

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

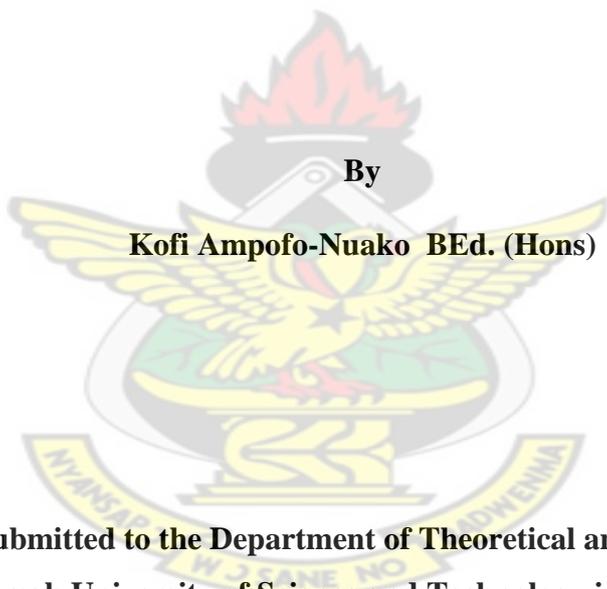
COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

**Chemical Investigation of Effluents from Chemistry Laboratories of Some
Senior High Schools in Kumasi, Ghana.**

By

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**A Thesis submitted to the Department of Theoretical and Applied Biology,
Kwame Nkrumah University of Science and Technology in partial fulfillment of
the requirements for the degree of**

MSc. ENVIRONMENTAL SCIENCE

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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 or anywhere, except where due acknowledgement has been made in the text.

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DEDICATION

With love, affection, gratitude and appreciation, I humbly dedicate this thesis to my parents: Mr. Joseph Baah Nuako and Mrs. Elizabeth Boakye Nuako. Thank you very much for giving me education. May God richly bless you.

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ABSTRACT

Many Senior High Schools in Ghana pursue science and science-related courses which require practical exercises. The Governments of Ghana have made conscious efforts to promote the study of science in senior high schools building of science laboratories and Science Resource Centres in selected senior high schools in the country. A variety of chemicals are used in the Chemistry Laboratories. With the increase in population of students who are pursuing chemistry and chemistry related courses, a lot of chemistry practical exercises are performed in the schools. The wastes generated during these practical exercises are disposed of into the sinks without any treatment. The effluents flow through the drains and eventually join water bodies. These water bodies may be used by people who live downstream for various domestic activities and for irrigation. In this study, laboratory effluents from five senior high schools in the Kumasi Metropolis were taken monthly from November 2010 to March 2011 for analyses. The objective of the study was to determine the quality of effluents from chemistry laboratories in selected Senior High Schools in the Kumasi Metropolis of Ghana and to assess whether the effluents could cause pollution using general effluent guidelines. The results were run using one way analysis of variance (ANOVA) and 95% confidence interval was set to determine the significant differences of the situations among the schools. The study revealed that most of the parameters measured were high above the recommended values by EPA Ghana for effluent from industries. There were no significant differences in most of the parameters among the schools. As the effluents flow downstream most of the parameters studied decreased in their levels. It was also found that the concentrations of phosphate were high in all the schools. This can

cause eutrophication and harm aquatic life and thereby cause pollution of receiving water bodies.

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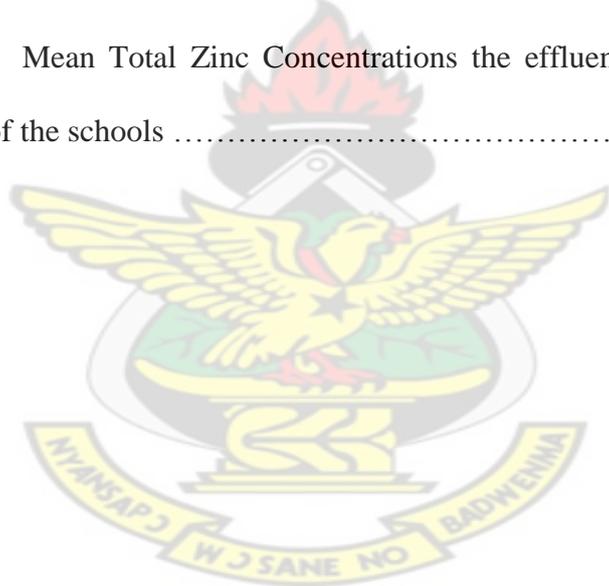
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ABBREVIATIONS

ANOVA	Analysis of Variance
APHA	American Public Health Association
ATSDR	Agency for Toxic Substances and Disease Registry
AWJ	African Water Journal
DFID	Department for International Development
EDTA	Ethylenediaminetetraacetic acid
EPA	Environmental Protection Agency
FMENV	Federal Ministry of Environment
GAST	Ghana Association of Science Teachers
GSS	Ghana Statistical Service
lsd	least significant difference
NEHF	National Environmental Health Forum
NPIA	National Pollution Inventory of Australia
NPK	Nitrogen: Phosphorus: Potassium
RPD	Relative Percentage Difference
SHS	Senior High School
TDS	Total Dissolved Solids
UNEP	United Nations Environment Program
USEPA	United States Environmental Protection Agency
WACAM	the Wassa Association of Communities Affected by Mining Changes
WASSCE	the West African Senior School Certificate Examination.
WHO	World Health Organisation

CHAPTNER ONE

INTRODUCTION

1.1 BACKGROUND

Cities in developing countries, including Ghana, are experiencing unparalleled population growth. The Ghana population structure shows that greater part of the population is of school-going age. About 37.3% of the population is aged between 1 and 14 (GSS, 2010). With the increase in Ghanaian population more senior high schools are being established to cater for the upcoming children's education. Many of the senior high schools in Ghana offer science and science related programmes (GSS, 2010).

The study of science and technology is known to be the backbone for the development of a country. The Government of Ghana has therefore realised the need to emphasise the study of science and technology. Science education involves practical demonstration to enhance understanding and improve skills of students. Practical work is done in the laboratories. For this reason, the Ministry of Education since 1997 established Science Resource Centres in selected Senior High Schools in Ghana to promote the study of science and technology. These centres are highly equipped with a variety of chemical reagents. Similarly, between 2004 and 2008, one senior high school in every district has been upgraded to a model school. Here the science laboratories were refurbished and restocked to beef up the existing facilities. With these reforms, many schools in the Kumasi Metropolis now place higher premium on the study of science.

Various chemicals are used in the chemistry laboratories for both quantitative and qualitative analysis. These chemicals include Zn, Al, Ca, $\text{NH}_3(\text{aq})$, NaOH, $\text{Pb}(\text{NO}_3)_2$, AgNO_3 , BaCl_2 , $\text{K}_4[\text{Fe}(\text{CN})_6]$ and $\text{K}_3[\text{Fe}(\text{CN})_6]$ etc are used for identification purposes.

The practices in the resource centres and the other science laboratories however do not take environmental issues into consideration. The chemicals from these laboratories are poured into sinks and are washed away into gutters and eventually run into water bodies. Some can also seep into underground water and contaminate it. People downstream use the untreated water from these water bodies for domestic purposes and irrigation of food crops especially vegetable and fruits that are produced in the urban areas (Bahri, 2009). Such food items may produce ill effects in consumers. One of the objectives of the Millennium Development Goals is to ensure environmental sustainability. However, these practices if not given prompt attention will not help us to achieve the goal (AWJ, 2007; Bahri., *et al*, 2008). As urban population expands, domestic water supply also increases. This has led to greater quantities of municipal wastewater (Raschid-Sally and Jayakody 2008).

Good quality drinking water is essential for life. Unfortunately, in many countries around the world, including Ghana, water has become a scarce commodity as only a small proportion of the populace has access to treated water (WaterAid, 2001). Alternative sources of water such as rainwater and ground water have become major sources of drinking water for people living in new settlements and some residents who do not have access to treated water in Ghana (Bahri *et al.*, 2008). Effluents generated by the schools are sources of pollution. Heavy metals contents in effluents

have been found to be carcinogenic, while others are poisonous depending on the dose and exposure period (Kupchella and Hyland, 1989; WHO, 2002). These chemicals are poisonous to man and aquatic life resulting in food contamination (Novick, 1999; WHO, 2003). A typical example is that ammonia is harmful to fish and other aquatic organisms at concentrations of 10 – 50 µg/l. The sulphate in effluents is of environmental concern (WHO, 2002) because it may lead to poor air quality of an area. The same is applicable to pH if water available for human use is not of the required quality (WHO, 1993). Wright (2003), adds that metals and their organo-metals forms cannot be degraded or broken down into simpler or less toxic forms. As a result they persist in the environment and may bioaccumulate through the food chain. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues.

1.2 STATEMENT OF THE PROBLEM

The study of science requires practical work. The Government of Ghana established the Science Resource Centres and other laboratories in the Senior High Schools to enhance teaching and learning of science. The senior high schools in Kumasi perform various chemistry practical exercises which involve the use of chemicals such as CN^- (in Potassium hexacyanoferrate (II) and Potassium hexacyanoferrate (III)), Zinc (Zn), Ammonia etc. These chemicals are eventually washed into water bodies through the drains. The water from the drains or streams is used for irrigation and for domestic purposes. The presence of the chemicals can harm both aquatic and human lives (Bahri, A., *et al*, 2008).

The EPA Ghana has no policy guidelines regarding the disposal of the laboratory effluents from educational institutions. It is based on these that the researcher wants to find out the quality of the effluents generated in the chemistry laboratories in selected senior high schools in Kumasi and the possible pollution they can cause.

1.3 GENERAL OBJECTIVE

The objective of the study was to determine the quality of effluents from chemistry laboratories in selected Senior High Schools in the Kumasi Metropolis of Ghana.

1.3.1 Specific Objectives

- To measure the water qualities- pH, conductivity, alkalinity, temperature, and hardness of the effluents from the laboratories.
- To measure the concentrations of some metals – (Al, Ca, Fe, Cu, Zn) and other inorganic ions such as Cl^- , NH_3 , NO_2^- , NO_3^- , SO_3^{2-} , SO_4^{2-} , PO_4^{3-} in effluents.
- To assess whether the effluents discharged could cause pollution using the general effluent guidelines.

1.4 JUSTIFICATION

Laboratory effluents contain a wide range of chemicals. Effluents released into the drains must meet effluents standards. These effluents are poured into sinks and eventually drain into water bodies without regard to such standards. The effluents when present in high concentrations can also contaminate soils and ground water. People downstream use the raw water containing these effluents for domestic and agricultural purposes to produce vegetables which are usually consumed in their raw states.

These water bodies also serve as habitat for fish and other aquatic lives. If the levels of toxicity are not determined to offer mitigation measures in a timely manner, the situation may get out of hand and its control may be more expensive. It is very important to assess the level of toxicity of the effluents from the senior high schools. This study is to characterise waste water from chemical laboratories in selected senior high schools in Kumasi.

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CHAPTER TWO

LITERATURE REVIEW

2.1 EFFLUENT

Effluent is an outflowing of water or gas from a natural body of water, or from a human-made structure. Effluent in the artificial sense is generally considered to be water pollution, such as the outflow from a sewage treatment facility or the wastewater discharged from industrial facilities (Akan *et al.*, 2009).

2.1.1 Sources of Effluents.

Effluents, contaminants and pollutants are from a variety of sources. Most effluents originate from industrial activities. These include mining, manufacturing and processing (chemical, metal, textile, tannery, paper and pulp, electroplating and battery manufacturing) Hasan and Aalbersberg (2008). Other effluents come from anthropogenic sources such as agriculture, domestic activities, commercial and health facilities (Conacher *et al.*, 1993; Velez and Montoro, 1998; Wang *et al.*, 2003; Fang *et al.*, 2006;).

Contaminants such as heavy metals, nitrates and salts can also originate from domestic activities and livestock (Singh and Mosley, 2003; Girgin *et al.*, 2010). Again, chemical weathering of rocks and soil, agricultural runoffs, batteries, lead based paint, gasoline and improper domestic waste, discharge into water ways (Anim *et al.*, 2011).

2.1.1.1 Industrial sources.

Industrial effluent is water polluted 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 slaughterhouses or food-processing plants (WHO, 2002; 2003). Effluent generated by the industries is one of the sources of pollution (Sonibare and Yusuff, 2004). For instance, the principal generators of industrial wastewater in Kumasi are the breweries; soft drink bottling plants and abattoir which, together, generate a total of about 1,000 cubic metres of effluents daily, which ends up in the city's drains and nearby streams (Keraita *et al.*, 2003). Contamination of drinking water supplies from industrial waste is a result of various types of industrial processes and disposal practices. Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources. Other disposal practices which cause water contamination include deep well injection and improper disposal of wastes in surface impoundments. (Tamburlini *et al.*, 2002)

Industrial waste consists of both organic and inorganic substances. Organic wastes include pesticide residues, solvents and cleaning fluids, dissolved residue from fruit and vegetables, and lignin from pulp and paper production. Effluents can also contain inorganic wastes such as brine salts and metals. USEPA (2005) has standards for the permitted release of a limited amount of contaminants into waterways. Air, soil, and water bodies contaminated by effluents from the industries are associated with heavy disease burden (WHO, 2002) and this could be part of the reasons for the

current shorter life expectancy in many developing countries when compared to the developed nations (WHO, 2003).

