35 to 200.48 mg/l and ascribed the high values to the movement of water through soil and rocks formations that contain sulphate minerals which through dissociation which could get into the wastewater by Apau, Agbovi and Wemegah (2013) as this study had low value.

A study by Ojo and Adeniyi (2012) conducted at Ile-Ife, Southwestern Nigeria on the impacts of hospital effluent discharges on the physico-chemical water quality of a receiving stream recorded sulphate effluent value of 43.4 mg/l which was lower than sulphate effluent of this study.

Calcium

This study recorded a mean calcium concentration of the influent slightly lower than effluent during the study period. The calcium concentration was found to be considerably lesser than the Ghana EPA guideline value.

A study conducted by Ojo and Adeniyi (2012) at Ile-Ife hospital on wastewater recorded calcium concentration of effluent 59.3mg/l which was higher than that of Cape Coast Teaching Hospital. High conductivity indicates the presence of high dissolved salt such as calcium in water or wastewater (Li, Zhou, & Zhao, 2010).

Magnesium

This current study identified the mean magnesium concentration for the influent to be higher than the effluent for the six-month period. Magnesium concentration was high than the Ghana EPA guideline value. The overall removal efficiency was 3.55%. Total dissolved solids have some small amounts of organic matter that are dissolved in wastewater to form magnesium. The suspended or colloidal particles, commonly referred to as total suspended solids (TSS), are all the extremely small suspended solids in water which will not settle out by gravity and contribute to the magnesium level in the wastewater.

The study by Ojo and Adeniyi (2012) on hospital wastewater had effluent magnesium value higher than that of Cape Coast Teaching Hospital.

Heavy metals Parameters of Wastewater in the Stabilization Ponds

The present study identified the mean concentrations of lead, mercury and cadmium to be within their respective threshold values recommended by the EPA which means that it will not pose any toxic effect on the biological treatment system of the hospital. The sample analysis showed that there was significant difference in the values of the effluent for iron and manganese. This shows that the treatment efficiency of the pond for heavy metals in terms of iron and manganese decreased in the final effluent. Manganese had the highest removal efficiency in this study. It might be due to the introduction of settle-able solids of the ponds. The removal of mercury was low as the effluent recorded a high value as compared to the influent. This happen as a result of bioaccumulation of mercury in the pond.

Concentration of cadmium exceeding 0.02 mg/l, will result in toxic effect of anaerobic processes in the effluent. If the concentration of chromium exceeds 2 mg/l, it has toxic effect on aerobic process. The concentrations of lead exceeding 0.1mg/l will inhibit biological wastewater treatment processes (Paul-Guyer, 2010). Though the values of most of the heavy metals in the treated wastewater were low, continuous release to an ecologically fragile environment, might result in bioaccumulation of these trace elements in the food chain (Pauwels & Verstraete, 2006). In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these elements. Also, human exposure has risen dramatically as a result of an exponential increase of their use in various industrial, agricultural, domestic and technological applications (Bradl, 2005).

According to Bai, Srikantaswamy and Shivakumar (2010), 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 impede with the potential beneficial uses. Based on this, the treated hospital wastewater can be recommended for agricultural use because, FAO regulates Cr concentration of 0.1 mg/l as the maximum contamination level (MCL) for reuse of the treated wastewater in agriculture. The reason for this conservative limit of chromium is that, it is not generally recognized as an essential growth element and the lack of knowledge on its toxicity to plants.

Biological Parameters of Wastewater in the Stabilization Ponds

Most pathogenic microorganisms remain in sewage sludge, which some of them together with the resultant effluent can easily reach the environment. The mean *E. coli*, total and faecal coliforms were higher than the Ghana EPA guideline as their removal efficiencies were also low in the studies. However, a study conducted at Akosombo stabilization ponds gave higher total coliform removal efficiency of 99.43% (Hodgson, 2007) and 99.99% (Hodgson, 2000), and higher *E. Coli* removal efficiency of 99.99% (Hodgson; Hodgson). The low removal efficiency could be attributed to the low pH levels of the pond water which were less than 8.00 units (Arceivala, 1981). The factors that influence coliform removal in both primary facultative and maturation ponds include retention time, temperature, *p*H and light intensity (Hodgson). Arceivala reported that the die-off rate of the micro-organisms was accelerated when pH of the pond water was greater than 9.3 units. Similarly, Hodgson and Larmie (1998) showed that no coliforms bacteria were detected in the final effluent when *p*H values were above 10.7 units.

