

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND
TECHNOLOGY, KUMASI**

DEPARTMENT OF ENVIRONMENTAL SCIENCE

**KNUST
COLLEGE OF SCIENCE**

**DETERMINATION OF EFFLUENT QUALITY OF TWO
WASTEWATER TREATMENT SYSTEMS:
AN ACTIVATED SLUDGE SEWAGE TREATMENT PLANT
AND WASTE STABILIZATION PONDS
AT JUAPONG**

BY

KAGYA AGYEMANG WILLIAM

SEPTEMBER, 2011

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AT JUAPONG**

KNUST
by

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Master of Science degree

in

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SEPTEMBER, 2011

DECLARATION

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

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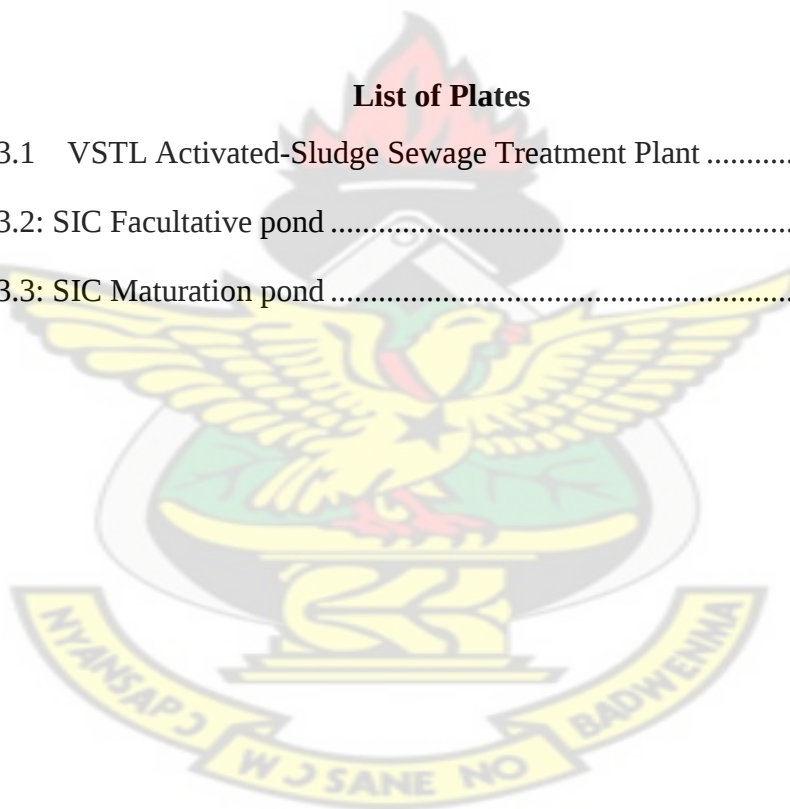
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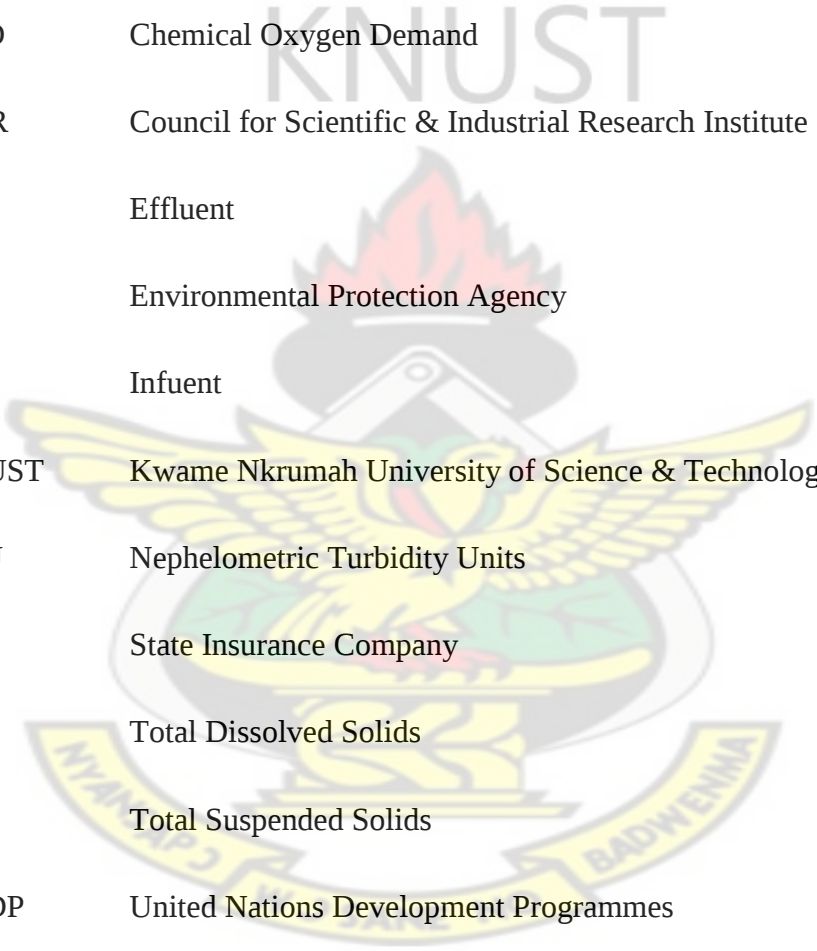
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ABSTRACT

The study was conducted to determine the effluent quality of the two domestic waste water treatment plants; the Volta Star Textile Limited Activated –Sludge Treatment Plant and the State Insurance Company Lowcost Housing Estates Waste Stabilization Ponds at Juapong. Wastewater samples were obtained monthly from the influent and effluent of the two treatment systems. Temperature, pH, conductivity, turbidity, colour, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), nitrate, nitrite, ammonia, phosphate, and counts of total coliform (TC), and *Escherichia coli* (*E. coli*) were analysed over a period of six consecutive months. The waste stabilization ponds (WSP) final effluent values obtained for temperature, pH, conductivity, colour, BOD, COD, TDS, nitrate, and phosphate were in compliance with the Ghana Environmental Protection Agency (EPA) guidelines for discharges into natural receiving water bodies. However, quality parameters such as turbidity, TSS, nitrite and ammonia were unacceptable. The treatment performance of the WSP for conductivity was 49.34%, turbidity 68.78%, colour 21.89%, BOD 80.61%, COD 62.32%, TSS 55.31%, TDS 43.36%, nitrate 16.47%, ammonia 93.43%, and phosphate 92.0%. With the exception of ammonia and nitrite which were unacceptable, all the effluent values obtained for the Activated-sludge treatment plant were in good agreement with EPA of Ghana guidelines. The treatment performance of this plant for conductivity was 25.18%, turbidity 86.29%, colour 65.48%, BOD 74.55%, COD 68.04%, TSS 79.07%, TDS 26.59%, ammonia 60.69%, and phosphate 77.27%. The treatment performances of the two plants for nutrients such as nitrite and nitrate were rather poor. Nitrite exhibited negative values which implied an increase in the effluent compared to the influent. Although reduction of Total coliform and *Escherichia coli* exceeded 95% indicating high performance of the treatment plants, the final effluent discharged did not satisfy the EPA of Ghana permissible values. Most of the effluent quality parameters of the two systems were found to satisfy the standard set by EPA. One way analysis of variance (Anova) ran indicated that statistically, the final effluent of most quality parameters did not differ significantly between the two wastewater treatment plants. The ability of the wastewater treatment plant to effectively deal with some key parameters suggests that the treatment plants are efficient. It is recommended that the final effluent be disinfected before disposal to improve the wastewater quality. All damaged embankments of the waste stabilization ponds be repaired and the times or duration of aeration of wastewater in the activated- sludge plant be increased to improve the effluent quality.

LIST OF ACRONYMS AND ABBREVIATIONS



ASTP	Activated- Sludge Treatment Plant
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CSIR	Council for Scientific & Industrial Research Institute
EFF	Effluent
EPA	Environmental Protection Agency
INF	Influent
KNUST	Kwame Nkrumah University of Science & Technology
NTU	Nephelometric Turbidity Units
SIC	State Insurance Company
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNDP	United Nations Development Programmes
VSTL	Volta Star Textiles Limited
WSP	Waste Stabilization Ponds
WWTP	Wastewater Treatment Plant

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The demand for water use and the generation of wastewater has become critical in recent times due to the rapid population growth, urbanisation and industrialisation. According to United Nations Development Programme (1998) by 2015, 88% of the one billion-person growth in the global population will occur in cities; the vast majority of this growth will occur in developing countries. Increases in urban water supply ensure increased wastewater generation. The depleted fraction of domestic and residential water use is typically only 15-25% and the remainder returns to wastewater (Scott *et al.*, 2004).

Thus increase in municipal wastewater generation originating from domestic, commercial and industrial facilities and institutions have resulted in considerable amounts of wastewater discharged into water bodies. As a result, despite a considerable amount of intervention by national and municipal authorities, serious water quality problems can now be found in many regions of the world.

Untreated wastewater usually contains high levels of organic materials, pathogenic microorganisms, toxic compounds, and heavy metals as well as nutrients. The discharge of the wastewater into receiving water bodies without

treatment or the appropriate treatment before disposal may therefore, cause adverse environmental and health hazards and the entire ecosystem is disturbed.

For this reason, the treatment of wastewater is not only desirable but also necessary. Treatment is necessary to correct wastewater characteristics in such a way that the use or final disposal of the treated effluents can take place in accordance with the rules set by the relevant legislative bodies without causing an adverse impact on the receiving water bodies (Njau and Mlay, 2003).

In most developing countries, like Ghana, efficient wastewater treatment is not an option for the municipal authorities due to high cost involved (Keraita *et al.*, 2002). Due to limited industrial development, domestic effluent and urban run-off contribute the bulk of wastewater generated in Ghana. The common treatment technologies adopted for domestic sewage treatment are trickling filters, activated sludge and waste stabilization ponds. The waste stabilization ponds installed in some of the towns and communities in Ghana have performed remarkably well (Hodgson, 2000). Monitoring of the wastewater treatment plants revealed that less than 25% are functional (EPA, 2001).

Juapong is a rural settlement situated about 5 km from the Adome Bidge on the Accra – Ho trunk road. There is scarce information about the performance of the two waste treatment plants in the town: the Activated sewage treatment plant of Volta Star Textiles Limited and that of the State Insurance Lowcost Housing Estates' Waste Stabilization Ponds. The final effluents from these two treatment

plants are discharged into tributaries of the Kadikadi stream which flows into the lower Volta River. The Volta River is a major source of water for the dense population of the industrial town of Tema, Accra and their environs as well as the communities along the river.

Most of the inhabitants in Juapong and its environs are predominantly farmers and rely on the Kadikadi stream and its tributaries to meet the water needs of their farm crops. Hence the study to determine the quality of waste streams disposed and the level of compliance with National environmental standards.

1.2 Problem Statement

The discharge of untreated or partially treated wastewater into surface waters affects water quality and poses a potential environmental threat, adverse human health and economic cost. Water is an essential for survival of human being. The global increase in scarcity of water, rapid growth in population, urbanization and high living standards require optimum utilisation and the appropriate water management practices.

The costs of poorly managed sewage or domestic waste are very high. In India, the 1994 plague epidemic resulted in a loss of tourism revenue estimated at \$ 200 USD million; in Peru, a recent cholera epidemic resulted in an estimated loss amounting to three times the expenditure on water and sanitation for the entire country over the preceding 10 years; and in Shanghai, China, a recent

major outbreak of hepatitis A was attributed to sewerage contamination (Rose, 1999).

In developing countries, it is a common practice to discharge untreated or partially treated sewage directly into storm drains, surface water bodies or put onto agricultural land. The incapacity of treatment plants to treat sewage to harmless level that meet the acceptable effluent quality standards is therefore likely to cause water-borne diseases like cholera , dysentery, etc., environmental and economic risks.

The purpose of constructing the sewage treatment plants at Juapong was to ensure the stabilization of the sewage generated before disposal into the tributaries of the Kadikadi stream. However, literature on the effluent quality is scanty. The performance efficiencies of the two plants in stabilizing the sewage to the required standard are not available or have not been assessed. It is in this light that the study aims at determining the quality of the treated effluents discharged into the environment and to demonstrate their compliance with Ghana EPA effluent quality guidelines.

1.3 Justification

By ensuring the discharge of quality effluents that meet water quality standards through effective wastewater treatment, receiving water bodies will be less contaminated, making such water bodies suitable for domestic consumption, agricultural and industrial use as well as other uses. Effective utilization through

the appropriate wastewater treatment methods will ensure the availability of good quality water, which will lead to the attainment of health and environmental objectives and less disturbance of the ecosystem. It is necessary to evaluate the effluent quality discharged and ascertain the treatment performance to safeguard the environment.

1.4 Objectives

The main objective of this study is to examine the final effluent quality of the activated sewage treatment plant and the waste stabilization ponds

1.4.1 Specific Objectives

The specific objectives are:

- To determine the level of contamination of the wastewater constituents
- To determine whether the treated effluents meet quality standards set by the Environmental Protection agency (EPA), of Ghana
- To assess the treatment performance of the sewage treatment systems.
- To recommend ways to improve the performance of the treatment plants

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Quality

Water quality is used to describe the chemical, physical and biological characteristics of water, usually in respect of its suitability for a particular purpose. There are many different measures of water quality and the quality of water is closely linked to water use and the state of economic development. According to Russell (2006) it is important to understand how the water upstream and downstream is being used because the downstream use will often dictate the overall water quality and that will affect the discharge criteria for water discharge. The utilization of water for a wide diversity of desirable purposes therefore affects water quality and the wastewater generated must be treated to save the environment from being polluted.

2.2 Wastewater Concepts

Wastewater may be defined as a combination of liquid or water-carried wastes that are removed from residences and institutions, as well as commercial and industrial establishments (Amoah, 2008). In addition, a combination of groundwater, surface water and storm water may be present (Metcalf and Eddy, 1995).

2.2.1 Municipal Wastewater

Municipal wastewater is a combination of water and water-carried wastes originating from domestic, commercial establishments, industrial facilities, and institutions, including hospitals. Due to the high rate of consumption of water in the municipal sector, there are considerably high volumes of wastewater generation and discharge.

2.2.2 Industrial Effluent

This represents wastewater generated by industrial processes and containing high levels of heavy metals or other chemical or organic constituents. Industrial effluent does not normally contain high levels of microbiological pollution unless it emanates from slaughter houses or food-processing plants. For most of the industries in Ghana (more than 70% of the industries) the effluent are discharged into receiving water bodies untreated thus, polluting the surface waters and therefore making it difficult to treat such waters for potable and industrial purposes (Hodgson, 1998).

2.2.3 Storm Water

Storm water is run-off precipitation that finds its way across surfaces into receiving waters. Urban storm run-off is collected and transported in storm or combined sewers. The composition of storm water reflects the composition of precipitation and the surfaces with which it is in contact (Environment Canada, 2006).

2.2.4 Domestic Wastewater

This consists of liquid wastes that flow from washrooms, toilets, kitchens, car washing and other household activities. Domestic wastewater usually contains gray water (also known as greywater) or sullage which is liquid wastes from kitchens, bathrooms, laundries etc., and may also contain blackwater which is wastewater consisting of faecal matter and urine and also some flush water.

2.3 Wastewater Quality

According to UN-EASCWA (2003) wastewater quality may be defined by its physical, chemical, and biological characteristics.

2.3.1 Physical Characteristics

The physical parameters of wastewater include temperature, turbidity, colour, suspended solids, conductivity, total dissolved solids, settleable solids and total chemical solids, etc. These characteristics are used to assess the reuse potential of wastewater and to determine the most suitable type of operation and processes for its treatment (Okoh, 2010).

2.3.1.1 Temperature

The temperature of the wastewater is a very important parameter as it affects the rate of both the chemical and biological treatment. If temperatures are high, the solubility of the chemicals for treatment increases and microbial action is more effective. However if temperatures are low, microbial activity is slow and more chemicals will be required (Drinan & Whiting, 2001).

Wastewater temperature also affects receiving waters. Hot water, for example, which is a byproduct of many manufacturing processes, can be a pollutant. When discharged in large quantities, it can raise the temperature of receiving streams locally and disrupt the natural balance of aquatic life. Wastewater temperatures, as high as 30 to 35°C have been reported for countries in Africa and Middle East (Tchobanoglous, *et al.*, 2003). Increased temperature, for example, could cause a change in the species of fish that could exist in the receiving water body (Okoh, 2010).

Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fish. Some compounds are also more toxic to aquatic life at higher temperatures. According to Middlebrooks *et al.*, (1988) high temperature is good for removing wastewater constituents like nitrogen through volatilisation.

Generally, high temperatures favour pathogen removal, however, in some instances, even increase in numbers of pathogens (Ahmed and Sorenson, 1995). Temperature is measured using a thermometer.

2.3.1.2 Odour

Wastewater treatment works have the potential to generate unpleasant smells or odours, which can result in annoyance and consequently have a detrimental

effect on a local population. The odour may also have a relevant impact on tourism economy (Zarra, 2007). Odours induced from wastewater treatment plants are considered to be the main cause of disturbance noticed by the exposed population (Stuetz and Frechen, 2001; Bidlingmaier, 1997; Frechen, 1988). Odour emissions from wastewater treatment plant are essentially caused by the degradation of organic matter and sulphur by micro-organisms under anaerobic conditions. Odours arise from several points at wastewater treatment facilities. One possibility is that odorous compounds are already present in the incoming wastewater and are released to the air during treatment activities. Another possibility is the formation of odorous compounds (Stuetz *et al.*, 1998). Odorous compounds include organic and inorganic molecules. The two major inorganic odours are hydrogen sulphide and ammonia. Organic odours are usually the result of biological activity that decomposes organic matter and forms a variety of extremely malodorous gases, for example amines.