2.1.1.2 Mining effluent.

Aqueous effluents from mining and other sources contain dissolved heavy metals which may have negative impact on the environment if left untreated. The characteristics and the intensity of such damage depend largely on the nature and the levels of the heavy metals in the effluents discharged from the sources (Shakoori *et al.*, 2004). Pollution of water bodies as well as air pollution in mining communities poses serious health implications to the people. The diseases people in the communities contract include skin and chest diseases, tuberculoses, diarrhoea, malaria, typhoid fever, dizziness and persistent headaches. There are recent media reports and complaints from communities about cyanide spillages as well as the release of other hazardous chemicals including Arsenic, Manganese, Cadmium, Iron, Copper, Mercury, Zinc and Lead into water bodies through mining operations in Ghana (Owusu-Koranteng, 2009).

2.1.1.3 Effluents from domestic and educational institutions.

Mason, 2002 agrees that domestic and institutional sewage are primary sources of pollutants that contain oxygen demanding substances, plant nutrients and pathogenic organisms. He adds that Nitrogen and Phosphorus, the major plant nutrients, are in sewage and drains as well as run-off from farms, suburban lawns and gutters from the industries and institutions. The N (Nitrogen) and P (Phosphorus) from NO_3^- and PO_4^{3-} respectively can cause eutrophication in lakes. The $\text{NH}_{3(\text{aq})}$ being used as test

reagents in educational institutions can also increase the quantity of NO_2^- and NO_3^- in the effluents (Keraita *et al.*, 2003).

2.1.1.4 Effluent from hospitals

In hospitals a large variety of substances are in use for medical purposes such as diagnostics and research. After application, diagnostic agents, disinfectants and excreted non-metabolized pharmaceuticals by patients, reach the wastewater. This form of elimination may generate risks for aquatic organisms (Emmanuel, 2005).

Most anti-tumour agents used at hospitals are known to be carcinogenic, mutagenic, teratogenic, embryotoxic or fetotoxic. Only little is known about the environmental impact of pharmaceuticals. Unmetabolized active substances are excreted and will show up in municipal wastewater (Kümmerer *et al.*, 1997). Again, a portion of administered pharmaceuticals are excreted unmetabolised by patients and can be found in hospital effluent and municipal sewage. Antibiotic-resistant bacteria and antibiotics are discharged in various amounts into the environment as a result of the increasing and often indiscriminate use of antibiotics in medical, veterinary, and agricultural practices. River waters are the main receptacles for these pollutants, since they receive the sewage of urban effluents. As rivers are one of the major sources of water (directly or indirectly), for human and animal consumption, this pollution may contribute to the maintenance and even the spread of bacterial antibiotic resistance (Goñi-Urriza, 2000).

2.2 TOXICITY OF EFFLUENTS

Toxicity may be defined as the degree to which a substance or a mixture of substances can harm humans or animals (Fauci, 2008). The toxicity of municipal effluents is dependent on a variety of factors, including the physical, chemical and biological characteristics of the receiving waters. In many cases the toxicity of effluents is due to un-ionized ammonia or, in the case of chlorinated effluents, to total residual chlorine. Other contaminants including cyanide, sulfides, phenols, surfactants and heavy metals, such as copper, zinc and chromium, also contribute to toxicity (Chambers *et al.*, 1997). Many factors that can moderate the toxicity in the effluent or receiving environment including pH, hardness, dissolved organic carbon and temperature.

Some heavy metals contained in effluents (either in free form in the effluents or adsorbed in the suspended solids) have been found to be carcinogenic (Tamburlini *et al.*, 2002), while other chemicals present can be poisonous depending on the dose and exposure duration (Kupchella and Hyland, 1989). These chemicals are not only poisonous to humans but also toxic to aquatic life (WHO, 2002) and they may result in food contamination (Novick, 1999). Ammonia is harmful to fish or other aquatic organisms at free (un-ionized) concentration of 10 – 50 µg/l. Sulphide in effluent is of environmental concern (WHO, 2000) because they can lead to poor air quality of an area if not properly taken care of, thus becoming a threat to human life, vegetation, and materials. The same is applicable to pH that has been identified to raise health issue if water available for human use is not of the required pH level (WHO, 1993). Exposure to elevated levels of toxic chemicals has had other

significant health implications such as reduced level of Intelligent Quotient (IQ) in children (Owusu-Koranteng, 2009).

The waste water or sewage water thrown out from industries is either used for irrigation purposes or it runs off to the natural sources of water. If these effluents are not treated before their disposal they can be harmful to human as well as the environment (Ahlawat and Kumar, 2009). These impacts can include harm to fish and wildlife populations, oxygen depletion, beach closures and other restrictions on recreational water use, restrictions on fish and shellfish harvesting and contamination of drinking water (Ghoreishi and Haghighi, 2003).

2.2.1 Effects of Effluents on Surface Water.

Rivers in urban areas have been associated with water quality problems because of the practice of discharging waste water from untreated domestic sources and small scale industries waste water into the water bodies. This leads to the increase in the level of metals concentration in river water (Rim-Rekeh *et al.*, 2006; Khadse *et al.*, 2008; Juang *et al.*, 2009; Venugopal *et al.*, 2009; Sekabira *et al.*, 2010). Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body (Buchholz, 1998). Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). In farming areas, the routine application of agricultural fertilizers is the major source of surface water pollution (Altman and Parizek, 1995; Emongor *et al.*, 2005). In urban areas, the careless disposal of industrial effluents and other wastes may contribute greatly to the poor quality of the water (Chindah *et al.*, 2004; Emongor *et al.*, 2005; Furtado *et al.*, 1998 and Ugochukwu, 2004).

With increasing urbanisation and industrialization, there has been a rapid increase in industrial effluent discharge into the stream water, leading to increased pollution load (Sekabira *et al.*, 2010). Most of the rivers in some urban areas of the developing countries are the destinations of effluents discharged from the industries (Phiri *et al.*, 2005). River Kaduna, in the city of Kaduna in Nigeria, receives the effluents from textile industries (Gefu and Kolawole, 2002). As a Northern Nigerian city, Kaduna is characterized by high evaporation during the long dry season. This could result in volatilization of chemicals in the effluents and the release of heavy metals as particulates due to their adsorption on the effluents' solids. Thus, air quality around the banks of this river and the entire city could negatively be affected. The discharge of effluents has caused severe pollution of surface water in the Noyyal River Basin region in India and has also contaminated agricultural land. The disposal of untreated wastewater on land and into the Noyyal River has affected the quality of surface water, ground water and the soil not only in Tiruppur but also throughout the downstream (Geetha *et al.*, 2008).

Faust and Aly (1983) admit that chemical analyses of N&P in waste water effluents are feasible. However, the amount of growth stimulation in the receiving waters depends on specific N&P compounds present in the effluents and on chemical and biological factors of the receiving waters. Faust and Aly (1983) again assert that, discharge of waste water into water bodies lead to microbial utilization of dissolved oxygen (DO) which results in the elimination of the desired populations and communities of aquatic organisms in the receiving waters.

2.2.2 Effect of Effluents on Ground Water.

Industrial effluents, if not treated and properly controlled, can also pollute ground water (Olayinka, 2004). Therefore, both bore holes and rivers generally have poor quality water in the affected areas. Since people use untreated waters from these sources, the result is continuous outbreaks of diseases such as cholera, bilharzia, diarrhoea and others (Phiri *et. al* 2005).

2.2.3 Uses of Effluent Water.

Effluent water can be used for many purposes. Industrial effluents are nowadays used for the irrigation purpose, due to the scarcity of water. It is difficult to find any clean water source for irrigation in and around most cities (Keraita *et al.*, 2003). Waste water from the industries runs off into the water bodies which serve as source of water for domestic and agricultural purposes (Ahlawat and Kumar, 2009). In most African countries, urban wastewater is widely used very partially treated or untreated to irrigate vegetables, rice and fodder for livestock (Bahri *et al.*, 2008). For example, in many cities in West Africa, the supply of vegetables largely depends on the availability of wastewater (Niang *et al.*, 2002 ; Obuobie *et al.*, 2006).

2.3 EFFLUENT STANDARDS

Industrial wastewaters have been strongly controlled by effluent standard. Either water quality-based or technology-based effluent standard could be adopted on the basis of the scientific rationale (Kim, 2010). A possible means for controlling water pollution is through defining, applying and enforcing effluent standards for waste water discharges (Konterman *et al.*, 2003). Most developing countries nowadays apply a set of effluent standards. However, in many developing countries the

definition of effluent standards is poor. They are either too stringent because they are based on standards from developed countries, or too relaxed and therefore not guaranteeing the intended safe uses of water (Bahri *et al.*, 2008).

2.4 WATER MANAGEMENT PROBLEMS IN DEVELOPING COUNTRIES.

Water resource issues and problems in the world's developing countries, present special management challenges. These issues and problems include inadequate drinking-water supply and sanitation facilities, water pollution, floods, the siltation of river systems, and the management of rivers and large dams (Bahri, 2000; Drechsel *et al.*, 2006). The scarcity of clean water and pollution of fresh water has therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three quarters of the rural dwelling population do not have access to reasonably safe water supplies (Lloyd and Helmer, 1992). The amount of freshwater available for each person in Africa is about one-quarter of what it was in 1950. Ghana is listed among countries that would experience water stress of 1700 cubic meters or less per person per year by 2025 (Owusu-Koranteng, 2009). Barriers to addressing water problems in developing nations include poverty, illiteracy, rapid population growth and ineffective institutions and policies for developing, distributing, pricing, and conserving water resources (IWMI, 2006). The complex patterns of these problems in the developing countries are shaped by differences in wealth, environment, and political systems. For example, extreme poverty in much of sub-Saharan Africa limits access to quality water services (Bahri, 2000).

2.5 ENVIRONMENTAL POLICY AND ADMINISTRATIVE FRAMEWORK ON UNDERTAKINGS.

The EPA-Ghana's Environmental Assessment Regulations have a list of a number of undertakings which require registration and environmental permit. According to EPA-Ghana, no developer shall be allowed to commence any of such undertakings or related undertakings unless prior to the commencement, the undertaking has been registered by the EPA and an environmental permit has been issued by EPA for the undertaking. It is further stated that no person shall commence an undertaking which in the opinion of the EPA has or is likely to have adverse effect on the environment or public health, unless prior to the commencement, the undertaking has been registered with the EPA and an environmental permit issued (EPA Ghana, 1999).

It can be deduced from the above regulations that, the building and running of chemistry laboratories in Senior High Schools require a special permit, but this is not the case in Ghana. The Ministry of Education must acquire a permit before putting up such structures. In the application of the permit the Ministry would state the mitigation measures of how to deal with the effluents. This is because a variety of chemicals is used and more often, after practical exercises the chemicals are just poured into the sinks indiscriminately.

2.6 ENVIRONMENTAL IMPACT OF EFFLUENTS FROM CHEMICAL LABORATORIES

The chemical effluents when released into the sinks in the chemistry laboratories drain into nearby water bodies. The water from these water bodies are used for a variety of purposes. Some use it directly for domestic purposes such as drinking,

washing and cooking. Breweries also use the water. Vegetable growers in the city also use the water for cultivation of their crops (Keraita *et al.*, 2002; Keraita, 2003).

A further special feature of toxic metals is that they are not biodegradable. Instead, they undergo a biogeochemical cycle with substantially different residence times in the various spheres and compartments of the environment. Within this cycle they would be taken up also by man, predominantly from food and drinking water. In this respect, toxic metals constitute a particular risk. They have the tendency to accumulate in vital organs (Karanja *et al.*, 2010).

2.7 WATER POLLUTANTS

Water pollutants include a wide range of chemical and physical changes. Many of the chemical substances found in water are toxic. Alterations of the physical chemistry include temperature, conductivity, pH, hardness and acidity (Svobodová *et al.*, 1993). Chemical pollutants include cations especially those of heavy metals and anions like NO_2^- , NO_3^- , Cl^- , SO_4^{2-} , PO_4^{3-} . Long term exposure to chemicals such as arsenic, fluoride, uranium, nitrate and boron may cause chronic illness, disability and death (Mosley *et al.*, 2004).

Metals enter rivers and lakes from a variety of sources, such as rocks and soils that are directly exposed to surface waters, decomposing dead organic matter, fallout of atmospheric particulate matter, and from man's activities, including the discharge of various treated and untreated liquid wastes into the water body. Heavy metals such as Cr, Mn, Co, Cu, Fe and Zn play biochemical roles in the life processes of aquatic plants and animals, and their presence in trace amounts in the aquatic environment is

essential. However, at high concentrations, these trace metals become toxic (Olayinka, 2004).

Increased concern by environmentalists and governments on the effects of heavy metals and an attempt to protect public health has resulted in increased research in the development of advance technologies to remove heavy metals from waters and wastewaters (Bong *et al.*, 2004; Karbassi *et al.*, 2007; Shetty and Rajkumar, 2009; Resmi *et al.*, 2010).

2.8 SOME WATER QUALITY PARAMETERS.

Water quality parameters are the physical and the chemical properties of water under which the study was done. The properties that were studied in this work were temperature, pH, electrical conductivity, total hardness, alkalinity, NH_4^+ , NO_2^- , NO_3^- , SO_3^{2-} , SO_4^{2-} , Cl^- , PO_4^{3-} , Al, Cu, Fe, Ca and Zn,

2.8.1 Temperature

Wastewater temperature is the degree of hotness of the water (Folland, 2010). Temperature is not a pollutant but affects many physical, biological, and chemical characteristics of wastewater (WHO, 2004). These include amount of oxygen that can be dissolved in water, rate of photosynthesis of plants, metabolic rates of animals, and the sensitivity of organisms to toxic wastes, parasites, and diseases (Okalebo *et al.*, 2002).

Temperature can also affect the solubility of substance. Solubility of solids varies with varying temperature. Most salts are more soluble in water at high temperatures.