The low removal efficiency could also be due to the low temperature recorded in the ponds. The mean temperature of the various ponds were below 27°C. Studies have shown that temperatures greater than 37°C must be maintained for 15 days to kill coliforms (Kudva, Blanch & Hovde, 1998; Larney, Yanke, Miller & McAllister., 2003).

Relationships among Parameters

Total dissolved solids had a significant positive correlation with conductivity in the ponds which indicates a strong relation (r= 0.999). A study conducted by Tanyol & Demir (2016) confirmed a very strong positive significant correlation both in the influent and effluent (r= 0.998) between EC and TDS.

Chloride correlated strongly with total dissolved solids and conductivity. Turbidity had a strong correlation with total suspended solids as nitrate with ammonia. Again, phosphorus correlated with ammonia as sulphate also correlated with ammonia, nitrate and phosphorus significantly. Biological oxygen demand correlated strongly with dissolved oxygen and temperature. Calcium had a correlation with both dissolved oxygen and manganese. Also, lead correlated with nitrate as magnesium with calcium significantly and total coliform with faecal coliform. The above parameters depict relationship which shows the same source as they correlate with each other. However, turbidity inversely correlated strongly with pH as cadmium with ammonia which indicate a negative correlation. However, no previous work has been done against which the findings of the current study can be compared.

In the current study, the significant relationships observed could be mere artefacts since some of the values were within the acceptable limits of wastewater.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study was carried out to examine the performance of the waste stabilization pond at the Cape Coast Teaching Hospital in the Central Region. The research sought to find answers to the following objectives:

Investigate the management practices observed around the stabilization pond.

Measure the various the physicochemical parameters and heavy metal concentration of the wastewater in the stabilization pond in the study area.

Assess the microbiological characteristics of wastewater from the stabilization pond.

Determine the removal efficiency of the stabilization pond based on the physicochemical, heavy metal and microbiological characteristics of the influent and effluent.

The relationships between qualities of wastewater from the various ponds.

The study was based on the completely randomized design and was carried out in the Cape Coast Teaching Hospital in the Central Region of Ghana. Fifty-four samples were taken for the study; comprised of eighteen each from anaerobic, facultative and maturation ponds. Wastewater samples were collected once every month for six months, beginning November 2016 to April 2017. The samples were analysed to assess their physical, chemical and biological parameters following the Standard Methods for the Examination of Water and Wastewater (APHA, 1995). The data were analysed statistically using both descriptive and inferential statistics. Descriptive statistics was employed to check for the normality of the distribution as well as for measures of central tendency and measures of dispersion. On the other hand; inferential statistics was used to determine whether or not the null hypothesis should be accepted and to establish spatial and temporal relationships of the parameters in the various ponds. The results were discussed in relation to permissible limits from the Ghana Environmental Protection Agency as well as results of earlier studies.

Summary of Findings

The major management practice observed around the stabilization pond was weeding.

There was not much difference in any particular parameter for the wastewater in the various ponds throughout the duration of the study with respect to the limits established by the Ghana Environmental Protection Agency.

This study revealed that generally, the physical characteristics of wastewater in the three ponds in the study area were within the acceptable limits of the Ghana EPA guidelines for wastewater apart from conductivity, TSS, and turbidity. In the same vein, the chemical parameters generally met the standards set by the Ghana EPA guidelines excluding magnesium. Moreover, the heavy metals such as iron, manganese, lead, chromium and cadmium were within the Ghana EPA guidelines except mercury.