2.3.1.3 Turbidity

Turbidity is an expression of the optical property of water/wastewater that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity is caused by suspended and colloidal particulate matter such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. It is another test used to indicate water quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. It is measured in NTU (Nephelometric turbidity units) using

a turbidity meter, however different readings can be obtained using different kinds of meters (Slaats *et al.*, 2003; APHA/AWWA, 1998). As observed by WHO (1985) high levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and exerts a significant chlorine demand. In all processes in which disinfection is practised, therefore, the turbidity must always be low, preferably below 1 NTU for effective disinfection. The recommended guideline is 5 NTU (WHO, 1985).

2.3.1.4 Conductivity

Conductivity is the ability of water to conduct electrical current. This depends on the ionic strength of the water sample. Conductivity increases as the concentration of ions increases, since electrical current is transported by ions in solution. The determination of electrical conductivity provides a rapid and convenient way of estimating the concentrations of dissolved ions or estimating the amount of total dissolved salts (TDS). Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in water. The greater the salinity level, the lower the saturation point (Okoh, 2010). Salinity is the total amount in grams of inorganic materials dissolved in 1kg water when all the carbonate has been converted to oxide, all the bromide and iodine have been replaced by chlorine and all organic matter have been completely oxidized (Annang, 2000).

The ability of the water to conduct a current is very temperature dependent. All specific electrical conductivity (EC) readings are referenced to 25°C to eliminate temperature difference associated with season and depth (<http://www.waterontheweb.org/under/waterquality/conductivity.html>)

2.3.1.5 Colour

The colour of water is the result of the different wavelengths that is not absorbed by the water itself or the result of particulate and dissolved substances present (Chapman and Kimstach, 1992). The colour of the wastewater is an indication that it contains contaminants of different materials and in varying concentrations. Some of these materials are chemical in nature. These are mostly industrial effluents discharged from factories. In such cases, the metallic ions present in these effluents impart different colours and in different hues depending on their strength and polluting potential (Runion, 2010).

The other types of effluents in wastewater that impart colour to it are organic in nature. These can be peat materials, different types of weeds, and humus. Plankton which can be present in large quantities can colour the wastewater.

Runion (2010) observed that another reason behind the coloration of wastewater is an increase in the value of the pH of the wastewater. Hence wastewater treatment chemistry makes use of the wastewater color to identify and then apply the right treatment method.

The result of the wastewater colour determination is usually divided between True Colour and Apparent Colour. Non turbid wastewater or the wastewater colour that is obtained after the suspended particles have been filtered is called as True Color. The Apparent Colour includes colour due to substances in solution and also due to suspended matter. It is determined on the original samples without filtration and centrifugation. This is applicable to nearly all samples of potable water and not applicable to most highly coloured industrial wastewater (APHA /AWWA, 1995).

2.3.1.6 Total Dissolved Solids (TDS) and Salinity

TDS are a measurement of inorganic salts, organic matter and other dissolved materials in water and are commonly correlated to Electrical conductivity (EC). TDS includes positive and negative ions, such as dissolved chloride, sulphate, phosphate, carbonate, bicarbonate, sodium, calcium, magnesium, potassium and other inorganic and organic matter.

They can be naturally present in water or the result of mining or some industrial or municipal treatment of water. In the water industry TDS are critical contaminants commonly used as general indicators of salinity.

TDS cause toxicity through increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions. Salinity affects the beneficial reuse of effluent for irrigation and can also impact the quality of fresh water streams.

A high salt content in water can increase the salinity of the soil and hence affect the growth and productivity of plants and/or crops (CISRO, 2006).

2.3.1.7 Total Suspended Solids or Sediments

Total Suspended Solids (TSS) is a common measure of water quality and refers to all suspended particulate matter in the water column. Suspended solids are the solids retained by a filter of 2.0 μm (or smaller) pore size under specific conditions (APHA/AWWA, 1995). High TSS is indicative of poor water quality (Shaw, 2000). 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 (FWPCA, 1968). 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 *et al.*, 2003).

2.3.2 Chemical Characteristics

Chemical parameters associated with the organic content of wastewater include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and total oxygen demand (TOD). Inorganic chemical parameters include salinity, hardness, pH, acidity and alkalinity, as well as concentrations of ionized metals such as iron and manganese, and anionic entities such as chlorides, sulphates, sulphides, nitrates and phosphates.

2.3.2.1 pH

The pH of a sample of water or wastewater is a measure of the concentration of hydrogen ions. It is the negative logarithm of hydrogen-ion (H^+) concentration (Pankraz, 2000). The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less than 7 have increase hydrogen- ion concentration and are acidic; substances with pH greater than 7 are basic and show less hydrogen- ion concentration. All micro-organisms have an optimum pH at which they grow best; a minimum pH which is the most acid range in which they will not grow and a maximum pH which is the most alkaline range that enhances their growth. (Tchobanogolous *et al.*, 2003) observed that the concentration range suitable for the existence of most biological life is quite narrow and critical; it is from 6 to 9. Levels of pH greater than 9 are effective in pathogen removal (Pearson *et al.*, 1992, Curtis, 1990). pH is measured using a portable pH meter.

2.3.2.2 Biochemical Oxygen Demand (BOD)

One of the most commonly measured constituents of wastewater is the biochemical oxygen demand, or BOD. Wastewater is composed of a variety of inorganic and organic substances. BOD measures the oxygen consumed by microorganisms as they decompose organic matter and includes any chemical oxidation of inorganic compounds. Effluents high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes. The BOD test measures the amount of oxygen consumed during a specified period of time,

usually 5 days at 20 °C and so is called BOD₅. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20°C, the BOD₅ can be determined (Greenberg *et al.*, 1992).

2.3.2.3 Chemical Oxygen Demand, (COD)

COD is often measured as a rapid indicator of organic pollutant in water. It is attractive as the test yield results within two hours. It is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. COD measures biodegradable and non biodegradable organic matter of wastewaters. COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution.

2.3.2.4 Ammonia-Nitrogen, Nitrate-Nitrogen and Nitrite-Nitrogen

Nitrogen occurs in natural waters as nitrate (NO₃), nitrite (NO₂), ammonia (NH₃), and organically bound nitrogen. All these forms of nitrogen as well as nitrogen gas (N₂), are components of the nitrogen cycle and are biochemically interconvertible (American Public Health Association, 1989). Total nitrogen TN, is simply the sum of the various nitrogen forms. The total nitrogen concentration in municipal wastewaters ranges from 15 to over 50 mg/L, on average (Reed and Brown, 1995).

As aquatic plants and animals die, bacteria break down large protein molecules containing nitrogen into ammonia. Sewage is the main source of nitrates added

by humans to water bodies. Another important source is fertilizer, which could be carried into natural waters by storm water runoff.

Nitrate levels in surface water is found to be generally low however, some groundwaters may attain high levels. In excessive amounts, it contributes to the illness known as methemoglobinemia in infants ("blue-baby syndrome"). The Canadian Water Quality Guidelines, developed by Environment Canada, has imposed a limit of 10 mg/l Nitrate-Nitrogen on drinking water to prevent this disorder (Agriculture and Agri-food Canada, 2000b).

In excess amount, nitrate leads to eutrophication in freshwaters (Horne, 1995). Excessive nitrate stimulate growth with algae and other plants, which later decay and increase biochemical oxygen demand as they decompose. In a wastewater treatment plant, ammonia is normally oxidised to nitrites and then to nitrates. The first oxidation to nitrite sometimes referred to as nitrification is by *Nitrosomonas* bacteria. The second groups of bacteria (*Nitrobacter*) take the nitrite and oxidize it to nitrate. Nitrite concentration in wastewater effluent is from 15 to 20 mg/l as N. Nitrite is extremely toxic to most fishes and other aquatic species so usually present in low concentrations. Ammonia, nitrite, nitrate and organic nitrogen concentrations are determined by colorimetric method (Tchobanoglous *et al.*, 2003).

2.3.2.5 Phosphorus

Phosphorus is usually present as phosphate (PO_4^{3-}) in water medium. Phosphorus is found in wastewater in three principal forms: orthophosphate ion, polyphosphates or condensed phosphates and organic phosphorus compounds (Mahmut and Ayhan, 2003). Organically bound phosphorus originates from body and food waste and, upon biological decomposition of these solids, is converted to orthophosphates. Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Polyphosphates can be hydrolyzed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-} , HPO_4^{2-} , and H_2PO_4^- . These may form chemical combinations with cations (positively charged ions). According to Clark, *et al.*, (1997) and Sedlak, (1991) the phosphorus concentrations in secondary effluent stand usually within the range of 3-7 mg/L, which mostly consist of orthophosphate and about 1 mg/L of organic phosphorus. Thus, it is necessary to reduce the concentration of phosphorus in secondary wastewater to prevent the algal bloom. Other sources of phosphorus aside human waste include animal wastes, industrial waste, soil erosion and fertilizers.

2.3.2.6 Trace Metals

Heavy metals are the group of metals that have density greater than 4 g/cm^3 . Under this group, the following elements are included: arsenic, cadmium,

chromium, copper, lead, mercury, zinc, nickel, molybdenum, and manganese (FAO, 1992). Heavy metals are important because they are often toxic and they impede or interfere with the biological treatment process when in excessive quantities. Depending upon the metal and the species, all the reactions are pH dependent (Russell, 2006). According to (Sorme and LagerKvist, 2002) heavy metals appear in wastewater and storm water collection systems from many sources that include household, drainage water, business, atmospheric deposition, traffic, building materials and chemicals. Most heavy metals are essential to plant growth at low concentrations. Nevertheless, these heavy metals become toxic and harmful at high concentrations. Toxicity generally results in impaired growth, reduce yields and cause plant death (FAO, 1992).

2.3.3 Biological Characteristics

Biological parameters include coliforms, faecal coliforms, and specific pathogens, and viruses.

2.3.3.1 Coliforms and Faecal coliforms

Wastewater usually contains millions of microorganisms per milliliter. However many of these organisms are harmless. Few disease-causing microorganisms called pathogens invade some part of the host and either grow and multiply or produce toxin which interferes with normal body processes. They are divided into categories with the most common groups associated with water pollution being bacteria, viruses, protozoa, helminthes (intestinal worms) and algae. These can exist naturally or can occur as a result of contamination from human or

animal waste. Contact with the contaminated water may lead to disease such as typhoid, cholera and gastrointestinal problems.

Coliform tests are useful for determining whether wastewater has been adequately treated and whether water quality is suitable for drinking, recreation or reuse. Coliform are a family of bacteria common in soils, plants and animals. Because they are very abundant in human wastes, coliform bacteria are much easier to locate and identify in wastewater than viruses and other pathogens that cause severe diseases. For this reason, coliform bacteria are used as indicator organisms for the presence of other, more serious pathogens. Coliforms are frequently monitored as total or faecal coliforms. Total coliform (TC) is defined as a large group of anaerobic, nonspore forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35 °C (Chapra, 1997). Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in soils, plants and in intestines of warm-blooded (humans) and cold-blooded animals. Some pathogens enter the human body through the skin but more commonly they are ingested with drinking water. Faecal coliform (FC) is a subgroup of TC that comes from the intestines of warm-blooded animals. However, since they do not include soil organisms, they are preferable to TC as an indicator organism. World Health Organization Guidelines for Drinking Water Quality state that as an indicator organism faecal coliform *Escherichia coli* (*E-coli*) provides conclusive evidence of recent faecal pollution and should not be present in water meant for human consumption. It is

generally assumed that the higher the number of coliform organisms found in a 100 ml sample, the higher the risk for waterborne disease (http://en.wikipedia.org/wiki/Indicator_bacteria). They are measured by running the standard total coliform test at an elevated temperature (44 °C) (Chapra, 1997).

There are two commonly used methods for determining the presence and density of coliform bacteria. The membrane filter (MF) technique provides a direct count of colonies trapped and then cultured. The multiple tube fermentation method provides an estimate of the most probable number (MPN) per 100 milliliters from the number of test tubes in which gas bubbles form after incubation.

2.4 Wastewater Treatment

The purpose of wastewater treatment is to remove as many of the wastes (contaminants) from the water as possible so that the treated effluent will have few, if any, detrimental effects when it is returned to the environment, lakes, streams, or ocean. Physical, chemical and biological methods are used to remove contaminants from wastewater. In order to achieve different levels of contaminant removal, individual wastewater treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary wastewater treatment. Natural systems are also used for the treatment of wastewater in land-based applications (UN- ESCWA, 2003).

The primary treatment wastewater involves the removal of gross particles and objects, sand, grit, scum, and suspended solids. Secondary treatment utilizes biological processes to remove organic matter and tertiary treatment may include processes to remove nutrients such as nitrogen and phosphorus compounds, pathogenic microorganisms and carbon adsorption to remove chemicals. The treatment can be done mechanically like in trickling filters, activated sludge methods or non-mechanically like in anaerobic treatment, stabilization ponds etc. According to Hodgson (2000) the major treatment methods found in Ghana are trickling filter, stabilization ponds, and activated sludge.

2.4.1 Trickling Filter

Trickling filters are widely used for the treatment of domestic and industrial wastes. The process is a fixed film biological treatment method designed to remove BOD and suspended solids (Spellman, 2003).

It consists of a bed of highly permeable medium to which organisms are attached, forming a biological slime layer, and through which waste-water is percolated. The filter medium usually consists of rock or plastic packing material. The organic material present in the wastewater is degraded by adsorption on to the biological slime layer. In the outer portion of that layer, it is degraded by aerobic micro-organisms. As the micro-organisms grow, the thickness of the slime layer increases and the oxygen is depleted before it has penetrated the full depth of the slime layer. An anaerobic environment is thus

established near the surface of the filter medium. As the slime layer increases in thickness, the organic matter is degraded before it reaches the micro-organisms near the surface of the medium. Deprived of their external organic source of nourishment, these micro-organisms die and are washed off (slough off) by the flowing liquid. A new slime layer grows in their place.

After passing through the filter, the treated liquid is collected in an underdrain system, together with any biological solids that have become detached from the medium. The collected liquid then passes to a settling tank where the solids are separated from the treated wastewater. A portion of the liquid collected in the underdrain system or the settled effluent is recycled to dilute the strength of the incoming wastewater and to maintain the biological slime layer in moist condition. This method is widely used in Accra, like at Burma Camp, the Nsawam Prison and in Kumasi at the University of Science and Technology (<http://homepage.mac.com/cityfarmer/Ghana/Chap6-Sanitation.pdf>).

2.4.2 Activated Sludge Process

As described by (UN/ESCWA, 2003), the activated-sludge process is an aerobic, continuous-flow system containing a mass of activated micro-organisms that are capable of stabilizing organic matter. The process consists of delivering clarified wastewater, after primary settling, into an aeration basin where it is mixed with an active mass of microorganisms, mainly bacteria and protozoa, which aerobically degrade organic matter into carbon dioxide, water, new cells, and other end products.

An aerobic environment is maintained in the basin by means of diffused or mechanical aeration, which also serves to keep the contents of the reactor (or mixed liquor) completely mixed. After a specific retention time, the mixed liquor passes into the secondary clarifier, where the sludge is allowed to settle and a clarified effluent is produced for discharge. The process recycles a portion of the settled sludge back to the aeration basin to maintain the required activated sludge concentration. The process also intentionally wastes a portion of the settled sludge to maintain the required solids retention time for effective organic removal.

Control of the activated-sludge process is important to maintain a high treatment performance level under a wide range of operating conditions (UN/ESCWA, 2003). The principal factors required in process control are the following:

- (a) Maintenance of dissolved oxygen levels in the aeration tanks;
- (b) Regulation of the amount of returning activated sludge;
- (c) Control of the waste activated sludge.

2.4.3 Waste Stabilization Ponds

Wastewater stabilization pond technology is one of the most important natural methods for wastewater treatment. Waste stabilization ponds are mainly shallow man-made basins (lagoons) comprising a single or several series of anaerobic, facultative or maturation ponds. Mixing may be either natural (wind, heat or fermentation) or induced (mechanical or diffused aeration). The primary

treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD_5). Anaerobic ponds are particularly effective in bringing about rapid stabilization of strong concentrations of organic wastes. The removal of organic matter in anaerobic ponds follows the same mechanisms that take place in any anaerobic reactor (Mara *et al.*, 1992. Peña, 2002).

In the aerobic-anaerobic (facultative) pond, the second stage, most of the remaining organic matter is removed through the coordinated activity of algae and heterotrophic bacteria. The bacterial population oxidizes organic matter, producing ammonia, carbon dioxide, sulphates, water and other end products, which are subsequently used by algae during daylight to produce oxygen. Bacteria then use this supplemental oxygen and the oxygen provided by wind action to break down the remaining organic matter. Wastewater retention time ranges between 30 and 120 days (UN/ESCWA, 2003). The wind velocity has an important effect on the behaviour of facultative ponds, as they generate the mixing of the pond liquid. As observed by (Mara *et al.*, 1992), a good degree of mixing ensures a uniform distribution of BOD_5 , dissolved oxygen, bacteria and algae, and hence better wastewater stabilization. The facultative ponds are of two types: primary facultative ponds receive raw wastewater, and secondary facultative

ponds receive the settled wastewater from the preliminary stage (usually the effluent from anaerobic ponds).

Maturation ponds are aerobic systems used as post treatment to facultative ponds, to further reduce organic matter, remove pathogenic microorganisms and nutrients (especially nitrogen) before disposal into natural water bodies. Mara *et al.*, (1992), Mara *et al.*, (1998) report a total nitrogen removal of 80% in all waste stabilization pond systems and 95% ammonia removal. However, the total phosphorus removal is low, usually less than 50%.