These include salts of NH_4^+ , Mg^{2+} , Zn^{2+} , Fe^{2+} , NO_3^- and SO_4^{2-} . However most ionic compounds of calcium are soluble only at low temperatures (Ameyibor and Wiredu, 1999). Metals like Zinc and Copper were more soluble in waste water at 100°C than found at 50°C (Aslam *et al.*, 2004).

2.8.2 Electrical Conductivity.

This is the ability of water to transmit electric current. It indicates the presence of dissolved ions in water. For example NaCl dissociates to produce Na^+ and Cl^- . Movements of these ions conduct electricity through the water (Pescod, 1992). Conductivity can be used as a measure of total dissolved solids (TDS). These solids are usually composed of the sulphate, bicarbonate, and chlorides of calcium, magnesium, and sodium. Conductivity can increase as a result of heavy metal ions released into a water body (Bruce, 2008).

2.8.3 pH

pH is the measure of acidity or alkalinity of the effluents. It is measured by hydrogen ion $[\text{H}^+]$ concentration (Ameyibor and Wiredu, 1999). pH of wastewater is measured on pH scale ranging from 0 to 14 with 0 being the most acidic and 14 most basic or alkaline. A range of pH 6.5 to pH 8.2 is optimal for most organisms. Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly. The toxicity level of ammonia to fish, for example, varies tremendously within a small range of pH values (Mosley *et al.*, 2004). Acid rain containing nitric and sulphuric acids can sharply lower the pH of a stream as the rain runs off streets and roofs into water bodies (Adeyeye and Ayejuyo, 2002). When water becomes acidic, it can cause heavy metals such as copper and aluminum to be

very soluble in the water. Copper from worn automobile brake pads is often present in runoff. Rapids growing algae remove carbon dioxide from the water during photosynthesis, which can result in a significant increase in pH levels. If a stream has pH <5.5 it may be too acidic for fish survival whereas stream pH of 8.6 may be too alkaline (WHO, 2004).

2.8.4 Alkalinity.

Alkalinity is not a pollutant. The alkalinity of water is its capacity to neutralise acid. The amount of a strong acid needed to neutralise the alkalinity is called the total alkalinity and is reported in mg/L as CaCO₃ (Adeyeye and Abulude, 2004). The alkalinity of some waters is due only to bicarbonates of calcium and magnesium. The pH of such water does not exceed 8.3 and its total alkalinity is practically identical with its bicarbonate alkalinity (UNEP/WHO, 1996).

Alkalinity is significant in many uses and treatments of natural and wastewater. The alkalinity of water is primarily based on carbonate (CO₃²⁻), bicarbonate (HCO₃⁻) and hydroxide (OH⁻) content and it is taken as an indication of the concentration of these constituents. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes (Adeyeye and Abulude, 2004).

2.8.5 Total Hardness.

Hardness is the measure of the ability of the water to form lather with soap (Abbey *et al.*, 2001). Hardness depends on the concentration of Ca²⁺ and Mg²⁺ in water. The presence of these ions wastes soap when the water is used for washing. Iron and Aluminium are seldom present but in insufficient amounts that can impact

significantly on the hardness determination. Hence, it is mostly assumed that water hardness is caused entirely by Calcium and Magnesium (Ameiybor and Wiredu, 1999). Most of the Calcium and Magnesium are present as bicarbonates, carbonates, sulphates and sometimes as nitrates and chlorides (Adeyeye and Abulude (2004). Hardness-producing substances react with soaps forming insoluble compounds before lather is produced (APHA, 1992).

Hardness is classified as temporary or permanent. Temporary hardness is caused by the presence of bicarbonates of magnesium and calcium and can be removed by boiling. Permanent hardness is caused primarily by calcium sulphate and this cannot be removed by boiling (Abbey *et al.*, 2001).

2.8.6 Chloride (Cl^-)

Chloride is one of the major inorganic anions found in water and wastewater. It is generally combined with Ca, Mg or Na. Most chlorides are water soluble. For this reason the chloride content in water is always high. It ranges between 10 and 100 mg/L (Ajai *et al.*, 2011). In potable water the salty taste produced by chloride concentrations is variable and depends on the chemical composition of the water (Mosley *et al.*, 2004). Some waters containing 250 mg/L of Cl^- may have a detectable salty taste if the cation is Sodium. On the other hand, the typical salty taste may be absent in waters containing as much as 1000 mg/L chloride when the predominant cations are Ca^{2+} and Mg^{2+} . High chloride concentration in water and wastewater can inhibit the growth of plants, bacteria and fish in surface waters; high levels can lead to breakdowns in cell structure (APHA, 1992; Bosnic *et al.*, 2000). High chloride content may indicate pollution by sewage or industrial wastes. A high chloride content has a corrosive effect on metal pipes and structures which makes it

harmful to most trees and plants (UNEP/WHO, 1996). Chlorides are relatively harmless to organism except when converted to Cl_2 and ClO_3^- which are toxic.

2.8.7 Sulphate (SO_4^{2-})

Sulphate occurs in almost all natural waters. Most sulphates originate from the oxidation of sulphite. Sulphate also results from the breakdown of sulphur-containing organic compounds. Sulphate is one of the least toxic anions (APHA, 1992). However, high sulphate concentration in drinking water causes a laxative effect when combined with Ca and Mg resulting in dehydration, catharsis and gastrointestinal irritation. Its concentration in water can range from a few milligrams to several thousand milligrams per litre. Industrial wastes may contain high concentrations of sulphate. It has a suggested level of 250 mg/L in drinking water standards (WHO, 2004).

2.8.8 Nitrate (NO_3^-)

Pollution of water resources by nitrate occurs due to domestic wastewaters and unconventional consumption of fertilizers in agriculture (Horold *et al.*, 1993; Pintar *et al.*, 2001; Mahvi *et al.*, 2005; Nouri *et al.*, 2008; Atafar *et al.*, 2010). Nitrate is the most stable oxidized form of combined nitrogen in most environmental media (USEPA, 2006). Nitrate is a very soluble anion in water. It is a strong oxidizing agent. Low levels of nitrates occur naturally in water but sometimes higher levels, which are potentially dangerous to infants, are found. Nitrogen containing compounds create serious problems including eutrophication, destroyed water quality and potential hazards on human and animal health when they enter into water resources (Nouri *et al.*, 2006; Ghafari *et al.*, 2008; Igbiosa and Okoh, 2009). High

concentration of nitrate causes eutrophication when phosphates are available at a concentration of 0.1 mg/L (Nkegbe *et al.*, 2005). Sewage is the main source of nitrates added by humans to water bodies. Nitrates are reduced to nitrites in the human body, which in turn, react with amines to form nitroamines, which are some of the most potent carcinogens known. Also, high concentrations of nitrites in drinking water are fatal to infants (Weier, *et al.*, 1994).

Another important source of nitrates is fertilizers, which can be carried into creeks by stormwater runoff. Nitrate pollution may occur from fertiliser runoff or seepage into groundwater and from discharge of human and animal waste (Mosley *et al.*, 2004). Excessive nitrates stimulate growth of algae and other plants, which later decay and increase biochemical oxygen demand as they decompose (APHA, 1992).

High nitrate levels in drinking water pose a health risk to infants because they may cause methemoglobinemia, a condition known as “blue baby syndrome.” High nitrate levels interrupt the normal body processes of some infants (UNEP/WHO 1996). Nitrate becomes toxic when it is reduced to nitrite, a process that can occur in the stomach as well as in the saliva. Infants are especially susceptible because their stomach juices are less acidic and therefore conducive to the growth of nitrate-reducing bacteria. Adults can consume large quantities of nitrates in drinking water or food with no known ill effects (APHA, 1992).

2.8.9 Nitrite (NO_2^-)

Nitrite is a toxic anion. It acts as both oxidizing and reducing agents. Nitrite is an unstable, intermediate stage in the nitrogen cycle and is formed in water either by

oxidation of ammonia or by reduction of nitrate. In natural waters nitrite is normally present in low concentrations. Higher concentrations may be present in sewage and industrial waste polluted waters (UNEP/WHO, 1996). Nitrite oxidises haemoglobin in blood stream to methemoglobin, limiting the ability of the blood to carry oxygen throughout the body. This can lead to anoxia and death. WHO maximum permissible level for nitrite in drinking water is 3 mg/L (WHO, 2004).

2.8.10 Phosphate (PO_4^{3-})

Phosphorus is usually present in natural water as phosphates (orthophosphates, polyphosphates, and organically bound phosphates). Phosphorus is a plant nutrient needed for growth and a fundamental element in the metabolic reactions of plants and animals (hence its use in fertilizers) (Nkegbe *et al.*, 2005). Sources of phosphorus in water or wastewater include detergents, human and animal wastes, industrial wastes, soil erosion, and fertilizers. Phosphorus present in domestic wastewater is an important macro-nutrient for plant and microorganisms growth. The discharge of large quantities of this nutrient, into natural receiving sources, raises the growth of algae and results in eutrophication of lakes and streams (Mervat and Logan, 1996). Excess phosphorus causes extensive algal growth called "blooms," which are a classic symptom of cultural eutrophication and lead to decreased oxygen levels in water bodies (APHA, 1992; UNEP/WHO, 1996).

2.9 SOME METALS COMMONLY FOUND IN WASTEWATER.

2.9.1 Aluminium (Al)

Aluminium is one of the most abundant metallic elements and constitutes in the earth's crust (Tuzen and Soylak, 2006). It occurs naturally in the environment as

silicates, oxides, and hydroxides, combined with other elements, such as sodium and fluoride, and as complexes with organic matter (Cox, 1991; WHO, 2003). Aluminium has a dull silvery appearance, because of a thin layer of oxidation that forms quickly when it is exposed to air (UNEP/WHO, 1996). Aluminium is one of the most widely used metals and also forms part of some of the most frequently found compounds in the earth's crust (Wiberg *et al.*, 2001; Enghag, 2004).

There is little indication that aluminium is acutely toxic by oral exposure despite its widespread occurrence in foods, drinking-water, and many antacid preparations (WHO, 1997). When one is exposed to high concentrations of Aluminium, it can cause health problems. The water-soluble forms of aluminium, which are ions, cause the harmful effects (APHA, 1992).

The uptake of aluminium can take place through food, breathing and skin contact. Longer periods in uptakes of significant concentrations of aluminium can lead to serious health effects, such as: damage to the central nervous system, dementia, loss of memory and severe trembling (WHO, 1997; NEHF, 1998).

Aluminium may accumulate in plants and cause health problems for animals that consume these plants. The concentrations of aluminium appear to be highest in acidified lakes. In these lakes the number of fish and amphibians is declining due to reactions of aluminium ions with proteins in the gills of fish and the embryo's of frogs (ATSDR, 1990). High aluminium concentrations can cause ill effects in birds and other animals that consume contaminated fish and insects (ATSDR, 1992). The consequences for birds that consume Al contaminated fish are eggshell thinning and

chicks with low birth-weight (Wiberg *et al.*, 2001). Aluminium is released to the environment mainly by natural processes. Several factors influence aluminium mobility and subsequent transport within the environment. These include chemical speciation, hydrological flow paths, soil–water interactions, and the composition of the underlying geological materials (ATSDR, 1992; WHO, 1997). Another negative environmental effect of aluminium is that its ions can react with phosphates, which causes phosphates to be less available to water organisms (WHO, 1997).

High concentrations of aluminium may not only be found in acidified lakes and air, but also in the groundwater of acidified soils. There are strong indications that aluminium can damage the roots of trees when it is located in groundwater. Aluminium mainly occurs as Al^{3+} (aq) under acidic conditions, and as $\text{Al}(\text{OH})_4^-$ (aq) under neutral to alkaline condition. Aluminium metal rapidly develops a thin layer of aluminium oxide of a few millimeters that prevents the metal from reacting with water (Ramade, 1987). When this layer is corroded a reaction develops, releasing highly flammable hydrogen gas.

Aluminium salts are also widely used in water treatment as coagulants to reduce organic matter, colour, turbidity, and microorganism levels. The process usually consists of addition of an aluminium salt (often sulfate) at optimum pH and dosage, followed by flocculation, sedimentation, and filtration (Health Canada, 1993).

2.9.2 Iron (Fe)

Iron is found at high percentage in the earth's crust. Iron rusts in damp air and dissolves readily in dilute acids (Porterfield, 1993). Iron is chemically active and

forms two major series of chemical compounds, the divalent iron (II), Fe^{2+} or ferrous compounds and the trivalent iron (III), Fe^{3+} or ferric compounds. Under reducing conditions iron exists in ferrous state (Fe^{2+}) (Sonawane, 2003). In the absence of complex-forming ions, the ferric form is not significantly soluble unless the pH is very low. On exposure to air or addition of oxidants, ferrous iron is oxidized to the ferric state and may hydrolyse to form insoluble hydrated ferric oxide (APHA, 1992). Some groundwater and acid drainage contain considerable amount of iron. Iron in water can cause staining of laundry and porcelain.

Iron is essential to most living things, from micro-organisms to humans. Iron can be found in meat, potatoes and vegetables. The human body absorbs iron in animal products faster than iron in plant products. Iron is an essential part of hemoglobin; the red colouring agent of the blood that transports oxygen through the body (ATSDR, 1992; Health Canada, 1993). Iron deficiency may cause conjunctivitis, choroiditis and retinitis if it comes into contact with and remains in the tissues (Health Canada, 1993).