However, analysis of the bacteriological quality of the wastewater revealed that of the faecal coliform, total coliform and *E coli* values exceeded the stipulated permissible limit of the Ghana EPA guideline wastewater quality.

More so, most of the parameters had negative values with regards to the percentage removal efficiency, except TSS, turbidity, magnesium, manganese, iron, cadmium and the three selected biological parameters.

The relationships between the parameters of the wastewater in the ponds were significant except temperature, conductivity, TDS, ammonia, chloride, nitrate, phosphorus, sulphate, dissolved oxygen, BOD, calcium, magnesium, lead, cadmium and mercury but chromium did not show any variability in the pond.

Conclusions

In this study, the relationship between the parameters of the wastewater in the stabilization pond were examined. Wastewater samples from anaerobic, facultative and maturation ponds were analysed to establish their concentrations, relationship between the ponds and efficiency removal of contaminants from the waste stabilization pond based on the physicochemical, microbiological and heavy metal characteristics of the influent and effluent. The treated effluent from the waste stabilization ponds met most of the criteria set by Ghana EPA; however a few were above the limits. Although the stabilization pond achieved high reduction in the efficiency removal in the final effluent some of the parameters rather increased in the effluent. Based on the low efficiency removal of some of the parameters, the effluent should be treated to prevent any possible pollution in the environment.

Recommendations

1. Though the wastewater quality in the present study presents a clear picture of the situation of the waste stabilization pond at the Cape Coast Teaching Hospital, there is still the need for regular monitoring of the wastewater quality in the pond.
2. Furthermore, there should be further analysis of the bacteriological aspect to isolate the types of bacteria present in the stabilization pond as it is from a hospital source.
3. More so, disinfection of the final effluent should be carried out before final discharge into receiving water bodies or the environment.
4. Also, the embankments of the waste stabilization ponds should be cemented to prevent decomposition of roots of weeds around in order to reduce the nutrient loads in the pond.
5. It is also recommended that maintenance should be done on the first pond which is the anaerobic pond to improve the conditions in it.
6. A further study should be conducted to investigate the on diversity of algae.

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APPENDICES

APPENDIX A:

ATOMIC ABSORPTION INSTRUMENT PARAMETERS

ELEMENT	WAVELENGTH nm	LAMP CURRENT mA	SLIT WIDTH nm	FUEL	SUPPORT
Pb	217.0	5	1.0	ACETYLENE	AIR
Fe	248.3	5	0.2	ACETYLENE	AIR
Mn	279.5	5	0.2	ACETYLENE	AIR
Ca	422.7	10	0.5	ACETYLENE	NITROUS OXIDE
Mg	285.2	4	0.5	ACETYLENE	AIR
Cr	357.9	7	0.2	ACETYLENE	AIR
Cd	228.8	4	0.5	ACETYLENE	AIR
Hg (BY HYDRIDE)	253.7	4	0.5	ARGON	AIR

APPENDIX B
ANOVA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	3.392	46	.074	5.958	.010
	Within Groups	.087	7	.012		
	Total	3.479	53			
TEMPERATURE	Between Groups	49.159	46	1.069	1.560	.280
	Within Groups	4.795	7	.685		
	Total	53.954	53			
CONDUCTIVITY	Between Groups	5633492.333	46	122467.225	2.275	.128
	Within Groups	376905.000	7	53843.571		
	Total	6010397.333	53			
TOTAL DISSOLVED SOLIDS	Between Groups	1325955.370	46	28825.117	2.337	.120
	Within Groups	86343.000	7	12334.714		
	Total	1412298.370	53			
TSS	Between Groups	503310.333	46	10941.529	11.482	.001
	Within Groups	6670.500	7	952.929		
	Total	509980.833	53			
Turbidity	Between Groups	245085.093	46	5327.937	6.352	.008
	Within Groups	5871.500	7	838.786		
	Total	250956.593	53			
NH3	Between Groups	2.463	46	.054	.723	.765
	Within Groups	.519	7	.074		
	Total	2.982	53			
Cl	Between Groups	188668.958	46	4101.499	1.699	.238
	Within Groups	16897.797	7	2413.971		
	Total	205566.755	53			
NO3-N	Between Groups	343.876	46	7.476	.652	.820
	Within Groups	80.284	7	11.469		
	Total	424.160	53			
PO4	Between Groups	.033	46	.001	.325	.990
	Within Groups	.015	7	.002		
	Total	.048	53			
SO4	Between Groups	4834.746	46	105.103	.685	.794
	Within Groups	1073.358	7	153.337		
	Total	5908.105	53			
DO	Between Groups	23.983	46	.521	.362	.983
	Within Groups	10.087	7	1.441		
	Total	34.071	53			