2.4.3.1 Routine Maintenance

Although it is a low-technology and simple, it is necessary to carry out regular routine maintenance tasks of the waste stabilization ponds to ensure optimal performance. According to Mara *et al.* (1998) the routine maintenance tasks are as follows:

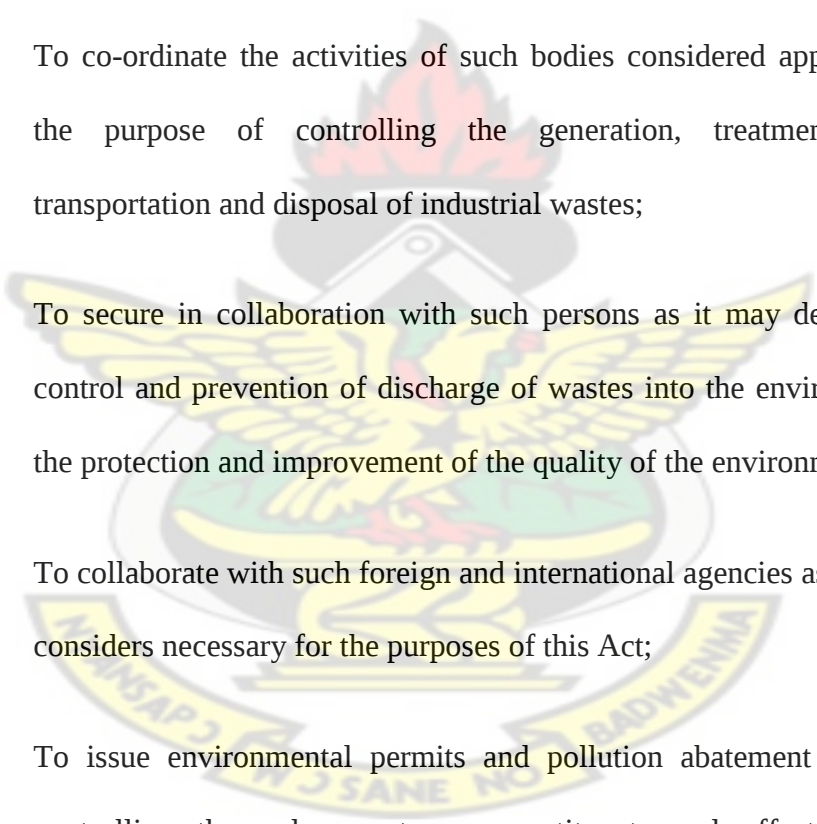
- Removal of screening and grit retained in the inlet works during the preliminary treatment.
- Cutting, pruning and removing the grass and vegetation that grows on the embankment to prevent it from falling into the pond and generating the formation of mosquito breeding habitats. The use of slow-growing grass or vegetation is recommended to minimise the frequency of this task.
- Removal of floating scum and macrophytes (e.g. *Lemna spp.*) from facultative and maturation ponds to maximise photosynthesis and surface re-aeration, and prevent fly and mosquito breeding.

- Spraying the scum on the surface of anaerobic ponds (which should not be removed as it aids the treatment process). In the event fly breeding is detected this material should be sprayed with clean water.
- Removal of any accumulated solids in the pond's inlets and outlets.
- Repair of any damage to the embankments caused by rodents or other animals.
- Repair of any damage to external fences and gates or points of access to the system.

2.5 Agency in Charge of Environmental Protection in Ghana

The Environmental Protection Agency (EPA), established December 1994 is mandated by the Government to administer the Environmental Protection Act, promulgated in December 1994 (Environmental Protection Act (Act 490), 1994). EPA's scope of responsibilities includes the setting of standards and guidelines values for gas emissions, noise pollution, discharge of domestic and industrial effluent, the disposal of solids wastes, control of toxic substances and all forms of environmental pollution.

Some relevant functions of EPA for domestic and industrial waste management include the following:

- 
- i) To advise the Ministry on the formulation of policies on all aspects of the environment and in particular makes recommendations for the protection of the environment
 - ii) To co-ordinate the activities of bodies concerned with the technical or practical aspects of the environment and serve as a channel of communication between such bodies and the Ministry.
 - iii) To co-ordinate the activities of such bodies considered appropriate for the purpose of controlling the generation, treatment, storage, transportation and disposal of industrial wastes;
 - iv) To secure in collaboration with such persons as it may determine the control and prevention of discharge of wastes into the environment and the protection and improvement of the quality of the environment;
 - v) To collaborate with such foreign and international agencies as the agency considers necessary for the purposes of this Act;
 - vi) To issue environmental permits and pollution abatement notices for controlling the volumes, types, constituents and effects of waste discharges, emissions, deposits or other sources of pollutants and of substances to the quality of the environment or any segment of the environment;

- vii) To prescribe standards and guidelines relating to the pollution of air, water, land and other forms of environmental pollution including the discharge of waste and the control of toxic substances;
- viii) To ensure compliance with any laid down environmental impact assessment procedures in the planning and execution of development projects, including compliance in respect of existing projects;
- ix) To liaise and co-operate with government agencies and institutions to control pollution and generally protect the environment;
- x) To promote effective planning in the management of the environment;
- xi) To develop a comprehensive database on the environment and environmental protection for the information of the public;
- xii) To co-ordinate with such international agencies as the agency considers necessary for the purpose of this Act.

2.5.1 National Effluent Quality Guidelines

The National guideline values given for the quality of wastewater/effluent to be discharged into inland water bodies such as streams, lakes/dams and rivers given by the Environmental Protection Agency (EPA) of Ghana (2000) is shown in the Table 2.1 below.

Generally, the guidelines values of developed countries are very stringent because of the advanced technology adopted for wastewater treatment and the possible enforcement by the responsible agents. However for the case of the developing countries including Ghana, Hodgson, (1998) explained that, the economy makes it quite difficult to use high level technologies to treat its domestic and industrial wastewater thus not easy to achieve the stringent guideline values adopted by the developed countries.

Table 2.1: EPA guideline values for the discharge of effluents into receiving water bodies.

PARAMETER	UINTS	EPA GUIDELINE VALUE
pH		6 – 9
Temperature	⁰ C	< 3 ⁰ C above ambient
Colour,	TCU	200
Turbidity	NTU	75
Conductivity	uS/cm	1500
Total Suspended Solids (TSS)	mg/l	50
Total Dissolved Solids (TDS)	mg/l	1000
Total Phosphorus	mg/l	2.0
Biochemical Oxygen Demand (BOD ₅)	mg/l	50
Chemical Oxygen Demand (COD)	mg/l	250
Nitrate	mg/l	50
Nitrite	mg/l	-
Ammonia as N	mg/l	1.0
Alkalinity as CaCO ₃	mg/l	150
Total Coliforms	MPN/100ml	400
E. Coli	MPN/100ml	0

Source: E.P.A (GHANA) 2000

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Description of Study Site

The study area is located at Juapong in the North Tongu district of the Volta Region as shown in figure 3.1. Juapong lies on latitude 6°15'N and longitude 0°08'E covering an area of about 9 km². It is situated about 5 km from the Adome Bridge on the Accra- Ho trunk road and has a population of about 6000 people.

The town is the first rural settlement in the Volta Region to have experienced the establishment of a factory (Juapong Textiles Limited in 1967) which at full capacity employed about 1500 workers. The presence of the factory led to rapid population growth which had outpaced the existing poor sanitary infrastructure. Domestic and storm water are discharged into open drains into the Kadikadi stream which finally ends up in the lower Volta river without treatment. Wastewater from kitchen and other parts of homes are directed to nearby open drains (where drains are available) or onto the bare ground. Majority of the households do not have toilet facilities and therefore patronized the few public toilets. Defecation in open drains, bushes and around households is a common practice.

The Volta Star Textiles Limited and the SIC Lowcost Housing Estate areas which cover about one-fifth of the land area of the town are sewered and offer

some treatment of their domestic effluents before discharge into the tributaries of the Kadikadi stream.

3.1.1 Climate

Juapong lies within the Dry Equatorial Climate Zone which experience substantial amount of precipitation. It has a double maximal rainy season which starts in April with the peak month in June - July and ends in November. The dry season sets in November-December and ends in March. The annual rainfall ranges between 67 – 1130 mm, and maximum temperature is 37.2 °C. The Relative humidity is generally high ranging from the highest of 98% in June to 31% in January. The town lies within the semi-deciduous Rainforest and Coastal Savannah Zone of Ghana.





Figure 3.1: Location Map of Volta Star Textiles Limited (VSTL) and State Insurance Corporation (SIC) Lowcost estates

3.1.2 Volta Star Textiles Limited (VSTL)

Volta Star Textiles Limited former called Juapong Textiles Limited was established in 1967 by the Ghana government in partnership with some multi-national companies to offer employment and help curbed the migration of the youth from Juapong and its environs into the urban centers. The factory is now fully government owned following the departure of the major multi-national partners in 2005 and now has staff strength of about 305.

The factory is located at the central part of Juapong Township and covers an area of about 0.25 km². It lies within the catchment of the Kadikadi stream, which originates from the hills to the east of Juapong Township. The stream flows in a south-westerly direction to join the Lower Volta downstream of the Adome Bridge. The drainage map of the area is shown in Figure A.1 (Appendix A).

The wastewater from the VSTL operations is categorized into the following:

- ❖ Wastewater (wash-water) from the canteen/kitchen and boiler house;
- ❖ Wash-water from warehouse/factory floor; and
- ❖ Domestic sewage from residences and offices.

The wash-water from the canteen and the boiler house is channelled through an open drain that empties into an open vast stretch of swampy area at the south-eastern end of the factory. Floor wash-water from the warehouse, workshop, technical store and the condensate from the chiller plant and storm water are

channelled through a drain at the northern section of the factory. The drain empties into the Kadikadi Stream.

The bulk of the company's wastewater is domestic sewage from the residences and offices. This is channelled to the Activated-sludge Sewage Treatment Plant (STP), Plate 3.1 below. The treated effluent is piped over 700m and discharged underneath a culvert on the Juapong-Ho road into a tributary of the Kadikadi Stream. The Stream flows into the Volta River. The detailed description of the plant is at appendix B.



Plate 3.1 VSTL Activated-Sludge Sewage Treatment Plant

3.1.3 SIC Lowcost Housing Estates

The SIC estate at Juapong consists of about 300 completed semi-detached lowcost houses and inhabited by over 1600 peoples. It is situated in the north

eastern part of the town and has a land area of about 0.35 km². The area also lies in the catchment of the Kadikadi stream as shown in Figure 3.1 The estates are sewerred and the waste stabilization ponds are used to treat the sewage (Plates 3.2 and 3.3). Storms or rain waters are directed through the storm drains into a tributary of the Kadikadi stream.

The description of the WSP is shown at appendix B 3.0



Plate 3.2: SIC Facultative pond



Plate 3.3: SIC Maturation pond

3.2 Methods used for Data collection

To assess the treatment performance of the VSTL Activated sludge treatment plant and the SIC Waste stabilization ponds, samples were taken of the raw sewage after screening and at the final discharge points. Samples were taken and analysed of physico-chemical properties including temperature, pH, conductivity, turbidity, colour, biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids, total dissolved solids, nitrate, nitrite, ammonia, phosphorus and microbiological parameters such as total coliform and *E. coli*.

3.2.1 Sampling procedure

Sampling was done monthly starting in October, 2010 to March, 2011. In all twenty four (24) samples representing six (6) influent and six (6) effluent samples taken at each treatment plant were analysed. Temperature of the samples was measured in-situ. The samples were immediately stored in an ice-chest and transported to the Water Research Institute, CSIR laboratories in Accra for analysis. Appendix D shows the process flow diagrams of the activated-sludge treatment plant and the waste stabilization ponds and points where the influent and the effluent samples were collected.

3.3 Procedures for Laboratory Analysis

3.3.1 Temperature

The temperature was measured in the field with a Hanna Instrument checktemp packet digital thermometer with stainless steel penetration probe. The cap of the probe was removed and the probe was rinsed with distilled water before dipping it in the sample to about 3cm to 4cm and reading allowed to stabilize. The temperature was then recorded.

3.3.2 pH

Apparatus

A pH meter Suntex Model SP 701 and combination electrode (Type No. PHM-110-010Y).

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 buffer 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.

3.3.3 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 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.

3.3.4 Turbidity

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)

3.3.5 Colour

By visual comparison method

Apparatus

BDH Lovibond Nesslerizer, colour disk, matched Nessler tubes 50 ml, tall form

Principle

Colour is determined by visual comparison of a sample with special glass colour disks, which have been calibrated.

Procedure

- a) The Nessler tube was filled to the 50ml mark with the sample
- b) The sample was placed in the right hand compartment of the Nesslerizer lighted cabinet
- c) Nessler tube filled with distilled water was placed in the left hand compartment for reference
- d) The colour disk was placed in the compartment
- e) The Nesslerizer light was switched on
- f) The disk was rotated until a colour match was obtained
- g) The colour was read from the disk. Since turbidity was not removed, it was recorded as apparent colour.
- h) When the colour exceeded 70 units, the sample was diluted and the colour was calculated as:

$$\text{Colour (TCU)} = (A \times 50)/B$$

Where A = estimated colour of diluted sample

and B = ml of sample taken for dilution

3.3.6 Biochemical Oxygen Demand (BOD₅)

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 °C for 5 days. The BOD is then calculated from the initial and final DO.

Procedure

1. Dilution water was prepared.
2. A desired quantity of the sample was made up to about 1 litre with the dilution water. Careful mixing was done to avoid the formation of bubbles
3. The mixed dilution was siphoned into two BOD (300 ml) bottles excluding air bubbles.
4. One of the BOD bottle was corked and incubated for five days at 20 °C
5. To the other BOD bottle, 2 ml of Manganous sulphate (MnSO₄), followed by 2 ml of alkaline-iodide azide were added and bottle corked carefully to exclude air bubbles
6. The content was mixed thoroughly by shaken and inverting several times and the precipitate allowed settling at the bottom of the sample

7. After the precipitate had settled, 2 ml concentrated sulphuric acid (H_2SO_4) was added, corked and the bottle inverted several times to dissolve the precipitate, an intense yellow colour was obtained
8. 100 ml of the solution was taken and titrated with 0.0125M sodium thiosulphate to a pale yellow colour and 1 ml starch was added as indicator. The titration was continued to the first disappearance of the blue colour
9. The above procedure was followed for the incubate samples at the end of the 5 days to determine the difference in DO for the computation of BOD.

Calculation for DO

$$\text{BOD}_5, \text{ mg/l} = (\text{D1} - \text{D2})/\text{P}$$

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

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

P = Decimal volumetric fraction of sample used (1/dilution factor)

3.3.7 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

The digestion tubes and caps were washed with 4M sulphuric acid first to prevent contamination. Five milliliter (5 ml) of the sample or a diluted aliquot is transferred into a labeled culture tube and 3 ml potassium dichromate solution (digestion solution) added. Seven millilitres (7 ml) H₂SO₄ reagent (silver sulphate in sulphuric acid) was added carefully to form an acid layer under the sample-digestion layer. The tube was tightly capped, shaken and inverted several times to mix completely. The tubes were placed in a digester at 150⁰C and reflux for two hours, and then cooled to room temperature. 1-2 drops of ferroin indicator was added and titrated with standard FAS solution until the colour changes from blue-green to reddish brown or wine (endpoint). The procedure was repeated for a blank sample containing the reagents and a volume of deionised water equal to that of the sample.

Calculation

$$\text{COD mg O}_2/\text{l} = \frac{(A-B) \times M \times 8000}{V}$$

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 = milliequivalent of oxygen x 1000 ml/l

3.3.8 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 °C.

The increase in weight of the filter represents the total suspended solids.

Procedure

1. The weight of the glass filter and petri dish was first measured
2. The filtration apparatus and filter were assembled and suction started
3. 10 ml of deionised water was passed through the filter to seat it on the funnel
4. The sample bottle was vigorously shaken and known volume (100 ml) of sample was rapidly transferred to the funnel.
5. The filter was washed with 3 successive 10 ml volume of distilled water to allow complete drainage.
6. The filter was removed and transferred into a weighing glass petri dish
7. The dish and the filter were placed in the drying oven and dried for at least one hour at 105 °C.
9. It was then cooled in a desiccator and weighed. The drying cycle was repeated until a constant weight was obtained.

Calculation

$$\text{TSS (mg/l)} = (A - B) \times 10^6 / C$$

A = weight of filter + dish + residue, g

B = weight of filter + dish, g

C = volume of sample filtered, ml

3.3.9 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 °C. The increase in weight over that of the empty dish is the weight of the TDS.

Procedure

The procedure follows the steps enumerated for TSS. However instead of residue on filter, rather the filtrate left after the filtration was evaporated on a water bath. The residue obtained was dried to a constant weight at 105°C in an oven.

Calculation

$$\text{TSS (mg/l)} = (A - B) \times 10^6 / C$$

A = weight of dish + dried residue, g

B = weight of dish, g

C = volume of sample filtered, ml

3.3.10 Nitrate- Nitrogen (NO₃-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-naphthyl)-ethylenediamine dihydrochloride to form a highly coloured azo dye which is measured spectrophotometrically.

Apparatus

6705 UV/VIS Spectrophotometer Jen Way

Procedure

Standard nitrate solutions of known concentrations ranging from 0.1 mg/l to 1.0 mg/l were prepared and absorbance read on a spectrophotometer for a calibration curve after treating them as a sample. A graph of concentration against absorbance was plotted using microsoft excel. 10 ml of the sample to be measured was pipette into a test tube and 1.0 ml of 0.3M NaOH added and mixed gently. The reducing mixture of 1.0 ml concentration was then added and mixed gently. A blank solution using deionised water was prepared in the same way as the sample. The samples were heated at 60 °C for 10 minutes in a water bath, cooled to room temperature and 1.0 ml colour developing reagent added. After shaking to mix, the absorbance at wavelength of 520 nm was read from

the spectrophotometer using a 1cm light path cuvette. The absorbance of the blank solution was determined by switching the spectrophotometer to zero. The calibration graph was used to determine the concentration of nitrate –nitrogen in the unknown sample.

3.3.11 Phosphate ($\text{PO}_4\text{-P}$)

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 690 nm are proportional to the concentration of the phosphate in sample.