Iron and manganese have also been found in elevated concentrations in water in Ghana (Keraita *et al.*, 2003). Iron is not a health concern in itself. However, high levels of iron affect the taste and quality of drinking water (Mosley *et al.*, 2004). Iron gives water a bitter, metallic taste which makes such water highly undesirable. This can lead to colouration of cooking utensils and food (Schäfer *et al.*, 2008). A bittersweet astringent taste is detectable at levels above 1 mg /L (UNEP/WHO, 1996).

2.9.3 Copper (Cu)

Copper is a reddish metal. It reflects red and orange light and absorbs other frequencies in the visible spectrum, due to its band structure; hence it has a nice reddish colour. It is malleable, ductile, and an extremely good conductor of both heat and electricity (ATSDR, 2004). Most copper is used for electrical equipment. Copper is ideal for electrical wiring because it is easily worked, can easily be drawn into fine wire and has a high electrical conductivity. (Landner & Lindstrom, 1999; Wiberg *et al.*, 2001).

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The production of copper has increased over the last decades and due to this copper quantities in the environment have also increased (USEPA, 1995). Copper can be released into the environment by both natural sources and human activities. Since copper is released both naturally and through human activity, it is very widespread in the environment and occurs virtually in all media: air, water and soil (ATSDR, 1990; UNEP/WHO, 1996).

Most copper compounds can settle and be bound to either water sediment or soil particles. Soluble copper compounds form the largest threat to human health. Usually water-soluble copper compounds occur in the environment after release through application in agriculture (ATSDR, 1990). In surface water copper can travel great distances, either suspended on sludge particles or as free ions (Skipton *et al.*, 2008).

High levels of copper can be harmful. Breathing high levels of copper can be irritating to the nose and the throat. Ingesting high levels of copper can cause nausea, vomiting, and diarrhoea. Very-high doses of copper can cause damage to

your liver and kidneys, and can even cause death (Wong, 1988; ATSDR, 2004,). Also, copper has been found to have a high chronic toxic effect on aquatic life even as low as a level of 0.3 mg/L total copper (Bosnic *et al.*, 2000).

2.9.4 Zinc (Zn)

Zinc is a very common substance that occurs naturally (Wiberg *et al.*, 2001). Many foodstuffs contain certain concentrations of zinc. Drinking water also contains some amounts of zinc, which may be higher when it is stored in metal tanks. Industrial sources or toxic waste sites may cause the zinc amounts in drinking water to reach levels that can cause health problems (ATSDR, 2005). Zinc concentrations in the environment keep rising unnaturally due to addition of zinc through human activities. Most zinc is added during industrial activities, such as mining, coal and waste combustion and steel processing (WHO, 2003; ATSDR, 2005).

The solubility of zinc depends on temperature and pH of the water in question. When the pH is fairly neutral, zinc in water is insoluble. Solubility increases with increasing acidity. Above pH 11, solubility also increases (Chang, 1998).

Severe zinc deficiency in animals has been associated with reduced fertility, fetal nervous system malformations, and growth retardation in late pregnancy (USEPA, 2005). In humans, labor abnormalities, congenital malformations, and preterm labor have been reported in otherwise healthy women with low maternal serum zinc concentrations (Simmer *et al.*, 1991).

In the environment, zinc may also increase the acidity of waters. Some fish can accumulate zinc in their bodies, when they live in zinc-contaminated waterways

(USEPA, 1995; Zu *et al.*, 2006). When zinc enters the bodies of fish, it is able to biomagnify in the food chain. Water-soluble zinc that is located in soils can contaminate groundwater (Zu *et al.*, 2006).

Zinc can be transported as particles released into the atmosphere or as dissolved compounds in natural waters. Zinc attaches to dust particles in the air which settle to the ground or are taken out of the air by rain. Zinc attaches to soil and sediment particles and most of the zinc will stay bound. Some zinc will move into the ground water and into lakes, streams, and rivers where it combines with other organic or inorganic matter. Zinc is likely to build up in fish and other organisms, but unlikely to build up in plants (NPIA, 1992; ATSDR, 2005).

Inhaling large amounts of zinc (as zinc dust or fumes from smelting or welding) can cause a specific short-term disease called metal fume fever, which is generally reversible once exposure to zinc ceases. However, very little is known about the long-term effects of breathing zinc dust or fumes (USEPA, 2005).

2.9.5 Calcium (Ca)

Calcium ions dissolved in water form deposits in pipes and boilers and make the water hard. That is, when water contains too much calcium or magnesium the water is said to be hard (House, 2008; Ameyibor *et al.*, 1999). The distribution of calcium is very wide; it is found in almost every terrestrial area in the world. This element is essential for the life of plants and animals. Calcium is present in the animal skeleton, in tooth, in egg shell, in the coral and in many soils (Ameyibor and Wiredu, 1999).

Calcium is the most abundant metal in the human body being the main constituent of bones and teeth. A lack of calcium is one of the main causes of osteoporosis. Osteoporosis is a disease in which the bones become extremely porous, are subject to fracture, and heal slowly (Wiberg *et al.*, 2001; Ameyibor *et al.*, 1999).

Calcium is not known to have any environmental effect. However, when calcium combines with sulphate and carbonate to form calcium sulphate and calcium carbonate at high concentrations, they cause water hardness (Ajai *et al.*, 2011).

2.10 WORK ON EFFLUENTS BY OTHER RESEARCHERS.

According to Akan *et al.*, (2009) high concentrations of heavy metals were observed to accumulate in all the effluent samples from tanneries and textile industries studied. The concentrations of sulphate, chloride, nitrate, nitrite and phosphate of effluent in all the industries sample studied were higher than the USEPA limits for the discharge of industrial effluent into river.

From Fakayode (2005), samples from Alaro River, which is receiving point of industrial effluent as a point source, were taken. The water quality of the river upstream and downstream after the point of effluent discharge was assessed with the view of determining the effect of industrial effluent on the water quality of the river. The parameters studied for the samples included pH, alkalinity, electrical conductivity, chloride, sulphate, phosphate and heavy metals. The levels of most parameters in the effluent exceeded the effluent guideline for discharge into surface water. River's recovery capacities for the water quality parameters were fairly good and ranged between 36 and 90 %.

Yusuff and Sonibare (2004) in their study entitled *Characterization of Textile Industries' Effluents in Kaduna, Nigeria and Pollution Implications*, the qualities of effluents studied, such as Aluminium, Iron, Zinc and Nitrate, were grossly below the set limits by the Federal Ministry of Environment in Nigeria and some world bodies like the World Health Organization in four of the five textile mills. However, Cu was detected in 80 % with limit exceeded about three folds on the average. Air pollution of the detected effluents' parameters could be in gaseous and particulates form and the potential threat they pose to the environment especially around River Kaduna basins calls for stringent control measure.

Awomeso *et al.*, (2010) found that, the results of various water parameters analysed in their study in *Pollution of Waterbody by Textile Industry Effluents in Lagos, Nigeria*, suggested that the effluents being discharged into the stream by the textile industry have considerable negative effects on the water quality of the sampled stream and as such, the stream is polluted and the water is not good for human consumption and other domestic use. Most of the parameters they studied had their levels higher than the recommended values for discharge into fresh water bodies. Based on this, they recommended that the effluents from the textile industry should be treated before disposing them off into water bodies.

Ipeaiyeda and Onianwa (2011), have also revealed that effluents from food and beverages industries in Ibadan city contributed significant pollution load to the Alaro river. The river is a recipient of effluents of poor quality. Some identified pollutants in the combined effluent are organic load, suspended solids, phosphate, nitrate and chloride which led to significant pollution of the Alaro river water. The receipt of the

combined effluent has rendered the river unwholesome for certain beneficial purposes such as cooking, drinking, irrigation and aquatic life support. Thus the effluent has a profound impact on the physicochemical structure of the Alaro River and also affects the consumers of the river water. They have therefore suggested that discharges from these industries should be given very high degree of treatment before final exist to the Alaro River.

Igbinoso and Okoh (2009) studied on the impact of discharge wastewater effluents on the physico-chemical qualities of a receiving watershed in a typical rural community. Their study was carried out to evaluate the impact of the treated final effluents of a typical wastewater treatment plant in a rural community of the Eastern Cape, South Africa, on the receiving watershed. The results revealed that the treatment plant exhibited effluent qualities that meet acceptable standard in some parameters, like pH and total dissolved solid. It was also observed that the effluents fell short of standard requirements that are critical to the provision of clean and safe water such as organic waste, phosphate, nitrate and nitrite. The results of this study therefore showed that the effluent could pose significant healthy and environmental risk to rural communities which rely on the receiving water as their source of domestic water purpose without treatment. The study concluded that there was a negative impact on the physico-chemical characteristics of the receiving watershed as a result of the discharge of inadequately treated effluents from the wastewater treatment plant.

In Ghana, Addo *et al.*, (2011) have established that some physicochemical parameters like conductivity, chloride, total alkalinity and total hardness in the

Kpeshie Lagoon were above specified guideline limits for natural waters. In addition, the presence of toxic metals in sediment and water in the aquatic environment of the lagoon has also been established. The identification and quantification of the heavy metal sources are important environmental issues. The study also identified Zn to posing a low environment risk, whereas Cr and Ni pose a high risk. The information gathered suggested that the pollution of the lagoon is on increase.

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CHAPTER THREE

METHODOLOGY

3.1 The Study Area

The selected schools for this study are located in the Kumasi Metropolis of the Ashanti Region of the Republic of Ghana. Fig. 3.1 shows the map of Ghana indicating Kumasi where the study areas are located. The Metropolitan area is located on latitude ($6^{\circ} 35' - 6^{\circ} 40' N$) $1^{\circ} 30' W$ and on longitude ($1^{\circ} 30' - 1^{\circ} 35'$) $6 W, 40 N$. The Metropolis covers an approximate area of 254 km^2 . The Metropolis is located in the centre of Ghana and this makes it a transit point to and from all parts of the country. This has resulted in a lot of negative impacts on the socio-economic development of the area in particular and the nation as a whole (KMA, 1996).

Sites for Educational facilities total about 3,469.4 hectares (17.3%) of the metropolitan area. The largest educational land user is the Kwame Nkrumah University of Science and Technology (KNUST) located in the eastern section of the Metropolis. There are five (5) other tertiary educational institutions and fifteen major public senior high schools located within the Metropolis (KMA, 2006).

The Kumasi metropolitan area falls within the wet sub-equatorial type of climate. The average minimum temperature is about $25.5^{\circ} C$ and a maximum average of about $30.7^{\circ} C$. The average humidity is about 84.16% at 1500 GMT. The moderate temperature, humidity and the double maximum rainfall regime which is 214.3 mm in June and 165.2 mm in September, have a bearing on the population growth and the sanitation (KMA, 1996). These make the land fertile for market garden and other farming and economic activities.

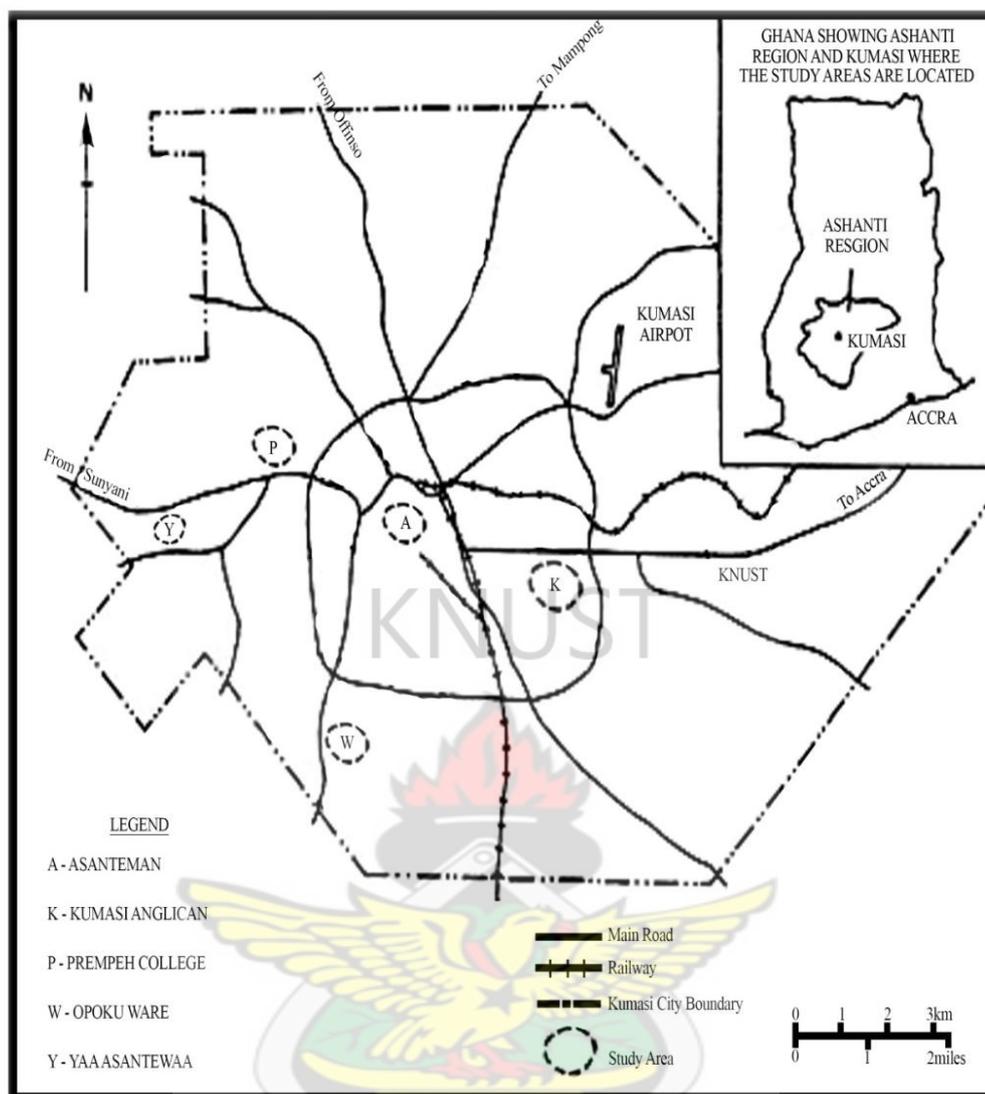


Fig 3.1 Map of Kumasi showing the study areas.