COD	Between Groups	9527.842	46	207.127	3.428	.046
	Within Groups	422.981	7	60.426		
	Total	9950.823	53			
BOD	Between Groups	24.449	46	.531	.399	.971
	Within Groups	9.329	7	1.333		
	Total	33.777	53			
Fe	Between Groups	4.962	46	.108	3.562	.042
	Within Groups	.212	7	.030		
	Total	5.174	53			
Mn	Between Groups	2.882	46	.063	161.779	.000
	Within Groups	.003	7	.000		
	Total	2.885	53			
Ca	Between Groups	1543.428	46	33.553	.664	.811
	Within Groups	353.831	7	50.547		
	Total	1897.259	53			
Mg	Between Groups	189.553	46	4.121	.930	.605
	Within Groups	31.013	7	4.430		
	Total	220.566	53			
Pb	Between Groups	.000	46	.000	.271	.997
	Within Groups	.000	7	.000		
	Total	.000	53			
Cr	Between Groups	0.000	46	0.000		
	Within Groups	0.000	7	0.000		
	Total	0.000	53			
Cd	Between Groups	.000	46	.000	1.441	.323
	Within Groups	.000	7	.000		
	Total	.000	53			
Hg	Between Groups	.000	46	.000	.635	.833
	Within Groups	.000	7	.000		
	Total	.000	53			
Faecal coliform	Between Groups	145258.815	5	29051.763	5.819	.000
	Within Groups	239653.111	48	4992.773		
	Total	384911.926	53			
Total coliform	Between Groups	71838.815	5	14367.763	1.421	.234
	Within Groups	485291.333	48	10110.236		
	Total	557130.148	53			

E-coli	Between Groups	1617.481	5	323.496	1.997	.096
	Within Groups	7777.333	48	162.028		
	Total	9394.815	53			

APPENDIX C:

POND 1 (ANAEROBIC)

Parameters	Nov.	Dec.	Jan.	Feb.	Mar.	April
pH	7.42	7.39	7.58	7.62	7.63	7.62
Temperature	25.40	27.87	26.43	24.07	25.73	26.27
Conductivity	1029.67	2088.00	1822.6 7	1564.33	1526.0 0	1553.3 3
Total Dissolved Solids	534.00	1038.67	901.33	782.00	769.00	783.00
TSS	145.33	60.33	240.33	190.33	170.33	175.33
Turbidity	205.33	77.33	138.33	190.67	151.00	156.67
Ammonia	0.00	0.00	0.01	0.01	0.01	0.01
Chloride	156.57	301.91	193.93	225.26	203.25	202.20
Nitrate As N	0.02	0.03	0.03	0.03	0.03	0.03
Phosphorus	0.01	0.02	0.02	0.03	0.02	0.02
Sulphate	5.40	8.18	7.91	8.02	7.41	7.49
Dissolved Oxygen	1.08	1.35	1.15	0.95	1.01	0.97
Chemical Oxygen Demand	93.75	81.85	69.52	61.09	61.19	61.26
Biochemical Oxygen Demand	0.47	1.35	0.45	0.25	0.24	0.23
Iron	0.47	0.09	0.62	0.61	0.60	0.51
Manganese	0.04	0.77	0.07	0.06	0.06	0.06
Calcium	30.40	33.20	27.73	26.17	26.20	26.19
Magnesium	11.12	12.57	10.02	10.39	10.50	10.37
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium	0.00	0.01	0.00	0.00	0.00	0.00
Mercury	0.00	0.01	0.01	0.01	0.01	0.01
TC	8400	933	19633	13833	4600	13400
FC	5333	767	11167	15900	16433	16267
E coli	2567	133	3700	1067	2500	1367