Procedure

Standard phosphate solutions (KH_2PO_4) of known concentrations were prepared and absorbance read on the spectrophotometer for a calibration curve. 100 ml sample free of colour and turbidity was taken and 0.01 (1 drop) phenolphthalein indicator added. When the sample turned pink, strong acid solution (mixture of conc. H_2SO_4 and HNO_3) was added dropwise to discharge the colour. A smaller volume of the sample was taken if more than 0.25 ml (5 drops) was required, and the sample was then diluted to 100 ml with de-ionised water and then a drop of phenolphthalein indicator was add. The pink colour was discharged with strong acid. With thorough mixing 4.0 ml ammonia molybdate

reagent 1[(NH₄)₆MO₇O₂₄.4H₂O)] was added and 0.5 ml (10 drops) stannous chloride reagent 1 (SnCl₂.H₂O) was also added with thorough mixing. A blank solution was prepared using de-ionised water. After 10 minutes, but before 12 minutes, the absorbance at a wavelength of 690 nm was measured on the spectrophotometer using 1cm light path. The absorbance of the blank solution was determined by switching the spectrophotometer to zero. The calibration graph was used to determine the concentration of (PO₄-P) in the unknown sample.

3.3.12 Ammonia-Nitrogen (NH₄-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

Standard ammonia solutions of known concentrations ranging from 0.2 mg/l to 1.0 mg/l were prepared and absorbance read on a spectrophotometer for a calibration curve. One to five millilitres (1- 5 ml) sample was pipette into 50 ml conical flask and diluted to the 50 ml mark with ammonia free water. 2 drops of Rochelle salt (KNaC₄H₄O₆.4H₂O), was added to the diluted sample, carefully mixed and 2 ml of Nessler's reagent added. A blank (50 ml ammonia-free water plus 5 drops of Rochelle salt and 2 ml nessler's reagent) was prepared. Samples

were allowed to stand for 10 minutes for colour development and absorbance determined on the spectrophotometer at a wavelength of 410 nm using a 1 cm light path cuvette. The absorbance at zero on the spectrophotometer was read for the blank solution. The calibration curve was used to determine the concentration of ammonia-nitrogen in the unknown sample.

3.3.13 Nitrite-Nitrogen ($\text{NO}_2\text{-N}$)

Diazotization method

Nitrite reacts in strongly acid medium with sulfanilamide. The resulting diazo compound is coupled with N- (1-naphthyl)-ethylenediamine dihydrochloride to form an intensely red-coloured azo-compound. The absorbance of the dye is proportional to the concentration of the nitrite present.

Procedure

Fifty millilitres (50 ml) of the wastewater sample or 10 ml diluted to 50 ml was placed in a Nessler tube. This was set aside and a series of standard nitrite solutions in 50ml Nessler tubes ranging from 0.01 to 0.20 ml were prepared. A blank solution was also prepared. Two milliliters (2 ml) of the buffer-colour reagent was added to samples, mixed well and allowed colour to develop for at least 15 minutes. The absorbance was measured at 540 nm. The absorbance at 540 nm was measured for the blank in the spectrophotometer when switched to zero. The nitrite concentration was read from the calibration curve. When the

sample taken was less than 50 ml (diluted samples), the concentration was calculated as follows;

$\text{NO}_2\text{-N in mg/l} = (\text{mg/l from standard curve} \times 50) / \text{ml of sample.}$

3.3.14 Total coliform and *Escherichia coli*

Membrane filter method

Agar Preparation

Twenty-seven grams (27 g) of 81938 Hicrome (TM) coliform Agar was suspended in 1 litre sterile distilled water by heating to boiling to dissolve the medium completely. It was sterilized by autoclaving at 121 °C for 15 minutes. Four milliliters (4 ml) of Sterilized medium was dispensed into all the petri dishes and allowed to solidify.

One millilitre (1 ml) of the samples was pipette into sterilized test tubes and diluted with 9 ml sterile distilled water and shaken well in a vortex mixer. The diluted sample was then filtered through a membrane filter by means of a filtration apparatus wagtech. The filter pad was transferred onto the agar plate (Hicrome coliform agar). To detect total coliforms, the plates were incubated upside down at 37 °C, and for *E. coli* at 44 °C for 24 hours. The number of colonies appearing on the plates were counted using karl kolb (Lab micr 2.22) microscope. The number of colonies in a sample is equal to the plate count multiplied by the reciprocal of the dilution (dilution factor).

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-Chemical Parameters

The physico- chemical parameters used to assess the quality of effluents discharged into the environment from the two waste water treatment systems are temperature, pH, conductivity, turbidity, colour, biochemical oxygen demand, chemical oxygen demand, total suspended solids, total dissolved solids, nitrate, nitrite, ammonia, and phosphate. The microbial quality parameters are Total coliform and Escherichia coli. A summary of the wastewater results of the study are given in appendix C, (Tables C.1, C.2, C.3 and C.4). The mean value of each parameter considered for the various sampling times have been computed and tabulated as well as the standard deviation and standard errors of 95% confidence interval.

4.2 Assessing quality of Waste Stabilization Ponds (WSP)

Table 4.1 below shows the mean values of the influent and the effluent parameters measured monthly for a period of six months at the Waste stabilization ponds (WSP), the corresponding percentage mean overall removal efficiencies and the EPA Ghana guidelines for discharge into natural water bodies.

4.2.1 Temperature

The temperature of the raw sewage or the influent wastewater ranged from 29.0 °C to 31.0 °C with a mean temperature of 29.95 °C. The effluent temperature ranged from 28.0 °C to 31.1 °C with a mean value of 29.90 °C. The results show a slight drop of 0.05 °C.

Table 4.1: Removal Efficiency of Waste Stabilization Ponds

MEAN OVERALL REMOVAL						
PARAMETER	INFLUENT		FINAL EFFLUENT		% REMOVAL	EPA STANDARDS
	RANGE	MEAN	RANGE	MEAN		
Temperature, °C	29.0 - 31.0	29.95	28.0 - 31.1	29.90	-	<3°C above ambient
pH	7.45 - 8.16	7.76	7.82 - 9.07	8.20	-	6 - 9
Conductivity, µS/cm	533 - 1571	1030.50	486 - 567	522.00	49.34	1500
Turbidity, NTU	50.5 - 584.0	318.30	70.2 - 128.0	96.20	69.78	75
Colour, TCU	50 - 500	237.50	50 - 350	185.50	21.89	200
BOD, mg/l	16 - 340	162.83	12.0 - 45.0	31.57	80.61	50
COD, mg/l	45.5 - 528.0	301.42	53.5 - 176	113.57	62.32	250
TSS, mg/l	60 - 430	233.83	70 - 160	104.50	55.31	50
TDS, mg/l	356 - 790	580.83	303 - 343	329.00	43.36	1000
Nitrate-N, mg/l	0.09 - 2.65	0.86	0.09 - 2.73	0.72	16.47	50
Nitrite-N, mg/l	<0.001-3.29	1.12	0.04 - 6.13	2.51	-124.16	-
Ammonia-N, mg/l	0.32 - 82.00	15.99	0.30 - 2.80	1.05	93.43	1.0
Phosphate-P, mg/l	0.19 - 53.90	12.04	0.31 - 2.15	0.96	92.00	2.0
T Coliform, N/100ml	37200 - 10230000	2950000	13900 - 110000	55800	98.11	400 MPN/100ml
E Coliform, N/100ml	10000 - 7230000	492000	300 - 22400	20700	95.79	0. MPN/100ml

4.2.2 pH

The influent samples analyzed were slightly alkaline and ranged from 7.45 to 8.16 with a mean value of 7.76. The effluent wastewater was also alkaline and ranged from 7.82 to 9.07 and recorded a mean pH of 8.20. The mean values were all within EPA Ghana guideline range of 6 to 9. Figures 4.1 is a plot of the mean influent (INF) and mean effluent (EFF) pH results of waste stabilization ponds (WSP) and activated- sludge treatment plant (ASTP) and Ghana EPA guideline.

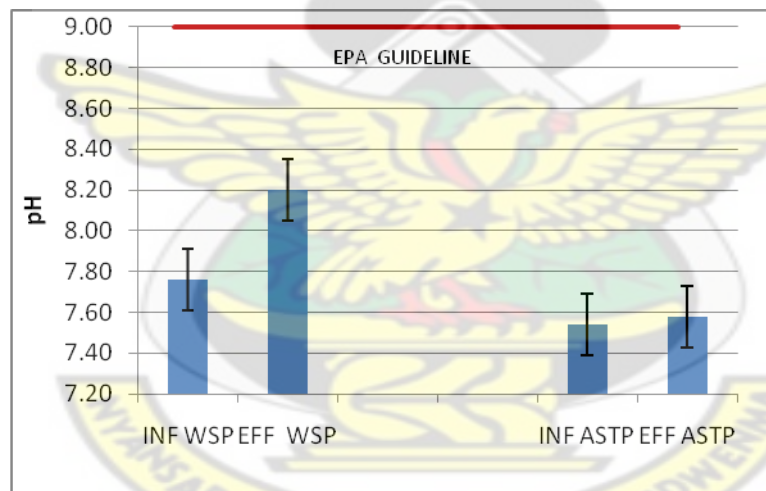


Figure 4.1: Mean Influent and Effluent pH and EPA Ghana guideline

4.2.3 CONDUCTIVITY

The conductivity of the influent ranged from 533 $\mu\text{S}/\text{cm}$ to 1571 $\mu\text{S}/\text{cm}$ with a mean of 1030.5 $\mu\text{S}/\text{cm}$. The conductivities of the final effluent were all less than 567 $\mu\text{S}/\text{cm}$ with a mean of 522 $\mu\text{S}/\text{cm}$. The mean conductivity values for both

the influent and the effluent were satisfactory compared to Ghana EPA guideline of 1500 $\mu\text{S}/\text{cm}$. Figure 4.2 is a plot of the mean influent and effluent conductivity results of the treatment systems in the study and Ghana EPA guideline.

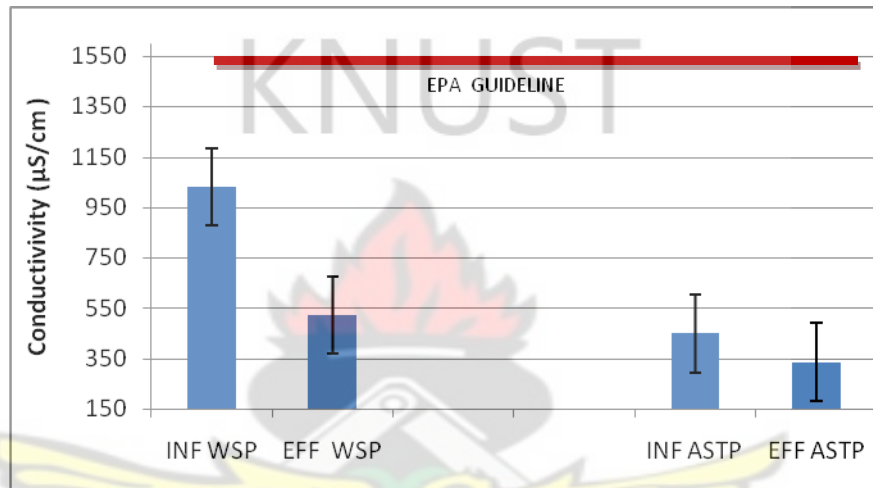


Figure 4.2: Mean Influent and Effluent conductivity and EPA Ghana guideline

4.2.4 Turbidity

The influent turbidity values of the waste stabilization ponds were between 50.5 and 584.0 NTU and the mean was 318.3 NTU. The final effluent turbidity ranged from 70.2 to 128.0 NTU with a mean of 96.2 NTU. The mean overall turbidity removal efficiency of the treatment ponds was 69.78%. The treated effluent was higher than the EPA Ghana guideline value of 75 NTU. Figure 4.3 is a plot of the mean influent and effluent turbidity results and EPA Ghana guideline.

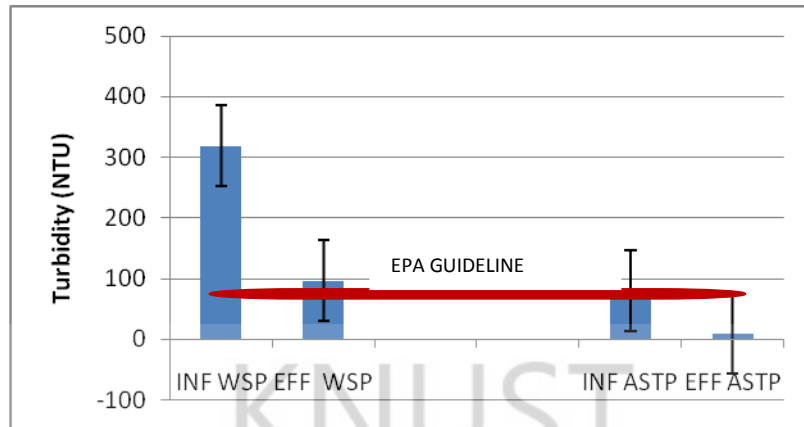


Figure 4.3: Mean influent and mean effluent turbidity and EPA Ghana guideline

4.2.5 Colour

The colour values of the influent wastewater measured ranged from 50 to 500 TCU, and the calculated mean was 237.5 TCU. The final effluent colour ranged from 50 to 350 TCU with a mean value of 185.5 TCU. The final effluent mean value was less than EPA guideline of 200 TCU. Figure 4.4 is a plot of mean influent and effluent colour of the waste stabilization ponds and the Activated-sludge treatment plant and EPA Ghana guideline.

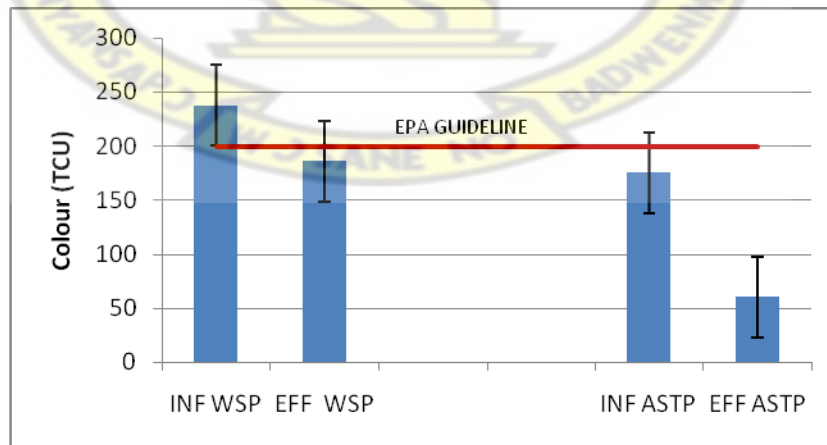


Figure 4.4: Mean influent and effluent colour and EPA guideline

4.2.6 Biological Oxygen Demand (BOD)

The influent BOD levels ranged from 16 mg/l to 340 mg/l with a mean load of 162.83 mg/l whilst a mean load of 31.57 mg/l was discharged in the final effluent. The BOD levels of the effluent ranged from 12.0 mg/l to 45.0 mg/l. The BOD of the final effluent compared favourably to the EPA Ghana guideline of 50 mg/l as depicted in Figure 4.5. The mean overall BOD removal efficiency was 80.6%.

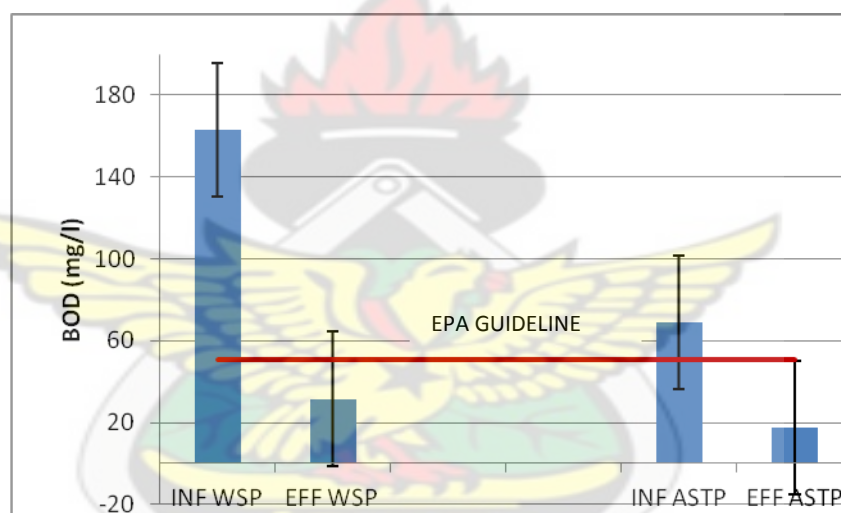


Figure 4.5: Mean influent and effluent BOD and EPA of Ghana guideline

4.2.7 Chemical Oxygen Demand (COD)

The COD levels of the influent wastewater ranged from 45.5 to 528.0 mg/l with a mean value 301.4 mg/l, whilst the final effluent COD ranged from 53.5 to 176 mg/l with a mean value of 113.6 mg/l. The mean overall removal efficiency was

62.3%. All the final effluent values measured were below the EPA guideline [Figure 4.6].

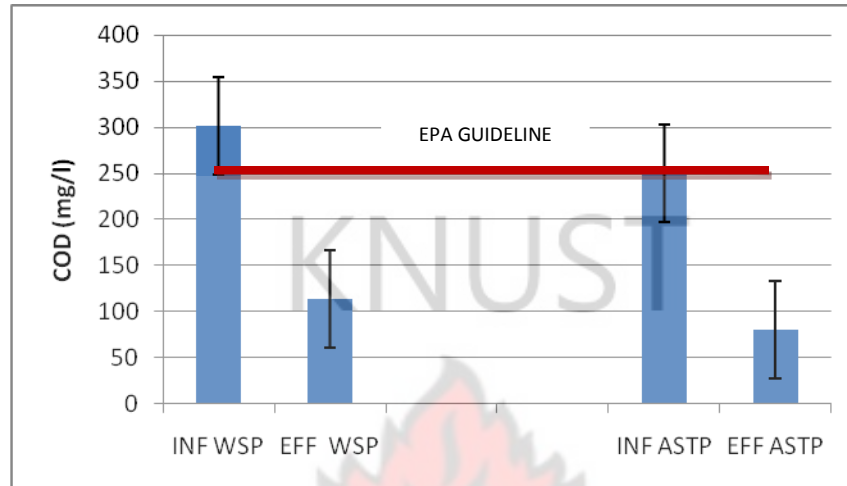


Figure 4.6: Mean COD influent and mean effluent and the EPA guideline.