3.2 Selection of Schools.

There are many Senior High Schools in Kumasi. Due to financial and time constraints only five senior high schools were selected as the representation of the rest. The schools were selected based on their populations. All the schools have student population not less than two thousand (2000). Also all these schools place premium on the study of science and therefore have many science students. Four out of the five schools are science resource centres who use a large range of chemicals for their practical work. In addition, other schools visit these resource centres for

practical exercises. Moreover, gender of the students was also considered. Two out of the five schools are boys, one is a girls' school and the remaining two are co-educational.

The selected schools were Asanteman SHS, Kumasi Anglican SHS, Opoku Ware SHS, Prempeh College and Yaa Asantewaa SHS were selected.

3.3 Sampling

One hundred and fifty sampling bottles, thirty for each school for the samples were taken and thoroughly washed with laboratory detergent (free from phosphate and nitrate to minimise interference) and distilled water. They were then soaked in 10 % nitric acid overnight to ensure minimum contamination. The bottles were rinsed with distilled water. They were then filled with distilled water and the pH meter was used to test for the pH of the sampling bottles. The pH was always between 6.8 and 7.0, indicating the neutrality of the bottles. The bottles were labeled A = Asanteman SHS, K = Kumasi Anglican SHS, P= Prempeh College, W= Opoku Ware SHS and Y = Yaa Asantewaa SHS.

Effluents from the chemistry laboratories of the selected schools were collected after chemistry practical work. Monthly samples were collected from each school between November 2010 and March 2011. In all, five sets of test samples were collected from each school. Effluents were collected from the outlet of the sink not more than 2 m away from the laboratory building. This point was labeled as point A. A second sample was collected at 100 m away from the building. This was labeled as point B. A third sample was again collected from another point which is 200 m away from

the building and labeled as C. Six test samples were collected from each school (two from each sampling point) on each sampling day. The samples were analysed for the parameters and the mean values of the parameters were determined for each sampling point. Fig 3.2 shows the various sampling points at each senior high school's laboratory.

The samples were transported in pre-washed ice chest to the Ghana Water Company's Analytical Laboratory, Kumasi which was the analytical centre where all the analyses were done. At the centre the samples were stored in the refrigerator.

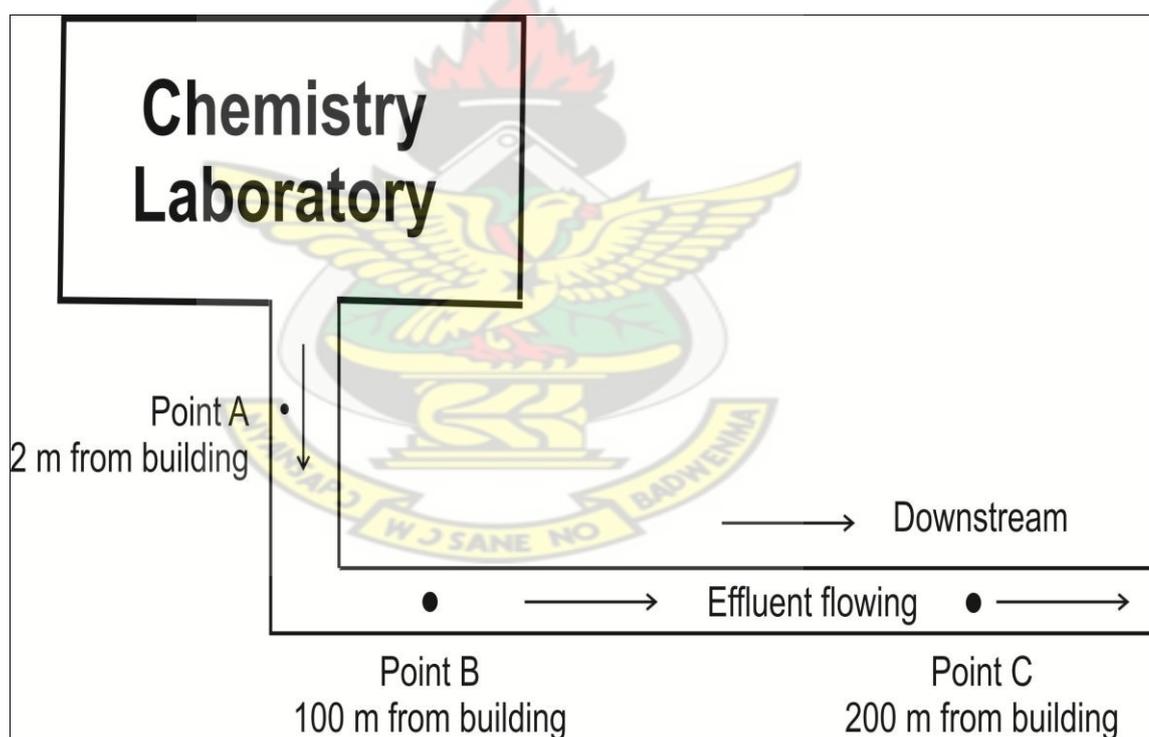


Fig 3.2 Sketch of sampling sites at various points from the laboratory.

3.4 Analytical Procedure.

Laboratory analyses of the parameters such as pH, temperature, conductivity, total alkalinity, total hardness, sulphate, sulphite, nitrate, nitrite, chloride, phosphate, ammonia, aluminium, copper, zinc, calcium and iron were carried out as follows:

3.4.1 Determination of Temperature using the Yokogawa TX 10-01

Thermometer

The temperatures of the samples were determined on site as soon as the samples were collected. This was done with the Yokogawa TX 10-01 digital thermometer. The thermometer was rinsed thoroughly with distilled water. A clean dry beaker was taken and it was rinsed with distilled water and then some of the sample of which temperature was to be determined. Some of the sample was poured into the beaker. The thermometer was immersed completely in the sample in the beaker such. Some time was allowed for equilibrium to be established. This was achieved when the signals become steady. Reading was taken.

3.4.2 Determination of Electrical Conductivity using Jenway 4510

Conductivity Meter

The conductivity meter was calibrated by pressing and holding the CAL button. The meter is auto-calibrated. Conductivity was also measured in the field immediately after taking the samples because conductivity changes with storage time. The Jenway 4510 Conductivity Meter was used. In the process, the conductivity cell was rinsed three times with the sample. The temperature of the portion of the sample was adjusted to ± 0.1 °C. The conductivity cell containing the electrodes was immersed in sufficient volume of the sample for the liquid level to be above the holes in the cell

of the conductivity meter. This was done such that there were no air bubbles clinging to the electrodes. The meter was turned on and then some time was allowed for the signal to be steady before taking the reading.

3.4.3 Determination of pH

The pH was measured on site using a Fisherbrand Hydrus 100 pH meter. The samples were taken into plastic bottles. The pH meter was calibrated with buffer solutions of pH 4, 7 and pH 11 before using for the pH determination. The pH meter was calibrated with buffer solutions of pH 4, 7 and pH 11 before using for the pH determination. The meter was rinsed with distilled water before placing them in the sample. The meter automatically displayed MEASURE. The tip of the meter was fully immersed in the samples. The meter was allowed to stand in order to settle and reach equilibrium before readings were taken. Equilibrium was determined when the signals on the meters became steady. The pH of the sample appears digitally on the screen and was recorded.

3.4.4 Measurement of Alkalinity

Two drops of phenolphthalein indicator was added to 100 ml of the sample in an Erlenmeyer flask on a white tile (surface). If no colour is produced, then phenolphthalein alkalinity is zero. When the sample turned pink after adding the indicator, it was titrated against a standard acid until the pink colour became colourless. Two drops of methyl orange indicator was added to the resulting mixture from the phenolphthalein titration. If the sample becomes orange without the addition of the acid the total alkalinity is zero. When the sample turned yellow it was

titrated with a standard acid until the first perceptible orange colour is observed at the end point.

Phenolphthalein Alkalinity as CaCO_3

$$P = \frac{100,000 \times A \times C}{V} \text{ mg/l}$$

Total Alkalinity as CaCO_3

$$T = \frac{100,000 \times B \times C}{V} \text{ mg/l}$$

A = volume of standard acid solution (ml) to reach the phenolphthalein end-point

B = volume of standard acid solution (ml) to reach the methyl orange end-point

C = concentration of acid in mol l^{-1}

V = volume of the sample used (ml)

3.4.5 Determination Total Hardness

A buffer solution was prepared. This was done by dissolving 16.9 g Ammonium chloride (NH_4Cl) in 143 ml of concentrated Ammonium hydroxide (NH_4OH). 1.25 g of magnesium salt of EDTA was added to the mixture and diluted to 250 ml with distilled water. Total hardness was determined by measuring 50 ml of the sample into a clean dry Erlenmeyer flask. 1 ml of the buffer solution prepared was also added followed by a few grams of the Eriochrome Black T indicator. This was titrated against 0.01 M EDTA solution, mixing gently until the colour changed from red to blue. The titre value was recorded and the concentration calculated from the formula:

$$\text{Total Hardness as mg/l CaCO}_3 = \frac{A \times B \times 1000}{\text{Sample Volume}}$$

Where

A = titre value for sample B = ml CaCO_3 equivalent to EDTA

3.4.6 Determination of Ammonia (NH_3)

Palintest Photometer 5000 was used to determine the concentration of ammonia. In the process, a blank sample was prepared. This was the sample without the test tablet. A wavelength of 640 nm was selected. The blank sample was placed in the test chamber. The ON button was pressed and held until the display read 100 % T. The ON button was released and the blank tube removed. The photometer was ready to be used.

The sample cell was filled with the test sample to the 10 ml mark. One Ammonia No 1 tablet was added to the sample in the cell. One Ammonia No 2 tablet was crushed and allowed to dissolve in the mixture. The set up was left for about ten minutes to allow colour to develop. A wavelength of 640 nm was selected on the Photometer. The Photometer readings were taken.

3.4.7 Determination Chloride (Cl^-)

3.4.7.1 Preparation of chromate indicator solution

50 g K_2CrO_4 was dissolved in a little distilled water. 0.10 M AgNO_3 solution was added until a definite red precipitate was formed. The mixture was allowed to stand for twelve hours, filtered and diluted to 1 litre with distilled water.

3.4.7.2 Preparation of 0.0141 M silver nitrate solution

2.395 g AgNO₃ was weighed and dissolved in distilled water and diluted to 1 litre. The solution was then stored in dark brown bottle.

3.4.7.3 Procedure for determining chloride

20 ml of the sample was measured and put in a clean dry Erlenmeyer flask. 1 ml of 5% Potassium chromate (K₂CrO₄) was added as an indicator. The resulting mixture was titrated against 0.0141 M AgNO₃ solution, swirling gently until the colour changed from yellow to brick red. The titre value was recorded as A to calculate the concentration using the relation below:

$$\text{Cl}^- (\text{mg/l}) = \frac{(A-0.2) \times 0.5 \times 1000}{\text{Sample Volume}}$$

NOTE: 1.00 ml of 0.0141 M AgNO₃ \equiv 0.5 mg Cl⁻

Where A = titre value

3.4.8 Determination of Nitrite (NO₂⁻)

3.4.8.1 Preparation of Hosvay's solution No 1

30 ml of 99.5% (Philip Harris) glacial acetic acid was mixed with 120 ml distilled water in the temperature kept at about 60 °C in order to dissolve 0.5 g Sulphanilic acid.

3.4.8.2 Preparation of Hosvay's solution No 2

0.1 g α -Naphthylamine was dissolved in 30 ml of glacial acetic acid and 120 ml distilled water added to the mixture.

3.4.8.3 Procedure for measuring nitrite

50 ml of the sample was measured into a clean dry Erlenmeyer flask. 2 ml of Hosvays' solution No. 1 was added to the sample in the flask. Another 2 ml of Hosvay's solution No. 2 was added and swirled gently. The mixture was allowed to stand for fifteen (15) minutes. The sample was transferred into a Nessler's tube and the value matching colour using the Nitrite disc comparator was read. The markings on the disc represent the actual amount of Nitrogen (N) present as Nitrite (APHA, 1992).

The formulae below were used:

$$N \text{ (mg/l)} = \frac{\text{Disc Reading} \times 0.5}{\text{Sample Volume}}$$

$$\text{NO}_2^- \text{ (mg/l)} = N \text{ (mg/l)} \times 3.284$$

3.4.9 Determination of Nitrate

50 ml sample was measured in a clean dry beaker and 2 ml acetic acid was added. Inorganic ions found in water such as chlorate and chloride, if present, interfere in the determination of nitrate. These were removed by precipitation before nitrate was determined. The chloride was precipitated with Ag_2SO_4 solution when Cl^- value was high. The Cl^- was filtered off and put into an evaporating dish until it evaporated to dryness. The mixture was allowed to cool and then dissolved with 1 ml Phenoldisulphonic acid. 25 ml each of NaOH solution and distilled water were added. The developed colour was matched with the standard (APHA, 1992).