APPENDIX D:

POND 2 (FACULTATIVE)

Parameters	Nov.	Dec.	Jan.	Feb.	Mar.	April
pH	7.75	7.41	7.70	7.89	7.83	7.81
Temperature	25.83	28.03	26.50	25.37	25.97	26.37
Conductivity	1435.67	1885.33	2176.67	1761.67	1768.33	1768.67
Total Dissolved Solids	724.00	934.00	1077.00	882.33	897.33	898.00
TSS	60.00	55.00	107.67	81.00	85.67	82.33
Turbidity	91.33	126.33	141.00	81.67	87.00	88.67
Ammonia	0.05	0.06	0.05	0.06	0.06	0.06
Chloride	181.82	241.26	267.25	295.64	260.25	259.45
Nitrate As N	0.40	0.43	0.24	0.24	0.24	0.24
Phosphorus	0.00	0.01	0.01	0.02	0.01	0.02
Sulphate	1.51	4.29	4.66	5.10	5.01	5.10
Dissolved Oxygen	1.08	1.56	1.30	0.51	0.56	0.54
Chemical Oxygen Demand	104.28	85.29	66.31	62.15	62.77	62.57
Biochemical Oxygen Demand	0.24	1.56	0.66	0.16	0.16	0.13
Iron	0.14	0.11	0.21	0.20	0.20	0.20
Manganese	0.01	0.21	0.04	0.04	0.04	0.03
Calcium	28.80	32.27	27.73	27.86	27.73	27.69
Magnesium	10.68	11.34	10.14	11.15	11.09	10.99
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium	0.00	0.00	0.00	0.00	0.00	0.00
Mercury	0.00	0.00	0.00	0.01	0.01	0.01
TC	8767	10000	11367	15600	23667	15700
FC	7033	6567	7300	4867	11733	15333
E. coli	2033	2267	2367	1867	567	1033

APPENDIX E:

POND 3 (MATURATION)

Parameters	Nov.	Dec.	Jan.	Feb.	Mar.	April
pH	7.81	7.67	8.04	7.99	7.94	7.96
Temperature	26.23	28.10	26.43	26.17	26.07	25.73
Conductivity	1317.33	1740.67	2130.00	1609.33	1656.33	1644.00
Total Dissolved Solids	667.33	864.67	1059.00	804.67	828.33	824.00
TSS	24.67	5.33	67.33	58.33	62.33	57.33
Turbidity	39.67	38.00	93.67	73.67	77.00	75.33
Ammonia	0.46	0.51	0.34	0.36	0.52	0.53
Chloride	239.01	235.93	287.24	288.58	281.18	282.07
Nitrate As N	4.43	4.52	4.48	4.22	4.12	4.12
Phosphorus	0.04	0.06	0.06	0.08	0.08	0.08
Sulphate	19.23	27.41	24.66	24.58	21.49	22.35
Dissolved Oxygen	1.63	3.05	2.22	0.65	0.68	0.66
Chemical Oxygen Demand	95.85	79.50	63.15	69.52	67.97	68.35
Biochemical Oxygen Demand	0.20	3.05	1.01	0.23	0.23	0.23
Iron	0.18	0.28	0.25	0.24	0.24	0.24
Manganese	0.02	0.06	0.05	0.05	0.04	0.04
Calcium	33.60	37.40	25.07	25.02	24.94	24.96
Magnesium	10.56	13.43	9.06	9.93	9.76	9.94
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	0.01	0.01	0.00	0.01	0.01	0.01
TC	1000	2800	11100	10767	8567	5600
FC	867	5100	8833	7500	29567	7567
E. coli	100	933	1633	1200	1400	0

APPENDIX F:

PICTURES OF THE RESEARCHER AT THE SAMPLING SITE