4.2.8 Total Suspended Solids (TSS)

A mean value of 233.83 mg/l of influent rich in TSS was received into waste stabilization ponds and TSS levels ranged from 60 to 430 mg/l. The TSS of the treated effluent ranged from 70 to 160 mg/l with a mean value of 104.5 mg/l. The mean overall removal efficiency of the pond system was calculated to be 55.3%. The TSS concentrations of the samples measured were high than the Ghana EPA guideline value of 50 mg/l. Figure 4.7 shows a plot of the mean influent and the mean effluent of the two systems under study and Ghana EPA guideline.

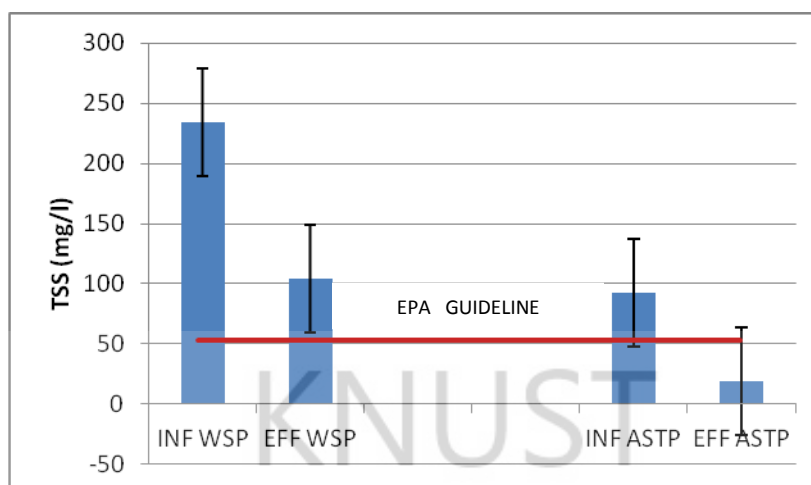


Figure 4.7: Mean influent and effluent TSS and EPA guideline

4.2.9 Total Dissolved Solids (TDS)

The TDS concentration of the influent wastewater ranged from 356 to 790 mg/l with a mean value of 580.83 mg/l. The TDS levels of the final effluent ranged from 303 to 343 mg/l with a mean of 329.0 mg/l. The mean overall TDS removal efficiency was calculated to be 43.36%. The TDS results from the study were all below the Ghana EPA guideline value of 1000 mg/l. Figure 4.8 is a plot of the mean influent (INF) and effluent (EFF) and EPA Ghana guideline.

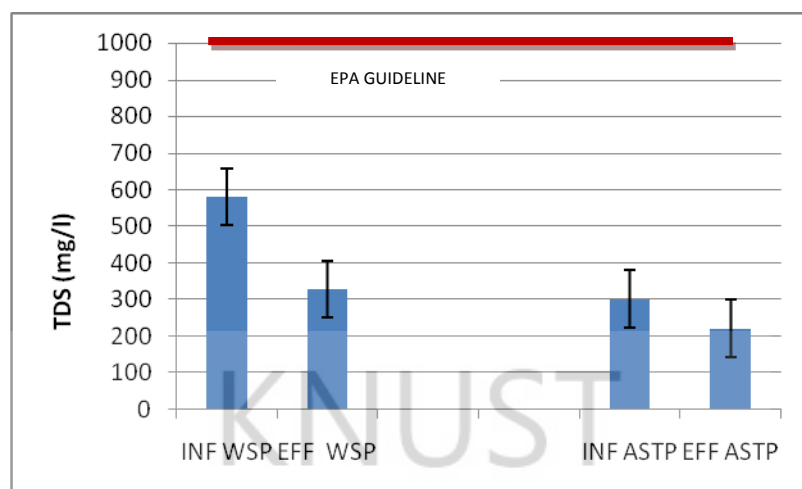


Figure 4.8: Mean influent TDS and effluent TDS and EPA guideline.

4.2.10 Nutrients

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

4.2.10.1 Nitrate-Nitrogen ($\text{NO}_3\text{-N}$)

The mean influent concentration of nitrate was 0.86 mg/l and the nitrate levels ranged from 0.09 to 2.65 mg/l. The effluent concentration of nitrate ranged from 0.09 to 2.73 mg/l with a mean effluent concentration of 0.72 mg/l. All the nitrate concentrations of both influent and the final effluent were satisfactory compared to the Ghana EPA guideline value of 50 mg/l. The mean overall nitrate removal efficiency of the pond system was 16.47%.

4.2.10.2 Nitrite-Nitrogen ($\text{NO}_2\text{-N}$)

The influent concentration of nitrite ranged from undetected values less than 0.001 to 3.29 mg/l with a mean value of 1.12 mg/l, whilst the effluent concentration ranged from 0.04 to 6.13 mg/l with a mean concentration of 2.51 mg/l.

4.2.10.3 Ammonia- Nitrogen ($\text{NH}_3\text{-N}$)

Free ammonia is formed as an initial product due to the decomposition of nitrogenous organic matter. The ammonia concentrations of the influent were between 0.32 to 82.0 mg/l with a mean value of 15.99 mg/l. The final effluent concentrations ranged from 0.3 to 2.8 mg/l with a mean concentration of 1.05 mg/l slightly higher than the Ghana EPA guideline value of 1.0 mg/l as shown in figure 4.9. The mean ammonia overall removal efficiency was calculated to be 93.4%.

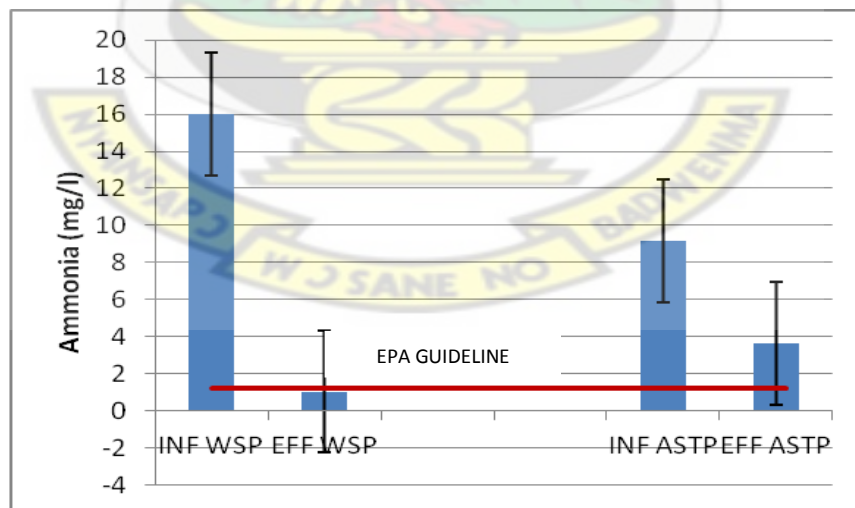


Figure 4.9: Mean influent and effluent ammonia and Ghana EPA guideline.

4.2.10.4 Phosphate-Phosphorus ($\text{PO}_4\text{-P}$)

The phosphate concentration of the influent ranged from 0.19 to 53.9 mg/l with a mean concentration of 12.04 mg/l whilst concentrations ranging from 0.31 to 2.15 mg/l with a mean value of 0.96 mg/l of the final effluent were discharged. The mean phosphate concentration of the final effluent was less compared to the Ghana EPA guideline value of 2.0 mg/l [Figure 4.10]. The mean overall phosphate removal efficiency of the pond system was 92.0%.

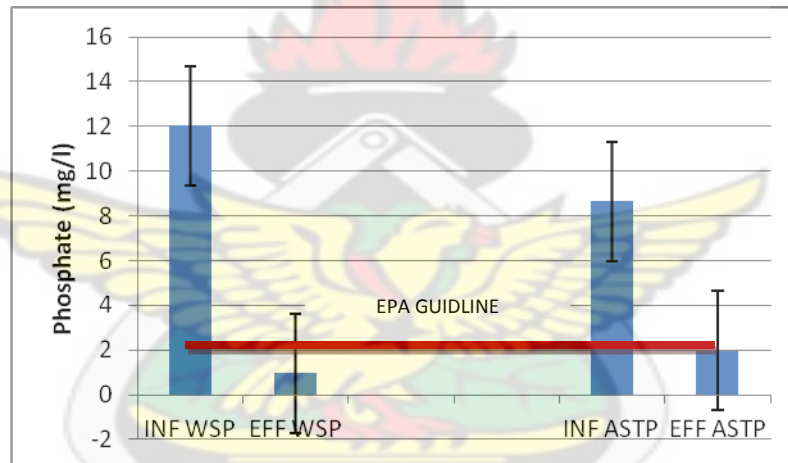


Figure 4.10: Mean influent phosphate and mean effluent and EPA guideline

4.2.11 Total Coliforms (TC) and Escherichia Coli (E. coli)

The factors that influence coliform removal in both primary facultative and maturation ponds include retention time, temperature, pH and light intensity (Hodgson, 2007). The influent total coliform levels ranged from 3.72×10^4 to 1.023×10^7 counts/100 ml with a mean value of 2.95×10^6 counts/100 ml. The

ponds final effluent levels ranged from 1.39×10^4 to 1.1×10^5 counts/100 ml with mean counts of 5.58×10^4 /100 ml. The mean total coliform removal efficiency was 98.1%.

The influent *E-coli* concentrations ranged between 1.0×10^4 to 7.23×10^6 counts/100ml with mean counts of 4.92×10^5 /100 ml, whilst the effluent *E-coli* concentrations were between 300 to 2.24×10^4 counts/100ml with a mean counts of 2.07×10^4 /100 ml. The mean overall *E-coli* removal efficiency was 95.79%. The mean final effluent results obtained for both total coliforms and *E- coli* concentrations are higher compared to the EPA Ghana guidelines of 400 counts/100 ml and 0 counts/100 ml respectively for discharge into natural water bodies.

4.3 Assessing quality of the Activated-sludge sewage treatment plant (ASTP)

Table 4.2 shows the mean values of the influent and the effluent parameters measured over a period of six months at the Activated-Sludge Sewage Treatment Plant (ASTP), the corresponding percentage mean overall removal efficiencies and the EPA Ghana guidelines for discharge into natural water bodies.

4.3.1 Temperature

The temperature of the raw sewage to the treatment plant ranged from 29.4 °C to 31.0 °C with a mean of 30.12 °C, whilst the final effluent temperature ranged from 27.8 °C to 30.0 °C and the mean temperature was 29.38 °C indicating a

slight drop compared to the influent temperature [Table 4.2]. The mean effluent temperature was within the EPA Ghana guideline of $<3^{\circ}\text{C}$ above ambient temperature which ranges between 29.5°C and 31.7°C .

4.3.2 pH

The mean pH of the influent wastewater was 7.54 and the pH levels ranged from 7.09 to 7.88 whilst the final effluent pH levels ranged from 7.42 to 7.66 with a mean pH of 7.58. All the influent and the effluent measured values were within to the Ghana EPA guideline range of 6 to 9, Figure 4.1 above shows the influent (INF ASTP) and effluent (EFF ASTP) and EPA guideline.

4.3.3 Conductivity

The conductivity of influent ranged from 278 to $694\ \mu\text{S}/\text{cm}$ and a mean of $488.83\ \mu\text{S}/\text{cm}$. The final effluent conductivity were between 314 to $354\ \mu\text{S}/\text{cm}$ with a mean of $335.83\ \mu\text{S}/\text{cm}$. The mean overall removal efficiency was 25.18%. The mean conductivity values for both the influent and the effluent satisfied the Ghana EPA guideline of $1500\ \mu\text{S}/\text{cm}$. Figure 4.2 above shows the influent (INF ASTP) and effluent (EFF ASTP) and EPA guideline.

Table 4.2: Removal Efficiency of the Activated-sludge waste treatment plant

MEAN OVERALL REMOVAL						
PARAMETER	INFLUENT		FINAL EFFLUENT		% REMOVAL	EPA STANDARDS
	RANGE	MEAN	RANGE	MEAN		
Temperature, °C	29.4 - 31.0	30.12	27.8 - 30.0	29.38	-	<3 ⁰ C above ambient
Ph	7.09 - 7.88	7.54	7.42 - 7.66	7.58	-	6 - 9
Conductivity, µS/cm	278 - 694	448.83	314 - 354	335.83	25.18	1500
Turbidity, NTU	52 - 124	79.57	5.70 - 21.3	10.91	86.29	75
Colour, TCU	75 - 225	175.00	25 - 150	60.42	65.48	200
BOD, mg/l	16 - 108	69.08	6 - 43.5	17.58	74.55	50
COD, mg/l	34.5 - 728	249.92	17.3 - 221.0	79.88	68.04	250
TSS, mg/l	80 - 123	92.12	4 - 43	19.28	79.07	50
TDS, mg/l	169 - 460	302.17	193 - 267	221.83	26.59	1000
Nitrate-N, mg/l	<0.001 - 0.08	0.35	0.20 - 1.52	0.73	-109.43	50
Nitrite-N, mg/l	<0.001 - 0.06	0.03	0.19 - 6.66	3.93	-15619.33	-
Ammonia-N, mg/l	0.40 - 40.0	9.18	0.43 - 8.98	3.61	60.69	1.0
Phosphate-P	1,54 - 36.5	8.64	0.82 - 2.59	1.96	77.27	2.0
Total Coliform, N/100ml	65100 - 376000000	66000000	15600 - 150000	53500	99.92	400 MPN/100ml
E Coli, N/100ml	2200 - 48000000	8315000	2000 - 16800	8700	99.90	0. MPN/100ml

4.3.4 Turbidity

The turbidity of the influent wastewater ranged from 52 to 124 NTU with a mean value of 79.57 NTU, whilst the final effluent turbidity levels ranged between 5.7 to 21.3 NTU with a mean of 10.91 NTU. The mean overall turbidity removal efficiency was 86.29%. The mean final effluent turbidity level was less than EPA guideline value of 75 NTU, as depicted in Figure 4.3.

4.3.5 Colour

The colour of the raw sewage ranged from 75 to 225 TCU, the mean value was 175 TCU. The final effluent colour ranged from 25 to 150 TCU with a mean value of 60.42 TCU. All final effluent levels were satisfactory compared with EPA guideline of 200 TCU [Figure 4.4]. The overall colour removal efficiency obtained was 65.48%.

4.3.6 Biochemical Oxygen Demand (BOD)

The BOD of the raw sewage to the plant ranged from 16 mg/l to 108 mg/l with a mean load of 69.08 mg/l whilst a mean load of 17.58 mg/l was discharged in the final effluent. The BOD levels of the effluent ranged from 6.0 mg/l to 43.5 mg/l. The results obtained in the study are in agreement with the EPA Ghana guideline of 50 mg/l. Figure 4.5 is a plot of the mean influent and the mean effluent BOD of the two waste treatment systems and the EPA Ghana guideline.

4.3.7 Chemical Oxygen Demand (COD)

The mean influent COD was found to be 249.92 mg/l and the COD levels ranged from 34.5 to 728 mg/l, while the final effluent COD levels ranged from 17.3 to 221.0 mg/l and a mean value of 79.88 mg/l. The mean overall removal efficiency was 68.04%. All the final effluent values measured were below the EPA guideline [Figure 4.6].

4.3.8 Total Suspended Solids (TSS)

A mean value of 92.12 mg/l of influent rich in TSS was received into Activated-sludge treatment plant and TSS levels ranged from 80 to 123 mg/l, whilst the TSS of the treated effluent ranged from 4 to 43 mg/l with a mean value of 19.28 mg/l. All the TSS concentrations of the final effluent measured were less compared to the Ghana EPA guideline value of 50 mg/l as depicted in Figure 4.7

4.3.9 Total Dissolved Solids (TDS)

A mean influent TDS value of 302.17 mg/l was observed with levels ranging from 169 to 460 mg/l, whilst levels of 193 to 267 mg/l of final effluent was discharged with mean value of 221.83 mg/l. The mean overall TDS removal efficiency was 26.59%. The TDS results from the study were all below the Ghana EPA guideline value of 1000 mg/l as shown in Figure 4.8

4.3.10 Nitrate- Nitrogen ($\text{NO}_3\text{-N}$)

From Table 4.2, the final effluent nitrate concentrations increased dramatically compared to that of the influent. The effluent nitrate concentrations ranging from 0.2 to 1.52 mg/l were greater than the highest influent nitrate value of 0.08 mg/l. The mean influent nitrate concentration was 0.35 mg/l, while that obtained for the effluent was 0.73 mg/l. All the Nitrate concentrations were less than the Ghana EPA guideline value of 50 mg/l.

4.3.11 Nitrite-Nitrogen ($\text{NO}_2\text{-N}$)

The results for nitrite showed similar trend like those of nitrate. The nitrite concentrations were high with greater variation in the effluent compared to the influent. Nitrite concentrations ranging from 0.19 to 6.66 mg/l were observed for the effluent with mean value of 3.93 mg/l, while levels less than 0.001 (not detected by equipment) to 0.06 mg/l with mean value of 0.03 mg/l were found for the influent.

4.3.12 Ammonia-Nitrogen ($\text{NH}_3\text{-N}$)

Ammonia concentrations of the influent ranged from 0.40 to 40 mg/l and the mean value was 9.18 mg/l, whilst the ammonia concentration of the effluent was between 0.43 to 8.98 mg/l with mean value of 3.61 mg/l. The overall removal efficiency was 60.69%.

4.3.13 Phosphate-Phosphorus ($\text{PO}_4\text{-P}$)

The mean influent phosphate concentration was 8.64 mg/l, whilst the mean of 1.96 mg/l was discharged in the effluent. The influent phosphate concentrations ranged from 1.54 to 36.5 mg/l and that of the effluent ranged from 0.82 to 2.59 mg/l. The mean phosphate removal efficiency during the study period was 77.27%. The mean phosphate concentration of the final effluent was found to be less than the Ghana EPA guideline value of 2.0 mg/l as depicted in Figure 4.10

4.3.14 Total Coliform (TC) and Escherichia coli (E Coli)

The influent Total Coliforms (TC) were found to vary from 65.1×10^3 to 37.6×10^7 counts/100ml with a mean of 66.0×10^6 counts/100ml, while counts of the effluent Total Coliform were found to vary from 15.6×10^3 to 15.0×10^4 /100ml with a mean 53.5×10^3 counts/100ml. The mean overall TC removal efficiency was 99.92%.