Calculation

$$\text{mg/l Nitrogen, N} = \frac{A \times 10}{\text{Sample Volume}} \quad \text{Where A = ml of standard nitrate}$$

3.4.10 Determination of Phosphate

To 100 ml of the sample, 0.05 ml (1 drop) phenolphthalein indicator was added. When sample turned pink, bench acid was added drop wise to neutralise it. 4 ml molybdate reagent 1 and 0.5 ml stannous chloride reagent 1 were added while mixing thoroughly. 10 ml of the prepared sample was taken and the absorbance at wavelength of 690 nm read after zeroing with distilled water. The corresponding concentration on the calibration curve was taken (USEPA, 2004).

$$\text{mg/l P} = \frac{\text{mg P in 100ml} \times 1000}{\text{Sample Volume}}$$

3.4.11 Determination of Sulphite

A blank sample was prepared. This was the sample without the test tablet. A wavelength of 570 nm was selected. The blank sample was placed in the test chamber. The ON button was pressed and held until the display read 100 % T. The ON button was released and the blank tube removed. The photometer was ready to be used.

The sample was filtered to obtain clear solution. The test tube was filled to the 10 ml mark. One Sulphitest No 1 tablet was crushed, added and mixed to dissolve. Sulphitest No 2 tablet was also crushed, added and mixed to dissolve. The tube was capped immediately to prevent oxidation to sulphate. The set up was left for about 2 minutes to allow full colour development to take place. Wavelength 570 nm was selected on the Photometer. The Photometer readings were taken.

3.4.12 Determination of Sulphate

100 ml of the sample was measured in to 250 ml beaker, filtered and 2 ml of 2 M HCl added. This was evaporated on the hot plate to half the initial volume. 5 ml 0.5 M BaCl₂ solution which was boiling was added and heated on the water bath until the precipitate settled. The chloride was filtered through an ashless filter paper and washed with hot distilled water. The filtrate was tested with 0.1 silver nitrate solution. The filter paper was dried and weighed in an empty crucible. The dry filter paper was folded into the crucible and heated for 1 hour at 80°C. The crucible was removed, put into a dessicator for 30 min to dry and then weighed (USEPA, 2004).



$$\text{mg/l SO}_4^{2-} = \frac{\text{A} \times 411.6}{\text{Sample Volume}} \quad \text{A} = \text{mg BaSO}_4$$

3.4.13 Determination of Calcium

50 ml of the sample was measured into a conical flask. 1 ml of 1 M NaOH (99% from Philip Harris) solution was added. A few grams of powdered ammonium murexide indicator was added. This was titrated against 0.01 M EDTA solution mixing gently until the colour changed from pink to purple. The titre value, A, was recorded and computed as follows:

$$\text{Calcium hardness as mg/l CaCO}_3 = \frac{\text{A} \times \text{B} \times 1000}{\text{Sample Volume}}$$

Where

A = titre value for the sample

B = ml CaCO₃ equivalent of EDTA

3.4.14 Determination of Aluminium

3.4.14.1 Reagents

- a. Standard alum, FeSO_4 (98% pure from BDH), solution
- b. 0.3 g of Alizarin red S is dissolved in H_2SO_4 and diluted to 100 ml with distilled water to obtain 0.3 % Alizarin red S;
- c. Sodium bicarbonate (99% pure from Philip Harris)
- d. 50 ml of glacial acetic acid diluted with 50 ml of boiled distilled water to obtain 50 % acetic acid

3.4.14.2 Experimental procedure for measuring of aluminium

50 ml of the sample was put into a conical flask. 1 ml alizarin red S solution was then added and boiled for about 2 minutes. Sodium bicarbonate (NaHCO_3) solution was added dropwise, until slight purple tinge was obtained. Exactly 0.5 ml of NaHCO_3 solution was added and boiled for 2 minutes. The mixture was cooled, washed into Nessler tube and topped up to 50 ml with distilled water. 1ml of acetic acid solution was added and it was made stand for 1 minute for the colour to develop and then compared the colour with the standard. The following formula was used to calculate the concentration of aluminium: (USEPA, 2006).

$$\text{mg/l Al}^{3+} = \frac{\text{ml of standard alum solution} \times 10}{\text{Sample Volume}}$$

3.4.15 Determination of Copper

A blank sample was prepared. This was the sample without the test tablet. A wavelength of 520 nm was selected. The blank sample was placed in the test chamber. The ON button was pressed and held until the display read 100 % T. The

ON button was released and the blank tube removed. The photometer was ready to be used.

A test tube was filled with 10 ml of the test sample. One Coppercol No 1 tablet was crushed and added. It was mixed to dissolve. A wavelength of 520 nm was selected on the Photometer. The Photometer readings were taken.

3.4.16 Determination of Iron

50 ml of the sample was measured into a clean dry Erlenmeyer flask. The sample was acidified with 1 ml of HNO₃ solution. About 1 ml of 0.2 M KMnO₄ solution was added drop wise until a permanent pale pink colour was obtained. The mixture was evaporated to half its volume on a hot plate. The mixture was allowed to cool to obtain room temperature and 2 ml of 10% ammonium thiocyanate solution was added. The sample was topped up to the 50 ml mark with distilled water. Blank was prepared using distilled water following the same procedure as above. The blank was titrated against a standard iron solution comparing the colours until a matching colour to that of the sample was obtained. The titre value T_v which gave the matching was recorded. The total Iron concentration was calculated from the formula: (USEPA, 2006).

$$\text{(Total) Iron in mg/l} = \frac{\mathbf{T_v \times 0.05 \times 1000}}{\mathbf{\text{Sample Volume}}}$$

NOTE: 1ml Standard iron solution \equiv 0.05 mg Fe

3.4.17 Determination of Zinc

A blank sample was prepared. This was the sample without the test tablet. A wavelength of 640 nm was selected. The blank sample was placed in the test chamber. The ON button was pressed and held until the display read 100 % T. The ON button was released and the blank tube removed. The photometer was ready to be used.

10 ml of the sample was pipette into a boiling tube. One zinc tablet was crushed and then mixed to dissolve. The mixture was allowed to stand for five minutes and then mixed again to ensure complete dissolution of the indicator. A wavelength of 640 nm was selected on the Photometer. The photometer readings were taken.

3.5 Data Analysis

After the completion of data collection, quantitative data was checked before the coding process. Data entering, analyzing and processing were done by application of the Microsoft Excel Programme. Descriptive statistics techniques such as mean values, percentages, one way ANOVA and bar charts were used for quantitative data analysis and the confidence level of 95% was set for the discussion.

CHAPTER FOUR

RESULTS

4.1 Results of Physical Parameters Measured in the Samples

Figure 4.1 shows the mean pH values of the effluents in the five senior high schools where the study was conducted. The mean pH values of most of the schools were high at 2 m distance from the point of discharge. The highest pH was recorded at Yaa Asantewaa SHS with the value of 9.24 ± 0.8 and the lowest was at Kumasi Anglican SHS which was 7.10 ± 2.90 . In all the cases the pH values generally reduced as the effluents moved downstream. At 100 m, Yaa Asantewaa SHS still had the highest mean pH value of 7.90 ± 1.00 whereas Prempeh College recorded the lowest mean pH of 6.92 ± 1.20 . Finally, at 200 m Kumasi Anglican SHS recorded the least mean pH of 7.34 ± 1.30 and Opoku Ware School had the highest mean pH value of 7.82 ± 0.40 . However the pH values for Kumasi Anglican SHS, Opoku Ware SHS and Prempeh College at 200 m away from the point of discharge were slightly higher than the values at 100 m away from the point of discharge. This means that the pH values for these schools slightly increased downstream.

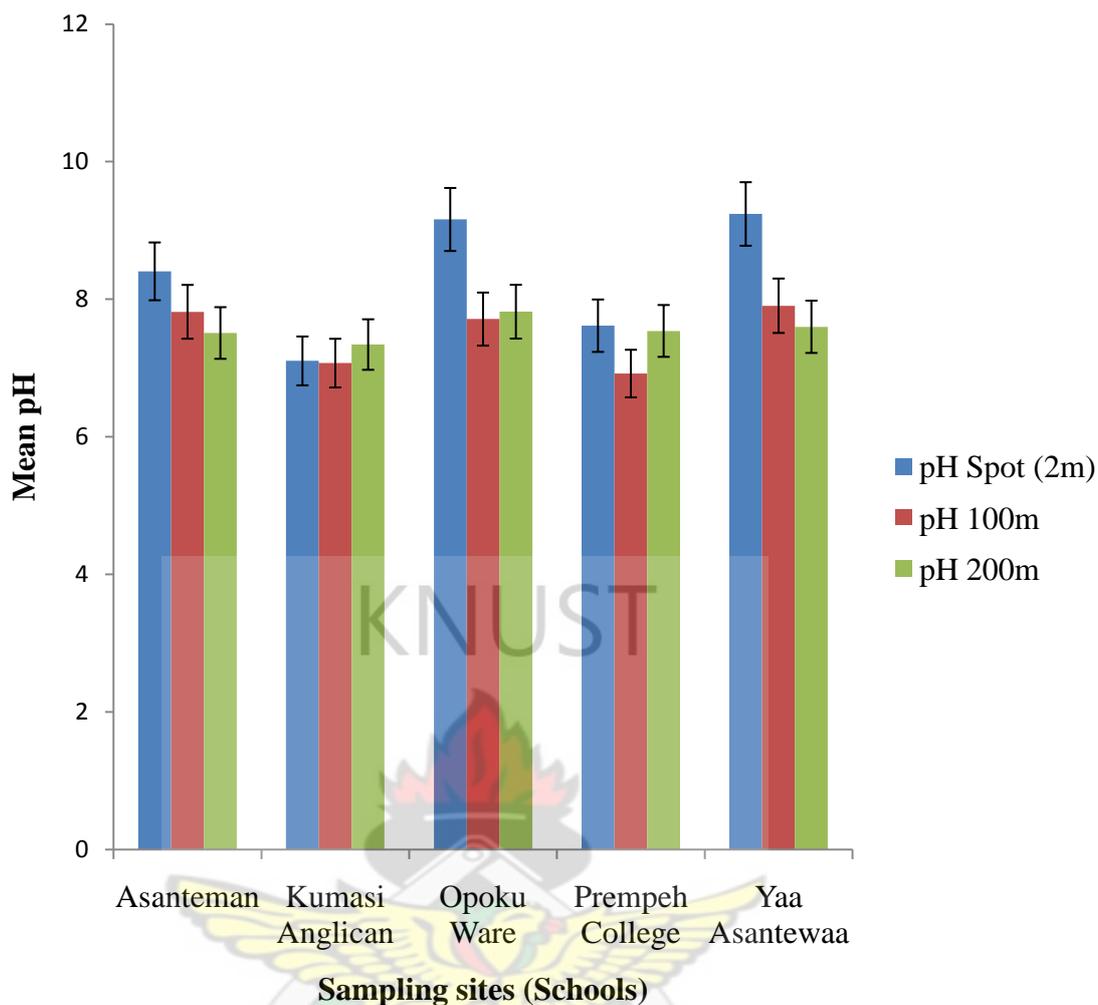


Figure 4.1 Mean pH of the effluents from the Chemistry Laboratories of the schools

Figure 4.2 shows mean electrical conductivities in the five senior high schools. Yaa Asantewaa SHS recorded the least value at 2 m away from the laboratory and the value was $27046.00 \pm 228.00 \mu\text{S/cm}$. The highest value which was $56098.00 \pm 947.00 \mu\text{S/cm}$ was recorded at Opoku Ware SHS at a point which is 2 m from the point of discharge. Mean conductivity values also decreased downstream. At 100 m, there was about 40 % reduction of the mean conductivity of Kumasi Anglican SHS, about 47 % reduction in that of Yaa Asantewaa SHS. At the 100 m distance away from the laboratory, the lowest mean conductivity value was at Prempeh College and

the value stood at $10541.00 \pm 757.00 \mu\text{S/cm}$ whereas the highest was recorded at Opoku Ware SHS ($35722.00 \pm 647.00 \mu\text{S/cm}$). At 200 m away from the laboratory, there was significant decrease in the conductivities. Yaa Asantewaa SHS recorded a reduction in conductivity from $14356.00 \pm 113.00 \mu\text{S/cm}$ at 100 m to $2796.00 \pm 14.00 \mu\text{S/cm}$ at 200 m which was about 81 % reduction. At Prempeh College, between 100 m and 200 m, conductivity reduced by about 63 % that is from $10541.00 \pm 757.00 \mu\text{S/cm}$ to $3944 \pm 42.00 \mu\text{S/cm}$.