A similar trend of result was observed for *E. Coli*. The influent *E. Coli* varied from 22.0×10^2 to 48.0×10^6 counts/100ml with a mean value of 83.1×10^5 counts/ml, whilst the effluent *E. coli* reduced dramatically with mean value of 87.0×10^2 counts/100ml and levels ranged from 20.0×10^2 to 16.8×10^3 counts/100ml. The mean overall *E. coli* removal efficiency was 99.90%. The mean results of both total coliform and *E- coli* concentrations are above the EPA Ghana guideline of 400 counts/100 ml and 0 counts/100 ml respectively for the discharge into natural water bodies.

CHAPTER FIVE

5.0 DISCUSSION

5.1 The Physico-Chemical Parameters of (WSP)

The physico-chemical parameters used to assess the effluent quality of the waste stabilization ponds (WSP) are discussed in this section;

5.1.1 Temperature

The mean temperature of the final effluent to be discharged dropped slightly by 0.05°C compared to the mean temperature of the influent wastewater. The slight drop in temperature could be due to the loss of heat by convection to the atmosphere and conduction to the walls of the asbestos pipe conveying effluent to the receiving drain. The temperature values recorded for both influent and the final effluent remain in the temperature range for the growth and activeness of most micro-organisms (Pearson *et al.*, 1987). The mean effluent temperature was within the EPA Ghana guideline of $<3^{\circ}\text{C}$ above ambient temperature which ranges between 29°C and 32°C .

5.1.2 pH

All the samples were alkaline. The mean pH of the influent (7.76) and the final effluent (8.20) were within the pH range of 6 to 9. According to (Tchobanogolous *et al.*, 2003) this concentration range is suitable for the existence of most biological life. The alkalinity of the influent wastewater may be due to the presence of chemicals in soaps and detergents used for bathing, cleaning and washing in the households. The increase in effluent pH compared

to influent pH is attributed to the decrease in dissolved CO₂ concentration through a reduction in the concentration of organic matter due to oxidation during the treatment (Colmenarejoa *et al.*, 2006).

5.1.3 Conductivity

Generally conductivity of wastewater is measured to obtain the ability of the water to conduct electrical current. The mean conductivity of the final effluent was 522 µS/cm, which is low and satisfactory compared to the Ghana EPA guideline value. This corroborates low mean conductivity values of 224 µS/cm in March and 204 µS/cm in June obtained in a similar study to determine the effect of seasonal changes on the final effluent of waste stabilization ponds (Hodgson, 2007). The mean overall removal efficiency was calculated to be about 49%. The mean conductivity values for both the influent and the effluent were less than the Ghana EPA guideline value. The low conductivity levels may be attributed to low concentrations of dissolved ions present in the raw sewage.

5.1.4 Turbidity

Turbidity is a measure of the optical property of wastewater that causes light to be scattered and absorbed rather than transmitted in straight lines. It is another test used to indicate water quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. The discharging of effluents with high levels turbidity can cause sludge deposition and create anaerobic conditions in the receiving water body. The mean turbidity values of the influent and the effluent wastewater were 318.3 NTU and 96.2 NTU respectively. The

results showed the mean turbidity of the influent and that of the effluent exceeded the EPA Ghana guideline value of 75 NTU. This may be attributed to high levels of suspended matter such as phytoplankton (suspended algae) in the wastewater.

5.1.5 Colour

The colour of the wastewater is an indication that it contains contaminants of different materials and in varying concentrations. The mean colour of the influent wastewater was 237.5 TCU which was reduced to a mean value of 185.5 TCU after the treatment. The results showed that there was some form of treatment, with about 22% colour removal been achieved.

5.1.6 Biological Oxygen Demand (BOD)

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 *et al.*, 2004; Huertasa *et al.*, 2008). Effluents with high concentrations of BOD can cause depletion of natural oxygen resources which may lead to the development of septic conditions (Hodgson, 2000). Compared to the EPA Ghana guideline of 50 mg/l, the BOD of the final effluent was acceptable. The mean overall BOD removal efficiency of 80.6% is high compared with other waste stabilization ponds which give BOD removal efficiencies greater than 70% (Arceivala, 1981, Hodgson, 2007).

The BOD/COD ratio has been proposed as indicator for biodegradation capacity (Metcalf and Eddy Inc., 1985). If BOD/COD ratio is more than 0.5 biodegradation will readily take place, if between 0.2 and 0.4 biodegradation will occur only in favorable thermal situation and if the ratio is below 0.2 biodegradation will not proceed (Contreras *et al.*, 2003). It was found that domestic wastewater has typically a BOD/COD ratio between 0.4 and 0.8 (Metcalf and Eddy Inc., 1985) and as reference, a BOD/COD ratio of 0.4 is generally considered the cut-off point between biodegradable and not biodegradable waste (Uz *et al.*, 2004). In this study, BOD/COD ratio in raw influent was around 0.54, which indicates the presence of considerable amount of organic materials vulnerable to biodegradation.

5.1.7 Chemical Oxygen Demand (COD)

The study showed that the mean COD level of the influent wastewater was 301.4 mg/l and final effluent was 113.6 mg/l. This showed a mean overall COD removal efficiency of 62.3%, which is low compared to 77.0% obtained in a similar study (Hodgson, 2007). The ratio of BOD to COD for the raw sewage was 0.54, which signifies high level of biodegradability.

5.1.8 Total Suspended Solids (TSS)

TSS is a very important quality parameter in wastewater treatment. High concentrations of suspended solids can cause many problems for stream health and aquatic life. The discharging of effluents with high levels of Suspended Solids can cause sludge deposition and create anaerobic conditions in the

receiving water body (Hodgson, 2000). High TSS can also cause an increase in surface water temperature and cause dissolved oxygen levels to fall, which can harm aquatic life in many other ways (Mitchell and Stapp, 1992).

A mean value of 233.83 mg/l of influent rich in TSS was received into waste stabilization ponds; while a mean TSS value of 104.5 mg/l treated effluent was discharged. The mean overall removal efficiency of the pond system was 55.3% which is low. Hodgson, (2007) reported TSS removal of 83.5% in a similar study at Akosombo, Ghana. TSS removal of 46.0% was also observed in treatment ponds in Akuse (Hodgson, 2000). The presence of high concentrations of algae in the final effluent may have influenced the TSS removal results in this study. All the TSS concentrations of the samples measured were unsatisfactory compared to the Ghana EPA guideline value of 50 mg/l. The high TSS concentrations 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.

5.1.9 Total Dissolved Solids (TDS)

TDS are a measurement of inorganic salts, organic matter and other dissolved materials in water. TDS cause toxicity through increases in salinity, changes in the ionic composition of the water, and toxicity of individual ions. The mean TDS concentration of the influent wastewater was 580.83 mg/l, and the final effluent was 329.0 mg/l. This showed that the treatment was able achieve overall mean TDS removal efficiency of 43.36%, which is low. This could be due to

low concentrations of dissolved inorganic and organic molecules and ions present in the wastewater.

5.1.10 Nitrate-Nitrogen ($\text{NO}_3\text{-N}$)

Nitrate in water is the end product of the aerobic stabilization of organic nitrogen and may enter the environment via run offs from agricultural lands or in treated effluents from wastewater plants. The study showed that all nitrate concentrations of both the influent and the final effluent were satisfactory compared to the Ghana EPA guideline value of 50 mg/l. The mean overall nitrate removal efficiency of the pond system was 16.47%. This is low when compared to 48.8% mean nitrate removal efficiency observed in waste stabilization ponds at Akuse, Ghana (Hodgson, 2000). The low percentage removal efficiency, the low influent and effluent nitrate concentration during the study could be attributed to the denitrification by bacteria, where nitrate is converted into nitrite and subsequent conversion of nitrite to nitric oxide, gaseous nitrous oxide and molecular nitrogen into the atmosphere under anaerobic conditions.

5.1.11 Nitrite-Nitrogen ($\text{NO}_2\text{-N}$)

The nitrite concentration of the influent wastewater of mean value 1.12 mg/l was received into the pond system, whilst mean value of 2.51 mg/l of the final effluent was discharged into the nearby stream. The increased effluent nitrite concentration compared to the influent showed that the ponds system was not efficient in treating nitrite. This could be attributed to unfavourable conditions

for nitrite oxidizing bacteria in the ponds. The Ghana EPA guideline value for nitrite could not be established. The mean effluent nitrite concentration of over 2.5mg/l is high and is not satisfactory compared to Switzerland official maximum concentration of 0.3 mg NO₂-N/l (Eawag, 2003). Nitrite is a strong fish poison and is considered as a possible cause of fishes populations decrease in Swiss waters (Fischnetz, 2004).

5.1.12 Ammonia- Nitrogen (NH₃-N)

Free ammonia is formed as an initial product due to the decomposition of nitrogenous organic matter. Generally the results obtained from the study, indicated that the ammonia concentrations of the influent wastewater were high compared to the ammonia concentrations of the effluent. The mean ammonia concentration of the influent was 15.99 mg/l and that obtained for the effluent was 1.05 mg/l. The high influent values could be due the anaerobic decomposition with the liberation of ammonia and the low final effluent values could be due to the volatilization of ammonia during the treatment processes. The mean final effluent results 1.05 mg/l was slightly above the Ghana EPA guideline value of 1.0 mg/l as shown in figure 4.9. The mean ammonia overall removal efficiency was calculated to be 93.4% which is appreciably high. Mara *et al.* (1992) and Mara *et al.* (1998) report a total nitrogen removal of 80% in all waste stabilization pond systems and 95% ammonia removal. Hodgson (2000); Hodgson (2007) reported comparable results of 92.0% and 93.1% respectively.

5.1.13 Phosphate-Phosphorus (PO₄-P)

While phosphates are not toxic and do not represent a direct health threat to human or other organisms, they do represent a serious threat to water quality. Phosphate can interfere with treatment process at concentrations as low as 0.2 mg/l (Peavey *et al.*, 1985). Phosphorus concentration of 0.01 mg/L can result in eutrophication (Nkegbe *et al.*, 2005). The mean phosphate concentrations of the influent and the effluent were 12.04 mg/l and 0.96 mg/l respectively. The results from study showed that the mean overall phosphate removal efficiency of the pond system was 92.0%, which is appreciably high and comparable to 94.0% obtained in a similar study (Hodgson, 2000).

5.1.14 Total Coliforms (TC) and Escherichia Coli (E. coli)

The factors that influence coliform removal in both primary facultative and maturation ponds include retention time, temperature, pH and light intensity (Hodgson, 2007). The total coliform of the influent wastewater reduced from mean value of 2.95×10^6 counts/100 ml to a mean of 5.58×10^4 /100 ml of the final effluent discharged. The mean total coliform removal efficiency was 98.1%. This is low compared to other waste stabilization ponds which give total coliform removal efficiency of 99.43% (Hodgson, 2007) and 99.99% (Hodgson, 2000). Waste stabilization ponds usually give such high micro-organism removal efficiencies. The low removal efficiency could be attributed to the low pH levels of the pond water which was less than 9.07 units. (Arceivala, 1981) reported that the die-off rate of the micro-organisms was accelerated when the

pH of the pond water was greater than 9.3 units. The low removal efficiency could also be due to the temperature of the pond water which never exceeded 31°C (mean temperature 29.9 °C). Studies have shown that temperatures greater than 37 °C must be maintained for 15 days to kill coliforms (Kudva *et al.*, 1998; Larney *et al.*, 2003).

Similarly the influent *E-coli* concentration of mean counts of $4.92 \times 10^5/100$ mg/l was reduced to effluent *E-coli* concentration of mean counts of $2.27 \times 10^4/100$ mg/l. The mean overall *E-coli* removal efficiency was 95.79% in this study, which is low compared to other waste stabilization ponds which give *Escherichia Coli* removal efficiency of 99.99% (Hodgson, 2007; Hodgson, 2000). Similarly, the low percentage *E-coli* removal efficiency of the pond water could be attributed to the low pH and low temperatures which never exceeded 31 °C. The mean final effluent results for both total coliforms and *E- coli* concentrations are unsatisfactory and do not meet the EPA Ghana guidelines of 400 counts/100 ml and 0 counts/100 ml respectively for discharge into natural water bodies.

5.2 The Physico-Chemical Parameters of (ASTP)

The physico- chemical parameters used to assess the effluent quality of the Activated- Sludge Treatment Plant are discussed below;

5.2.1 Temperature

The mean temperature of the influent wastewater was 30.12 °C, whilst the final effluent mean temperature was 29.38 °C indicating a slight drop compared to the influent temperature. The drop in temperature could be due to the loss of heat by convection to the atmosphere and conduction to the walls of the receiving tanks of the treatment plant. The temperature values obtained are in the temperature range suitable for the growth and activeness of most micro-organisms (Pearson *et al.*, 1987). Mostly optimum temperatures for bacterial activities are in the range from about 25 °C to 35 °C (Tchobanoglous *et al.*, 2003).

5.2.2 pH

Similar to the results obtained for the waste stabilization ponds, all the influent and the effluent samples analyzed were alkaline. The mean influent and effluent pH were 7.09 and 7.58 respectively. The results lie in a pH range which is optimum and favours the growth of most micro organisms (Pearson *et al.*, 1987). All the influent and the effluent analysed were satisfactory compared to the Ghana EPA guideline range of 6 to 9.

5.2.3 Conductivity

The mean conductivity of the raw sewage was 488.83 µS/cm, and the mean value of 335.83 µS/cm was calculated for the effluent wastewater. These conductivity values for the influent and the effluent were satisfactory compared with Ghana EPA guideline of 1500 µS/cm. The mean overall removal efficiency

was 25.18% which is relatively low. This could be attributed to low concentrations of dissolved ions present since the raw sewage is mostly blackwater.

5.2.4 Turbidity

High levels of turbidity in industrial effluents contribute large amounts of suspended solids to receiving water bodies. The mean turbidity of the influent wastewater was 79.57 NTU, whilst mean turbidity of the final effluent was 10.91 NTU. The mean overall turbidity removal efficiency was 86.29% which is high. The high total suspended solids removal and the significantly high micro organisms' removal (Table 4.2), might have influenced the results. The reduction in turbidity values is directly linked with that of TSS and Total coliform (Awuah and Abrokwa, 2008). The mean final effluent turbidity level was satisfactory compared to the Ghana EPA guideline value of 75 NTU.

5.2.5 Colour

The colour of the wastewater is an indication that it contains contaminants of different materials and in varying concentrations. A mean colour of value 175 TCU of the raw sewage was received in the ASTP, while a mean colour of value 60.42 TCU effluent was discharge from the plant. The results showed that there was some form of treatment, with about 65.48% colour removal been achieved.

5.2.6 Biochemical 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). The mean influent BOD load was 69.08 mg/l and the maximum sampling load was 108 mg/l, whilst a mean load of 17.58 mg/l was discharge in the effluent. The maximum sampling load obtained for the effluent was 43.5 mg/l. The results obtained in the study are in agreement with the EPA Ghana guideline of 50 mg/l. The BOD/COD ratio of the raw influent was calculated to be about 0.28 which indicates the presence of considerably, small amounts of organic materials vulnerable to biodegradation. The mean overall BOD removal efficiency of 74.55% is high.

5.2.7 Chemical Oxygen Demand (COD)

The mean influent COD from the study was 249.92 mg/l and the maximum sampling value was 728 mg/l, while the maximum final effluent COD was 221.0 mg/l and a mean value of 79.88 mg/l. The mean overall removal efficiency was 68.04%. All the final effluent values measured satisfied the limit set by Ghana EPA.

5.2.8 Total Suspended Solids (TSS)

TSS and turbidity are indicators of the aesthetic aspects of water and are increasingly accepted as physico-chemical parameters for monitoring performance of wastewater treatment plant and quality in water reuse. They are of low cost, easy to analyze and they are informative (Hamoda *et al.*, 2004;

Arevalo *et al.*, 2009).). A mean value of 92.12 mg/l of influent rich in TSS was received into Activated-sludge treatment plant and a mean TSS value of 19.28 mg/l was discharged in the effluent. The low TSS value of the effluent is due to sedimentation of the activated sludge. This is a good indicator of the high performance of the plant in the removal of organic and inorganic suspended materials (Alberta Environment, 2000; MWE, 2006). The mean overall removal efficiency of the plant was 79.07% which is relatively high. All the TSS concentrations of the final effluent were acceptable compared to the Ghana EPA guideline.

5.2.9 Total Dissolved Solids (TDS)

The maximum TDS value obtained for all the samples analyzed was 460 mg/l, which indicated that the TDS results were below the Ghana EPA guideline value of 1000 mg/l. The mean TDS values of the influent and the effluent wastewater were 302.17 mg/l and 221.83 mg/l respectively. The results observed shows that the plant under study is performing well comparing to similar plants; Santa Rosa Laguna and Montecito Sanitary District plants both in California, USA where values 484 and 940 respectively of final effluent are discharged (Asano and Tchobanoglous, 1987). The mean overall TDS removal efficiency was 26.59% which is low and could be attributed to low concentrations of dissolved inorganic and organic molecules and ions present in the wastewater.

5.2.10 Nitrate- Nitrogen (NO₃-N)

All the nitrate concentrations of the effluent were higher than those obtained in the influent wastewater. The mean influent nitrate concentration was 0.35 mg/l while that of the effluent was 0.73 mg/l, which may indicate poor treatment of nitrate by the plant due to slow rate of denitrification. According to Horne (1995), bacterial nitrification and denitrification have the greatest nitrogen removal potentials. The high nitrate concentration may be due to the fact that more organic matter was broken down to oxides and nitrate (Nkegbe *et al.*, 2005). The results obtained in the current study are favourable compared to those of Santa Rosa Laguna and Montecito Sanitary District plants in California, USA with levels of 8 mg/l and 5 mg/l respectively (Asano and Tchobanoglous, 1987). All the Nitrate concentrations were acceptable compared to the Ghana EPA guideline value of 50 mg/l.

5.2.11 Nitrite-Nitrogen (NO₂-N)

In Activated Sludge systems Nitrite develops as an intermediate product of nitrification and denitrification. Nitrite concentration in wastewater treatment plants (WWTP's) is very low under normal conditions around 0.1 mg/l (Eawag, 2003). Increased concentrations are usually an indication of a disturbance of microbiological processes, of an overloaded plant or insufficient aeration capacity. Microbiological inhibition can be caused by toxic substances, seasonal variations in temperature or generally unfavourable conditions for Nitrite Oxidizing Bacteria (Eawag, 2003).

The results for nitrite showed similar trend as observed for nitrate. The effluent nitrite concentrations were high compared to the influent. The mean nitrite concentration of the effluent was 3.93 mg/l, while the mean value of 0.03 mg/l was found for the influent. The increased effluents levels could be attributed to insufficient aeration (Eawag, 2003). During the current study it was observed that aeration was done for only two days per week, and the duration of the aeration was about 7 hours per day. The study could not establish any Ghana EPA guideline value for nitrite. The final effluent nitrite concentration of 3.93 mg/l was high and not satisfactory compared to Switzerland official maximum concentration of 0.3 mg NO₂-N/l (Eawag, 2003).

5.2.12 Ammonia-Nitrogen (NH₃-N)

The mean ammonia concentration of the influent wastewater was high compared to the mean concentration of the final effluent. The mean ammonia concentration of the influent was 9.18 mg/l, whilst the mean ammonia concentration of the effluent was 3.61 mg/l. The drop may indicate some rate of ammonium oxidation. According to Okoh (2010), the high influent values could be due the anaerobic decomposition with the liberation of ammonia and the low final effluent values could be due to the volatilization of ammonia during the treatment processes. From the current study the result obtained compared favourably to the plant at Santa Rosa Laguna district with the discharge of ammonia concentration of 10 mg/l. It is not in good agreement with the plant at the Montecito Sanitary District, California, USA with discharge of 1.4 mg/l

(Asano and Tchobanoglous, 1987). The proposed discharge limit to natural water bodies according to Ghana Environmental Protection Agency standard is 1.0 mg/L. Although there was 60.69% ammonia removal during the treatment process, the final effluent level was high and above the EPA acceptable limit.

5.2.13 Phosphate-Phosphorus ($\text{PO}_4\text{-P}$)

The mean influent concentration was 8.64 mg/l whilst the mean of 1.96 mg/l was discharged in the effluent. The reduction could be due to the presence of polyphosphate accumulating organisms present in the system. According to Beychok (1971) these micro-organisms can accumulate large quantities of up to 20% their mass of phosphorus in their cells. Microbes utilize phosphorus during cell synthesis and energy transport. As a result, 10 to 30 percent of the influent phosphorus is removed during traditional mechanical/biological treatment (Wenzel and Ekama, 1997; Mulder and Rensink, 1987; Metcalf and Eddy, 1991; Henze, 1996; Sedlak, 1991). The mean phosphate removal efficiency during the study period was 77.27%. The mean phosphate concentration of the final effluent was found to be satisfactory compared to the Ghana EPA guideline value of 2.0 mg/l.

5.2.14 Total Coliform (TC) and *Escherichia coli* (*E. Coli*)

The influent Total Coliforms (TC) recorded a mean value of 66.0×10^6 counts/100 ml, and the mean effluent TC was 53.5×10^3 counts/100ml. The mean overall TC removal efficiency was 99.92% which is high.

A similar trend of result was observed for *E. coli*. The mean influent *E. coli* calculated was 83.1×10^5 counts/ml, whilst the mean effluent *E. coli* was reduced to 87.0×10^2 counts/100ml. The mean overall *E. coli* removal efficiency was 99.90% which is also high. A decrease in *E. coli* by 60 – 70% was observed by (Kawamura and Kaneko, 1986) and attributed the reduction of pathogens to biological treatment. In this study the high pathogen removal efficiencies observed could be due to the settlement of bacteria, which are adsorbed on or entrapped within suspended solids (Paluszak *et al.*, 2002). Settling of organic matter with adsorbed coliforms has been proposed as a possible mechanism of coliform removal (Coombes and Collett, 1995). An observation by Gearheart (1999) indicated that sedimentation of suspended matter is an important coliform removal mechanism. The predatory activities of predator micro-organisms present in the treatment tanks which devour the bacteria could have also contributed to the high pathogen removal. The mean results of both total coliform and *E. coli* concentrations are unsatisfactory and do not meet the EPA Ghana guideline of 400 counts/100 ml and 0 counts/100 ml respectively for the discharge into natural water bodies.

5.3 Comparing the waste treatment systems

The two treatment systems during the study discharged effluent with temperature within the range of the ambient temperature, though the WSP discharged effluent with slightly higher temperature. The temperature of the effluent in the two systems yielded a p-value of 0.29 at $\alpha=5\%$ (appendix E),

indicating no significant difference between the two systems. The waste stabilisation ponds (WSP) achieved a higher mean overall removal efficiency of conductivity of over 49% compared to the 25% by the Activated-sludge treatment plant. The final effluent conductivity differ significantly ($p=0.000$) in both systems. Similarly the effluents pH of the two treatment plants differ significantly $p=0.011$ at $\alpha=5\%$. The study observed low removal efficiency of turbidity (69.78%) and colour (21.89%) for the WSP compared to that of the ASTP (86.29%) and (65.48%) respectively. However, the final effluent turbidities differ significantly ($p=0.000$), whilst the colour of the effluent of the systems indicated no significant difference ($p=0.054$) at 95% confidence interval.

On organic matter removal, whilst the WSP achieved a mean BOD removal efficiency of about 80%, that of the ASTP was about 74%. However, the COD removal of the WSP of about 62% was low compared to the ASTP of COD removal 68%. The effluent BOD and COD yielded p-values of 0.14 and 0.22 respectively, indicating no significant difference between the two systems.

The WSP obtained a low removal of TSS of 55% compared to 79% observed for the ASTP. Although the two treatment systems obtained low TDS removal efficiencies, the treatment performance of the WSP 43% was high when compared to that of the ASTP value of about 26%. The two systems differ significantly in the effluent recording p-values of 0.001 for TSS and 0.000 for TDS respectively.

The study revealed that the treatment performance of nutrients in the WSP system was high when compared to ASTP. Whereas the WSP system recorded mean overall removal of ammonia and phosphate above 90% [Table 4.1], the ASTP system recorded removal efficiency about 61% and 77% of ammonia and phosphate respectively. The nitrate removal of the WSP was just 16%, however, the nitrate removal of the ASTP was calculated to be negative (- 109%). Thus instead of an expected decrease, the effluent nitrate concentration rather increased; more than double, over that of raw influent nitrate concentration. Similarly, although the two systems recorded increased nitrite concentrations of the final effluent over that of the influent, the nitrite concentration of the ASTP system calculated was extremely high compared to the WSP system as indicated in tables 4.1 and 4.2. Apart from the phosphate effluent which differs significantly ($p=0.002$), all the other effluent nutrients; nitrate ($p=0.853$), nitrite ($p=0.112$) and ammonia ($p=0.109$) at $\alpha=5\%$, did not indicate any significant difference between the two treatment systems.

Hodgson, (2000) observed micro-organisms removal efficiencies of over 99.9% and stated that waste stabilization ponds usually give such high micro-organism removal. The results from the current study showed that the removal efficiencies of Total coliform (98.11%) and *Escherichia coli* (95.79%) of the WSP were low when compared to ASTP which recorded Total coliform and *Escherichia coli* efficiencies of 99.92% and 99.90 respectively. The final effluent Total coliform and *E. coli* of the WSP and the ASTP obtained p-values of 0.932 and 0.851 respectively, indicating no significant difference between the systems.

The WSP effluent quality parameters such as turbidity, TSS, Ammonia, TC and EC were not satisfactory compared to Ghana EPA guideline values, while the ASTP effluent parameters such as ammonia, TC and EC were also not satisfactory.

From the discussions above, most of the quality parameters studied including Temperature, Colour, BOD, COD, Nitrate, Nitrite, Ammonia, Total Coliform and *E. Coli* showed statistically no significant difference between the effluent of the two treatment systems. Parameters which include pH, Conductivity, Turbidity, Total Suspended Solids, Total Dissolved Solids and Phosphate, statistically differ significantly between the treatment systems.



CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Based on the study conducted to determine the quality of the effluent from the two wastewater systems the following conclusions have been made:

- The treated effluent from the activated-sludge treatment plant met most of the criteria set by EPA of Ghana; however parameter such as ammonia was unsatisfactory.
- The treated effluent from the waste stabilization ponds met most of the criteria set by EPA of Ghana; however parameters such as turbidity, TSS, ammonia were unsatisfactory.
- Although the two treatment systems achieved high pathogen micro-organisms reduction greater than 95%, the final effluent contain total coliforms and *E.coli* levels which were not in good agreement with the permissible levels set by EPA of Ghana for the discharge into receiving environment.
- The treatment plants were not efficient in treating nutrients such as nitrate and nitrite. The effluent discharged is likely to cause undesirable phytoplankton growth in the receiving water body (Hodgson, 2007).
- The performance of the activated sludge treatment plant appears to be high compared to the waste stabilization ponds. This could be due probably to the strength of the raw sewage of ASTP which is weaker

(mean BOD level of 69.08 mg/l) than that of the WSP of mean BOD level of 162.83 mg/l.

- Statistically most of the quality parameters of the final effluent showed no significant difference between the two wastewater treatment systems.

6.2 Recommendation

- Disinfection of the effluent wastewater may be carried out before final discharge into receiving water bodies.
- The damaged embankments of the waste stabilization ponds should be repaired
- Regular cleaning of the inlet and the outlet chambers of the waste stabilization ponds are recommended.
- The time or period of aeration of the Activated- sludge treatment plant should be increased to enhance activated sludge formation and separation through sedimentation.

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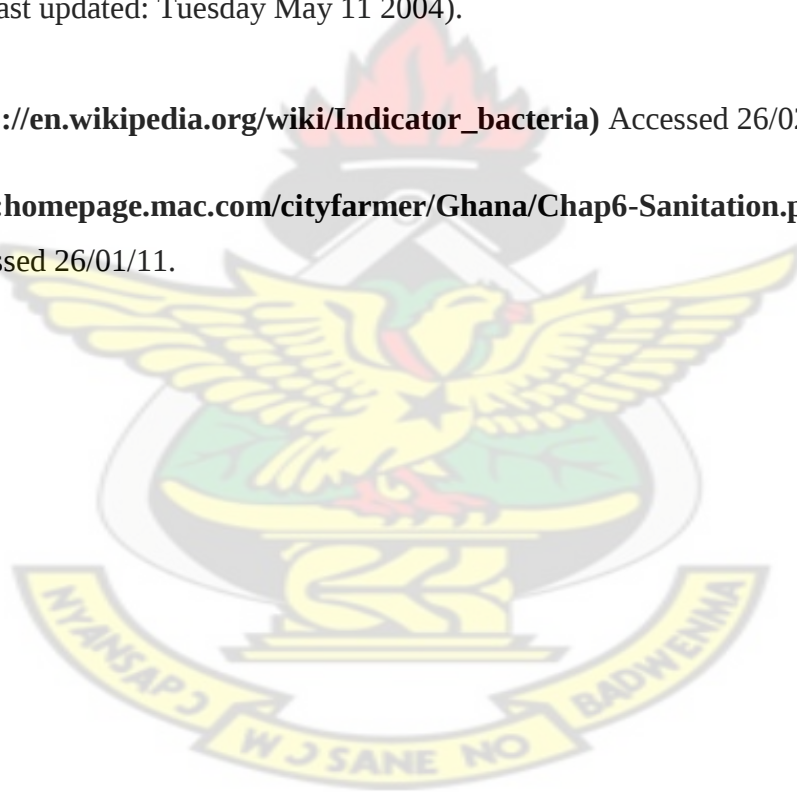
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APPENDICES

Appendix A: A1: Drainage map of Juapong



Appendix B: B1.0 Description of Production Activities

The main production processes comprise opening, carding, drawing, roving, spinning, winding, warping, sizing, weaving of cotton yarn into grey baft or grey cloth and inspection and delivery of grey baft.

The factory consists of the main Security Block, Spinning Block, Weaving/Finishing Block, Maintenance Workshop, Cotton Warehouse, Material Warehouse, Boiler House, Canteen Block, Accounts and Administration Blocks and The Residential Quarters. Others include the Activated-Sludge Sewage Treatment Plant (STP), Transport. The operation of the Water Treatment Plant (WTP) at the time of this study has been transfer to the Ghana Water Company Limited at kpong.

B2.0 Wastewater Management at VSTL

B2.1 The Volta Star Textiles Limited Waste Treatment Plant

The treatment plant is the activated- sludge type and consists of five main components; Screening, Dorr Clarifier, Dorr-Oliver Surface Aerators, Final Settling Tank and Cold Digester Tank.

B2.2 Screening

The screening section is a small rectangular chamber 1.4m by 0.5m and consists of vertical screen steel bars distributed equally across the channel through which

the wastewater flows. Preliminary wastewater treatment is achieved by the removal of wastewater constituents that may cause maintenance or operational problems with the treatment operations, processes and ancillary systems. Examples are screening for the removal of debris, cotton fluffs, rags, grit removal for the elimination of coarse suspended matter that may cause wear or clogging of equipment.

B2.3 Dorr Clarifier

The Circular Peripheral Flow Dorr Clarifier is for primary treatment and involves the partial removal of suspended solids and organic matter from the wastewater by means of physical operations by screening and sedimentation. It is circular in shape, has a capacity of 40 m^3 and is made of inner stainless steel and outside reinforce concrete wall. It operates with the wastewater flow entering the system at the periphery. The wastewater flow is distributed evenly and spirals down around the annulus of the clarifier. It is offered with a rake drive which travels on the peripheral tank wall. It is automatically operated and desludging is done periodically.

B2.4 Dorr-Oliver Aerator Clarifier

The Dorr-Oliver Aerator Clarifier is the first stage of secondary treatment and it is rectangular concrete tank with capacity of 170 m^3 . Wastewater, after primary settling, is pumped into the aerator clarifier (an aeration basin) where it is mixed with an active mass of microorganisms, mainly bacteria and protozoa, which

aerobically degrade organic matter into carbon dioxide, water, new cells, and other end products. The mechanical agitator in the clarifier ensures an aerobic environment is maintained, which also serves to keep the wastewater and the microorganisms (the mixed liquor) completely mixed and kept in suspension. After a specific retention time, the mixed liquor discharges into the final settling tank (secondary clarifier) for further treatment. It is automatically operated.

B2.5 Final Settling Tank

The final settling tank is rectangular in shape, made of concrete and has a capacity of 140m^3 . The Final Settling Tanks receives the overflow (the mixed liquor) of the aeration tank where the activated sludge settles out. The sludge is still active and it is able to remove more BOD from the wastewater. A portion of the settled sludge (return sludge) is returned to the aeration tank to maintain an optimum concentration of acclimated microorganisms in the aeration tank to break down the organics. This is a key factor to increase BOD removal from the wastewater. Occasionally, a portion of the settled sludge (excess sludge) is discarded to maintain the required solids retention time for effective organic removal.

B2.6 Cold Digester Tank

The cold digester receives sludge removed from the primary dorr clarifier and the discarded sludge in the final settling tank. It has a capacity of 340m^3 and it is cylindrical in shape. The sludge is stabilized through biological activity and involves the anaerobic reduction of organic matter in the sludge by anaerobic

microorganisms. Gases produced are allowed to escape through a vent pipe at the top of the digester. Periodically the processed sludge is discharged into the drying bed.

B3.0 SIC Waste Stabilization Ponds (WSP)

The Waste Stabilization Ponds at the SIC Lowcost Housing Estates consist of one facultative pond and a maturation pond. The facultative pond has a depth of about 1,5 m and covers an area of about 4780 m², while the maturation pond covers about 2770 m² with a depth of about 0.8m. The embankments of the ponds are made of soil (clay). The sewage enters a concrete retention chamber where pre-treatment or screening takes place to remove rags, tissues, sand etc., and then flows by gravity to the facultative pond.

In the facultative pond, aerobic and anaerobic biological activities by microorganisms take place to remove organic matter. Maturation pond serves as an aerobic system and used as post treatment to facultative ponds, to further polish or reduce organic matter, remove pathogenic microorganisms and nutrients before disposal into natural water bodies.