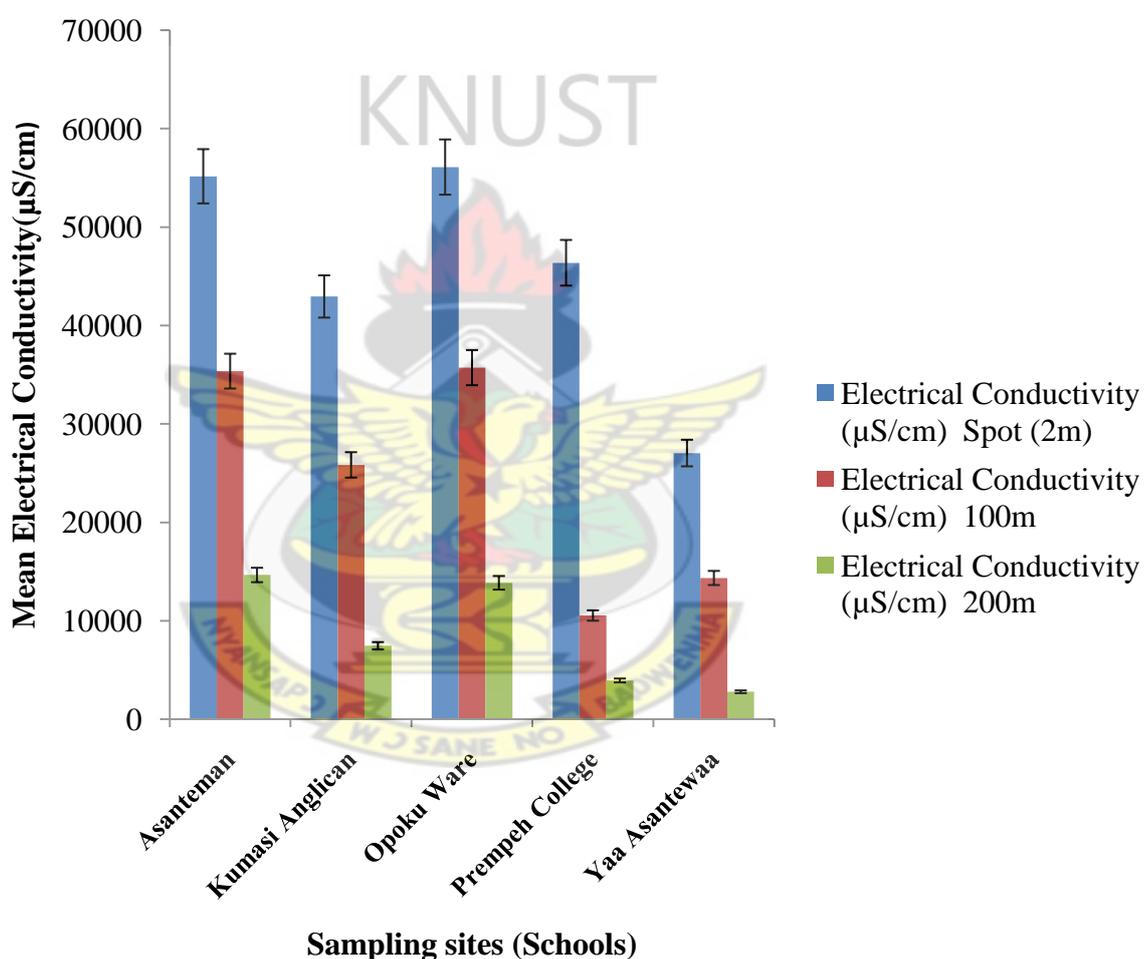
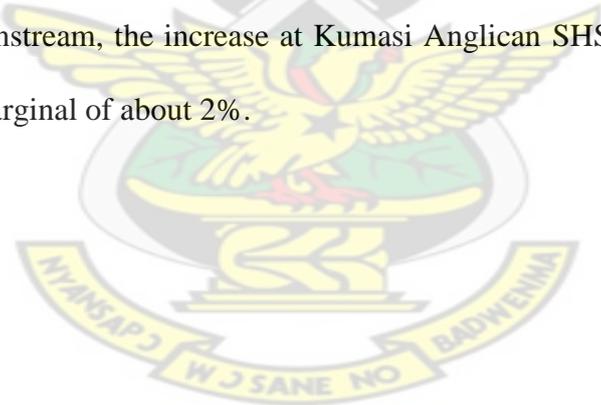


Figure 4.2 Mean Electrical Conductivity of the effluents (in $\mu\text{S/cm}$) from the Chemistry Laboratories of the schools

Figure 4.3 shows the mean temperature values of the effluents. In all the schools, temperature values of the effluents increased as the effluents moved downstream. The highest mean temperature measured at 2 m was at Kumasi Anglican SHS which was $26.36 \pm 2.20^{\circ}\text{C}$ and the least at that distance from the laboratories was at Asanteman SHS which was $24.64 \pm 2.10^{\circ}\text{C}$. The value for Opoku Ware SHS was $25.80 \pm 2.00^{\circ}\text{C}$, Prempeh College $25.10 \pm 2.0^{\circ}\text{C}$. At 100 m downstream, Asanteman SHS recorded mean temperature $26.76 \pm 1.10^{\circ}\text{C}$, Kumasi Anglican SHS $26.88 \pm 1.30^{\circ}\text{C}$, Prempeh College $26.64 \pm 1.40^{\circ}\text{C}$, Opoku Ware SHS $26.78 \pm 1.50^{\circ}\text{C}$ and Yaa Asantewaa SHS $26.42 \pm 0.90^{\circ}\text{C}$. At 200 m, the mean temperature values were $27.30 \pm 1.2^{\circ}\text{C}$ for Asanteman SHS, $28.26 \pm 1.40^{\circ}\text{C}$ for Kumasi Anglican SHS, $27.80 \pm 1.10^{\circ}\text{C}$ for Opoku Ware SHS, $27.04 \pm 1.20^{\circ}\text{C}$ for Prempeh College and $27.38 \pm 1.10^{\circ}\text{C}$ for Yaa Asantewaa SHS. Though temperature values increased downstream, the increase at Kumasi Anglican SHS between 2 m and 100 m was only marginal of about 2%.



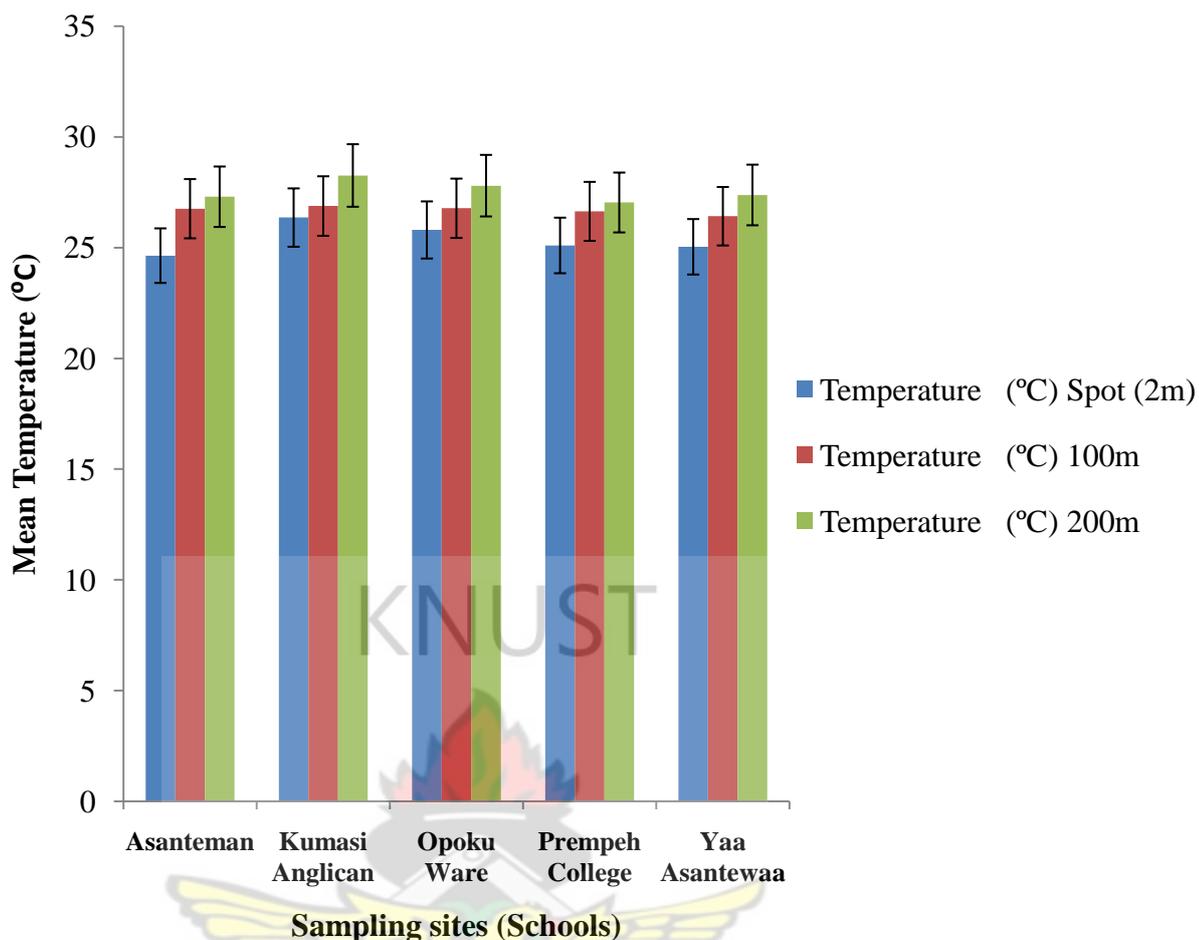


Figure 4.3 Mean Temperature of the effluents (in °C) from the Chemistry Laboratories of the schools

Figure 4.4 shows the mean total hardness (TH) of the effluents sampled. Mean total hardness (TH) generally decreased as the effluents moved downstream. At a distance of 2 m away from the laboratory, the highest value recorded was at Opoku Ware SHS with a value of 7810.00 ± 84.00 mg/l and the least was recorded at Kumasi Anglican SHS with a value of 2818.00 ± 29.00 mg/l. At 100 m, the mean TH in all the schools decreased from the values recorded at 2 m sampling points. Between 100 m and 200 m there was significant decrease in the mean TH except that of Opoku Ware SHS whose TH increased from 4942.00 ± 57.00 mg/l to 11912.00 ± 241.00

mg/l. For instance, there was about 66% reduction in the mean TH levels in the effluent at Kumasi Anglican SHS and about 73% reduction in that of Asanteman SHS. At 200 m, Opoku Ware SHS recorded the highest mean TH which was 11912.00 ± 241.00 mg/l which represents 140% increase over those sampled at 100 m from the laboratory whereas the least value was Kumasi Anglican SHS which was 464.00 ± 4.50 mg/l which was about 66 % reduction from the value recorded at 100 m sampling point.

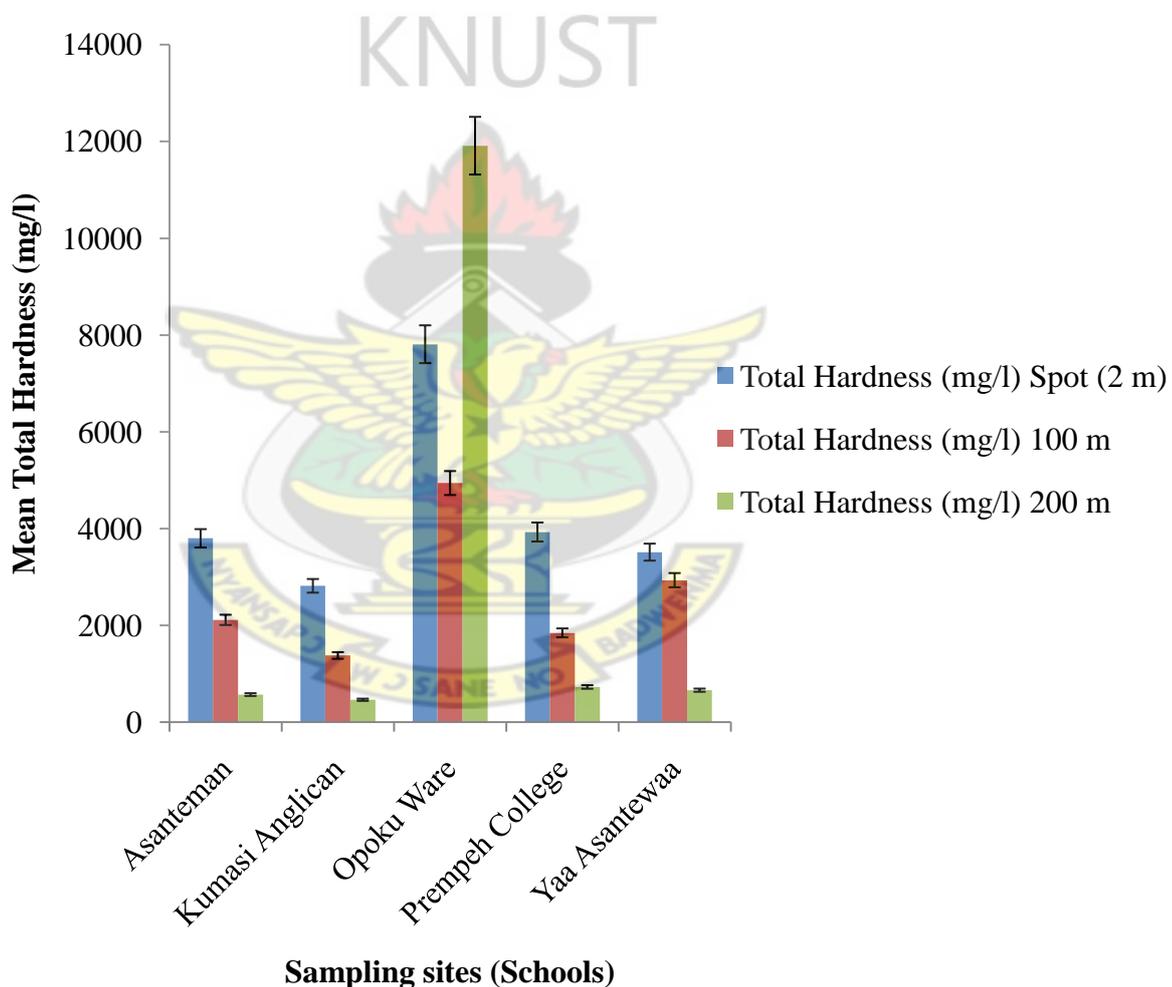


Figure 4.4 Mean Total Hardness of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.5 shows the mean total alkalinity of the effluents in the five senior high schools. Mean total alkalinity values generally decreased as the effluents moved downstream in all the schools. At 2 m the highest value recorded was 9330.00 ± 93.00 mg/l at Asanteman SHS and the least which was 3146.00 ± 20.00 mg/l was recorded at Yaa Asantewaa SHS. There was about 50% reduction in total alkalinity between 2 m and 100 m sampling points in all the schools except Opoku Ware SHS where the reduction was about 40%. Between 100 m and 200 m interval, there was significant reduction in the total alkalinity values. Yaa Asantewaa SHS for instance had reduction which was about 70%, about 50% reduction in the case of Prempeh College and Opoku Ware SHS, and about 65% reduction at Asanteman SHS. At 200 m Yaa Asantewaa SHS recorded the least total alkalinity value of 442.00 ± 32.00 mg/l whereas Prempeh College had 1732.00 ± 19.00 mg/l.