Appendix C: Results of influents and effluent analysis - Waste Stabilization Ponds (WSP) and Activated Sludge Sewage Treatment Plant (ASTP)

Appendix C.1

Table C.1 : Results of influents analysis - Waste Stabilization Ponds (WSP)									
Parameter	Sampling points/ Date Sampled						MEAN	Standard Deviation	Standard error
	1	2	3	4	5	6			
Temperature, °C	30.4	30.1	31.0	29.4	29.0	29.8	29.95	0.71	0.29
Ph	8.16	7.48	7.45	7.75	7.86	7.88	7.76	0.27	0.11
Conductivity, µS/cm	533	708	781	1314	1571	1276	1030.50	411.47	167.98
Turbidity, NTU	50.5	85.3	177	584	526	487	318.30	240.07	98.01
Colour, TCU	50	200	150	375	150	500	237.50	167.15	68.24
BOD	99	16	132	198	340	192	162.83	109.60	44.74
COD	264	45.5	269	300	528	402	301.42	160.87	65.68
TSS	130	60	160	383	430	240	233.83	146.44	59.78
TDS	356	484	527	627	790	701	580.83	156.94	64.07
Nitrate-N	2.65	0.68	<0.001	0.75	0.135	0.092	0.86	1.04	0.47
Nitrite-N	<0.001	3.29	<0.001	<0.001	0.062	0.013	1.12	1.88	1.08
Ammonia-N	1.70	0.80	0.32	82.00	2.58	8.53	15.99	32.48	13.26
Phosphate-P	2.17	3.13	2.89	9.96	53.9	0.187	12.04	20.77	8.48
T Coliform, N/100ml	3255×10 ³	1023×10 ⁴	1488×10 ²	384×10 ⁴	372×10 ²	1860×10 ²	2950×10 ³	3946×10 ³	1611×10 ³
E Coliform, N/100ml	204×10 ³	186×10 ⁴	232×10 ²	465×10 ³	120×10 ²	100×10 ²	429×10 ³	723×10 ³	295×10 ³
All units are in mg/l unless otherwise stated									

Sampling Dates

- | | | |
|---------------|---------------|---------------|
| 1. 25/10/2010 | 2. 19/11/2010 | 3. 14/12/2010 |
| 4. 18/01/2011 | 5. 15/02/2011 | 6. 09/03/2011 |

Appendix C.2

Table C.2 : Results of effluents analysis - Waste Stabilization Ponds (WSP)									
Parameter	Sampling points/ Date Sampled						MEAN	Standard Deviation	Standard error
	1	2	3	4	5	6			
Temperature, °C	31.1	29.6	28.9	30.9	28.6	30.3	29.90	1.04	0.42
Ph	8.13	8.06	7.82	8.08	8.01	9.07	8.20	0.44	0.18
Conductivity, µS/cm	532	525	490	486	567	532	522.00	30.18	12.32
Turbidity, NTU	70.2	105	77	90	107	128	96.20	21.39	8.73
Colour, TCU	50	150	113	300	150	350	185.50	115.16	47.0133
BOD	28.5	45.0	34.4	31.5	12.0	38.0	31.57	11.15	4.55
COD	53.5	87.5	72.4	172	120	176	113.57	51.64	21.08
TSS	160	70	90	80	127	100	104.50	33.49	13.67175
TDS	303	341	333	340	343	314	329.00	16.60	6.78
Nitrate-N	2.73	0.650	0.350	0.400	0.096	0.091	0.72	1.01	0.41
Nitrite-N	6.13	4.17	2.18	2.49	0.038	0.078	2.51	2.37	0.97
Ammonia-N	0.32	0.500	0.400	2.80	1.98	0.298	1.05	1.07	0.44
Phosphate-P	0.308	1.25	0.68	0.526	2.15	0.868	0.96	0.66	0.27
T Coliform, N/100ml	13.9×10^3	4.0×10^4	220×10^2	110×10^3	744×10^2	744×10^2	558×10^2	368×10^2	15030.25
E Coliform, N/100ml	7.4×10^3	1.0×10^4	92×10^2	8.0×10^3	224×10^2	3.0×10^2	95.5×10^2	7183.80	2932.775

All units are in mg/l unless otherwise stated

Sampling Dates

- | | | |
|---------------|---------------|---------------|
| 1. 25/10/2010 | 2. 19/11/2010 | 3. 14/12/2010 |
| 4. 18/01/2011 | 5. 15/02/2011 | 6. 09/03/2011 |

Appendix C.3

Table C.3 : Results of influents analysis - Activated-Sludge sewage treatment plant (ASTP)

Parameter	Sampling points/ Date Sampled						MEAN	Standard Deviation	Standard error
	1	2	3	4	5	6			
Temperature, °C	30.0	29.4	30.5	31.0	29.7	30.1	30.12	0.57	0.23
Ph	7.20	7.70	7.09	7.88	7.73	7.62	7.54	0.32	0.13
Conductivity, µS/cm	452	533	365	694	371	278	448.83	147.97	60.41
Turbidity, NTU	52.4	55.1	76.6	79.9	124	89.4	79.57	26.14	10.67
Colour, TCU	75	200	150	200	225	200	175.00	54.77	22.36
BOD	73.5	16	108	107	68	42	69.08	36.12	14.75
COD	206	34.5	230	168	133	728	249.92	244.00	99.61
TSS	80.0	83.3	90	80	123	96.4	92.12	16.42	6.70
TDS	226	353	258	460	347	169	302.17	104.87	42.81
Nitrate-N	<0.001	<0.001	<0.001	0.800	0.063	0.185	0.35	0.40	0.23
Nitrite-N	<0.001	0.056	<0.001	<0.001	0.013	0.006	0.03	0.03	0.02
Ammonia-N	6.20	0.40	0.41	40.00	1.59	6.50	9.18	15.35	6.27
Phosphate-P	2.32	1.54	2.40	7.08	36.5	1.99	8.64	13.80	5.63
T Coliform, N/100ml	74.4×10 ³	1953×10 ⁴	186×10 ³	376×10 ⁶	651×10 ²	1209×10 ²	6600×10 ⁴	1521×10 ⁵	6208×10 ⁴
E Coliform, N/100ml	51.15×10 ³	1767×10 ³	558 ×10 ²	480 ×10 ⁵	22×10 ²	132×10 ²	8315×10 ³	1945×10 ⁴	7942×10 ³

All units are in mg/l unless otherwise stated

Sampling Dates

1. 25/10/2010
2. 19/11/2010
3. 14/12/2010
4. 18/01/2011
5. 15/02/2011
6. 09/03/2011

Appendix C.4

Table C.4 : Results of Effluents analysis - Activated-Sludge sewage treatment plant (ASTP)

Parameter	Sampling points/ Date Sampled						MEAN	Standard Deviation	Standard error
	1	2	3	4	5	6			
Temperature, °C	29.7	30.3	29.7	29.1	27.8	29.7	29.38	0.86	0.62
Ph	7.62	7.64	7.42	7.58	7.53	7.66	7.58	0.09	0.07
Conductivity, µS/cm	327	314	336	337	347	354	335.83	14.22	10.22
Turbidity, NTU	6.74	9.31	5.7	12.4	10	21.3	10.91	5.62	3.96
Colour, TCU	25	150	37.5	50	50	50	60.42	45.01	29.86
BOD	43.5	9	6	9	16	22	17.58	13.97	10.11
COD	62.6	17.3	21.1	51.3	106	221	79.88	76.27	55.74
TSS	22	6.67	43	4	20	20	19.28	13.88	9.30
TDS	193	216	208	203	267	244	221.83	28.08	22.44
Nitrate-N	<0.001	0.925	0.41	0.6	1.52	0.203	0.73	0.51	0.39
Nitrite-N	5.68	5.1	5.25	6.66	0.695	0.194	3.93	2.76	2.32
Ammonia-N	3.55	0.9	0.43	5	2.8	8.98	3.61	3.13	2.25
Phosphate-P	0.819	2.38	1.96	2.05	2.59	1.98	1.96	0.61	0.38
T Coliform, N/100ml	372×10 ²	150×10 ³	156×10 ²	60×10 ³	352×10 ²	232×10 ²	535×10 ²	496×10 ²	343×10 ²
E Coliform, N/100ml	48×10 ²	13×10 ³	84×10 ²	20×10 ²	168×10 ²	72×10 ²	87×10 ²	54×10 ²	41×10 ²

All units are in mg/l unless otherwise stated

Sampling Dates

- | | | |
|---------------|---------------|---------------|
| 1. 25/10/2010 | 2. 19/11/2010 | 3. 14/12/2010 |
| 4. 18/01/2011 | 5. 15/02/2011 | 6. 09/03/2011 |

Appendix D: Process flow diagrams of the VSTL Sewage Treatment Plant and the SIC Waste Stabilization Ponds

Figure D.1: Process flow diagram of the VSTL Sewage treatment plant

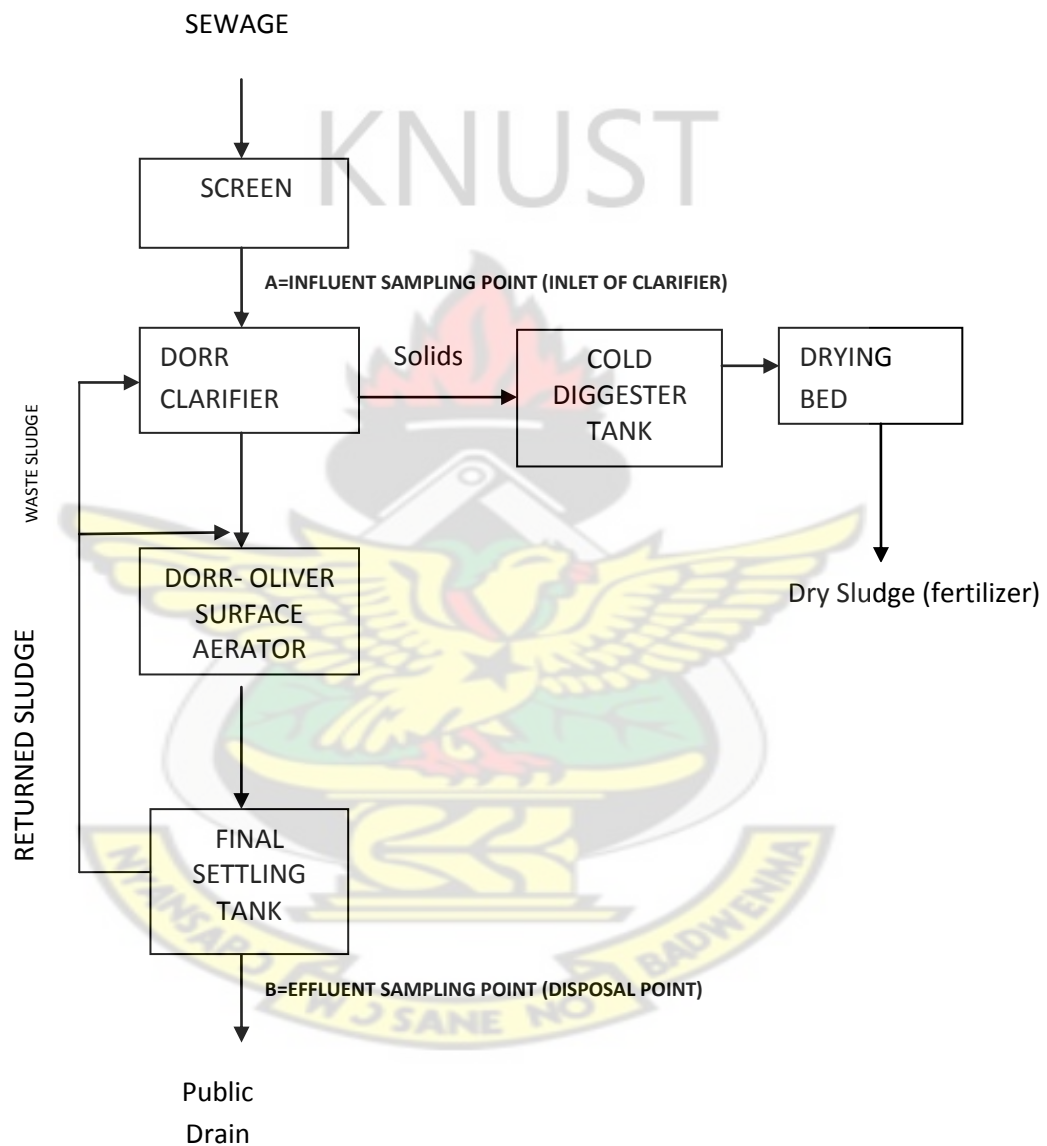
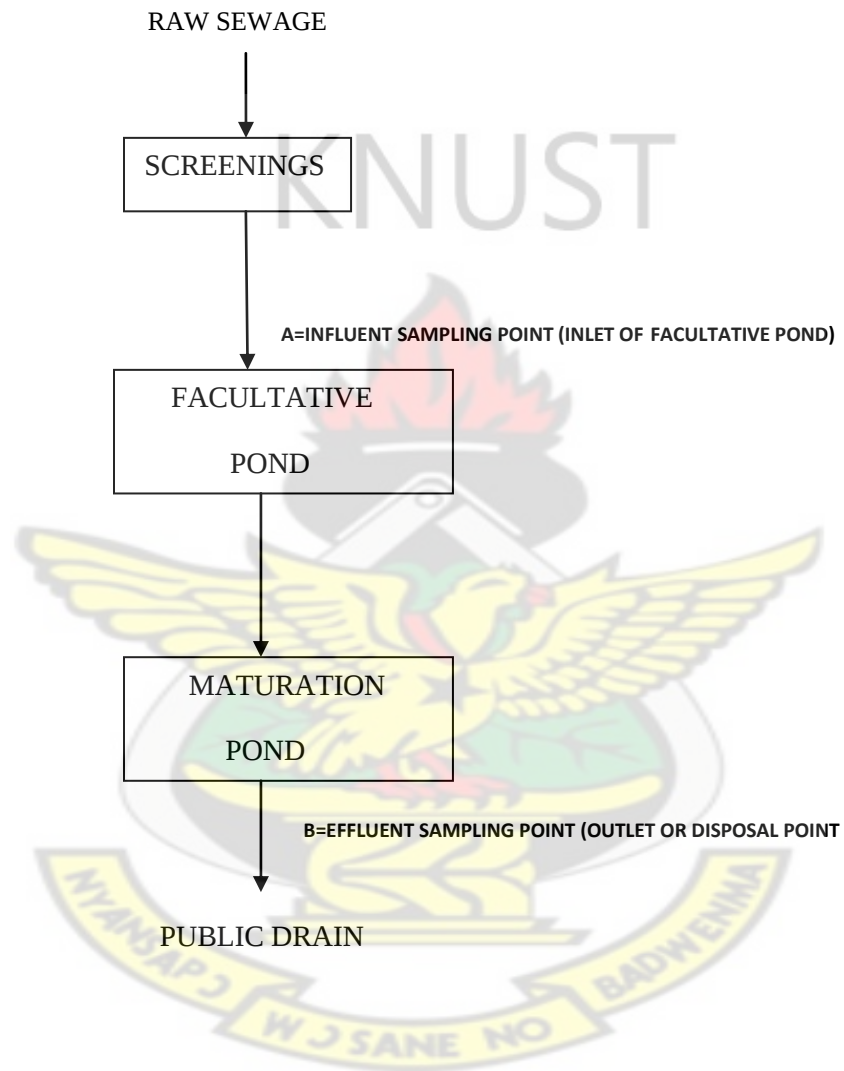


Figure D.2: Process flow diagram of SIC Stabilization ponds



Appendix E:

ANOVA

TEMPERATURE

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	6.244167	5	1.248833	2.180099	0.206243	5.050329
Columns	0.800833	1	0.800833	1.398022	0.290214	6.607891
Error	2.864167	5	0.572833			
Total	9.909167	11				

pH

Rows	0.6364	5	0.12728	1.677828	0.291957	5.050329
Columns	1.1532	1	1.1532	15.20169	0.011422	6.607891
Error	0.3793	5	0.07586			
Total	2.1689	11				

CONDUCTIVITY

Rows	3265.417	5	653.0833	1.420107	0.354862	5.050329
Columns	103974.1	1	103974.1	226.088	2.36E-05	6.607891
Error	2299.417	5	459.8833			
Total	109538.9	11				

TURBIDITY

Rows	1728.955	5	345.7909	2.409563	0.178285	5.050329
Columns	21824.01	1	21824.01	152.0755	6.21E-05	6.607891
Error	717.5386	5	143.5077			
Total	24270.5	11				

COLOUR

Rows	38962.6	5	7792.521	1.039693	0.483485	5.050329
Columns	46937.52	1	46937.52	6.262494	0.054324	6.607891
Error	37475.1	5	7495.021			
Total	123375.2	11				

BIOCHEMICAL OXYGEN DEMAND (BOD)

Rows	631.0375	5	126.2075	0.653042	0.674262	5.050329
Columns	586.6008	1	586.6008	3.03528	0.141941	6.607891

Error	966.3042	5	193.2608			
Total	2183.943	11				
CHEMICAL OXYGEN DEMAND						
Rows	33607.49	5	6721.498	3.813696	0.084063	5.050329
Columns	3403.701	1	3403.701	1.931219	0.223326	6.607891
Error	8812.314	5	1762.463			
Total	45823.5	11				
TOTAL SUSPENDED SOLIDS (TSS)						
Rows	3914.917	5	782.9834	1.473908	0.340364	5.050329
Columns	21788.2	1	21788.2	41.01467	0.001376	6.607891
Error	2656.147	5	531.2294			
Total	28359.26	11				
TOTAL DISSOLVED SOLIDS (TDS)						
Rows	3377.417	5	675.4833	1.737876	0.279452	5.050329
Columns	34454.08	1	34454.08	88.64307	0.000228	6.607891
Error	1943.417	5	388.6833			
Total	39774.92	11				
NITRATE- NITROGEN (NO₃-N)						
Rows	1.805858	5	0.361172	0.378792	0.844832	5.050329
Columns	0.03608	1	0.03608	0.037841	0.85342	6.607891
Error	4.767413	5	0.953483			
Total	6.609351	11				
NITRITE- NITROGEN (NO₂-N)						
Rows	57.89198	5	11.5784	7.101366	0.025329	5.050329
Columns	6.010921	1	6.010921	3.686672	0.112918	6.607891
Error	8.152232	5	1.630446			
Total	72.05514	11				
AMMONIA- NITROGEN (NH₃-N)						
Rows	28.56026	5	5.712052	1.095281	0.46144	5.050329
Columns	19.66592	1	19.66592	3.770923	0.109805	6.607891
Error	26.07574	5	5.215148			
Total	74.30192	11				

PHOSPHATE- NITROGEN (PO₄-N)						
Rows	3.616494	5	0.723299	7.734663	0.021204	5.050329
Columns	2.997001	1	2.997001	32.0487	0.002391	6.607891
Error	0.46757	5	0.093514			
Total	7.081065	11				
TOTAL COILFORM (TC)						
Rows	9.43E+09	5	1.89E+09	0.976726	0.509994	5.050329
Columns	15187500	1	15187500	0.007864	0.932777	6.607891
Error	9.66E+09	5	1.93E+09			
Total	1.91E+10	11				
ESCHERICHIA COLI (E. COLI)						
Rows	3.6E+08	5	72086000	5.829371	0.037781	5.050329
Columns	480000	1	480000	0.038816	0.851572	6.607891
Error	61830000	5	12366000			
Total	4.23E+08	11				