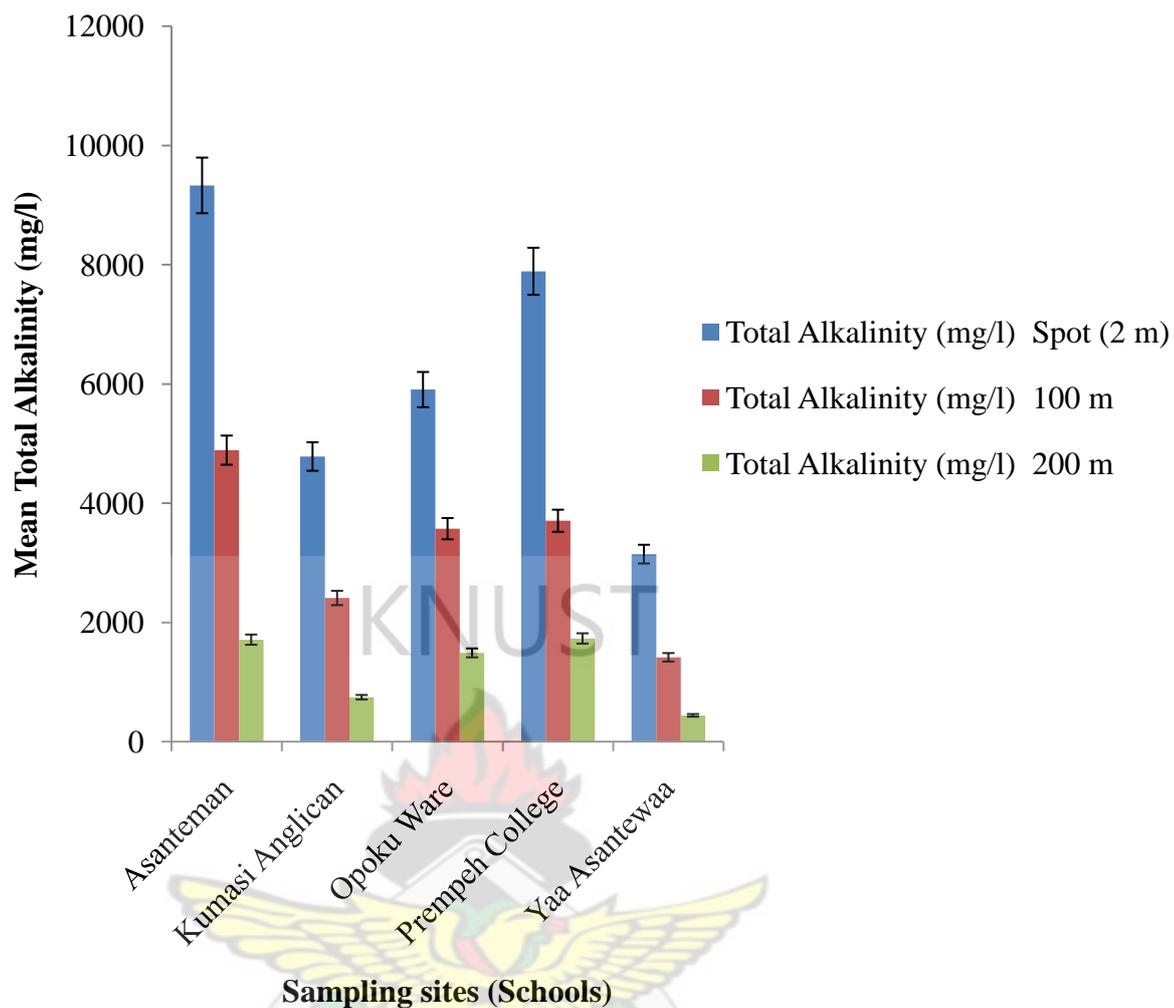


Figure 4.5 Mean Total Alkalinity of the effluents (in mg/l) from the Chemistry Laboratories of the schools

4.2 Results of Chemical Parameters Measured in the Samples

Figure 4.6 represents the mean chloride concentrations in the samples from the various schools. From Figure 4.6, it can be observed that mean chloride concentrations reduced as the effluents travel downstream. At the 2 m spot, Opoku Ware SHS recorded the highest mean chloride concentration of 4620.00 ± 22.60 mg/l followed by Asanteman SHS which recorded 4600.00 ± 16.40 mg/l. The least chloride value recorded at 2 m sampling point was at Kumasi Anglican SHS which

was 2718.00 ± 15.00 mg/l. Between 2 m and 100 m sampling there was at least 50% reduction in chloride concentration in all the schools. At 200 m the least chloride concentration was at Prempeh College which was 544.00 ± 4.60 mg/l and the highest was at Asanteman SHS which was 714.00 ± 3.60 mg/l.

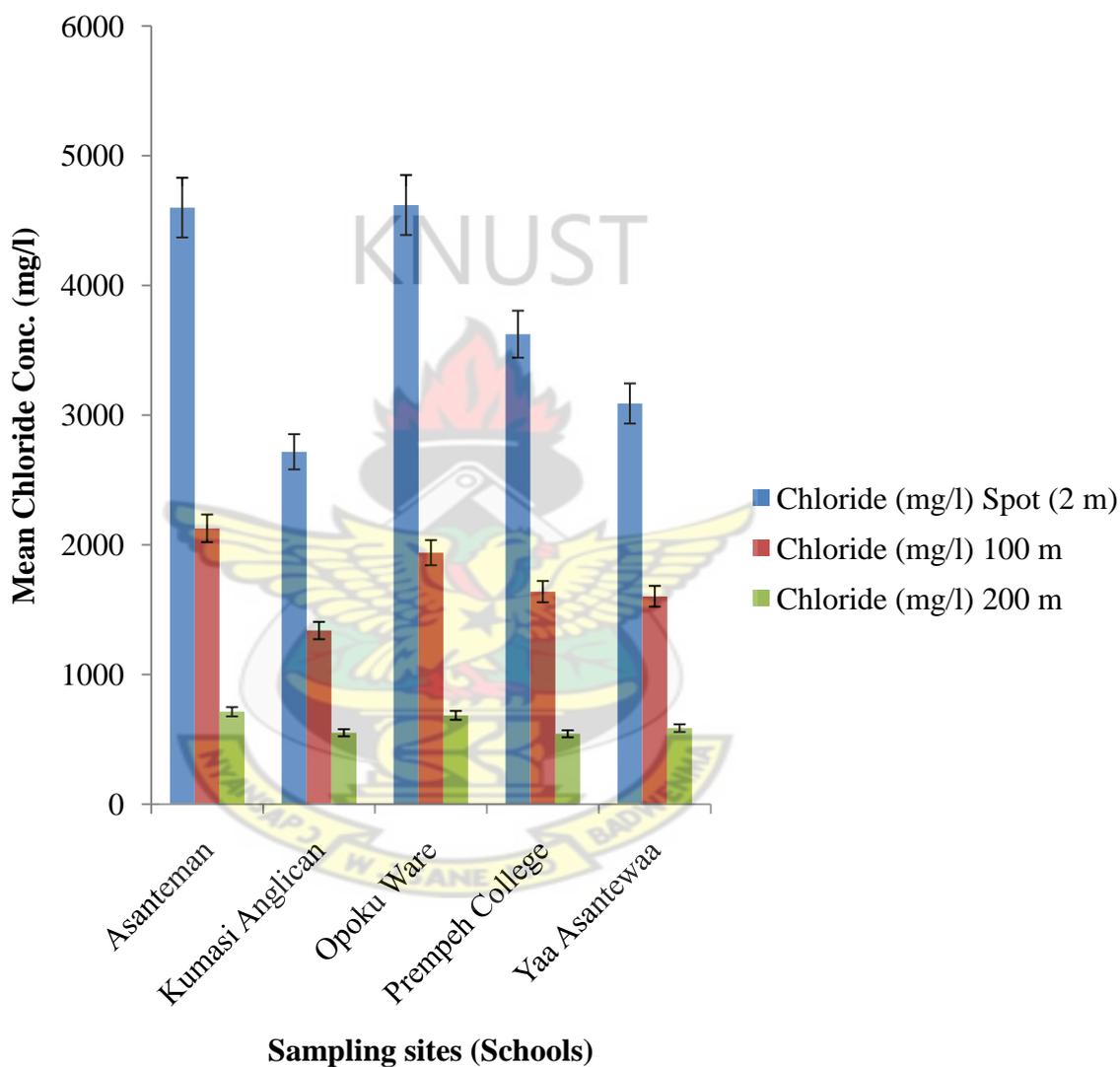


Fig 4.6 Mean Chloride concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.7 below represents mean sulphate concentration. The highest value recorded at 2 m sampling point was at Prempeh College which was 189.80 ± 11.00 mg/l. The least mean sulphate recorded was at Opoku Ware SHS which was 115.40 ± 13.00 mg/l. The concentrations reduced with distance away from the laboratory. At the farthest point measured which was 200 m away from the point of generation of the effluent, Asanteman SHS recorded the highest concentration of sulphate which was 67.00 ± 6.00 mg/l and the lowest value was at Opoku Ware SHS which stood at 25.00 ± 1.10 mg/l.

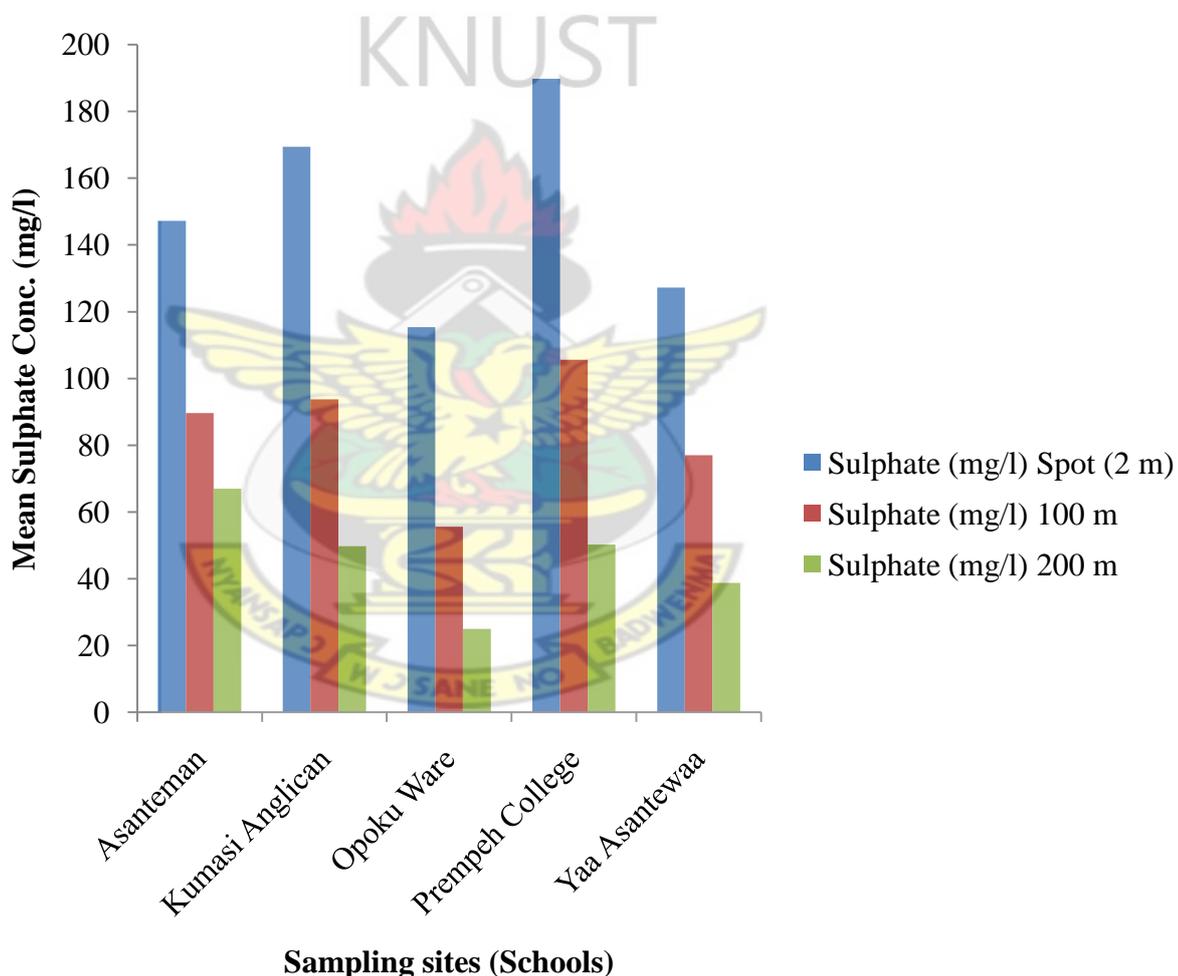
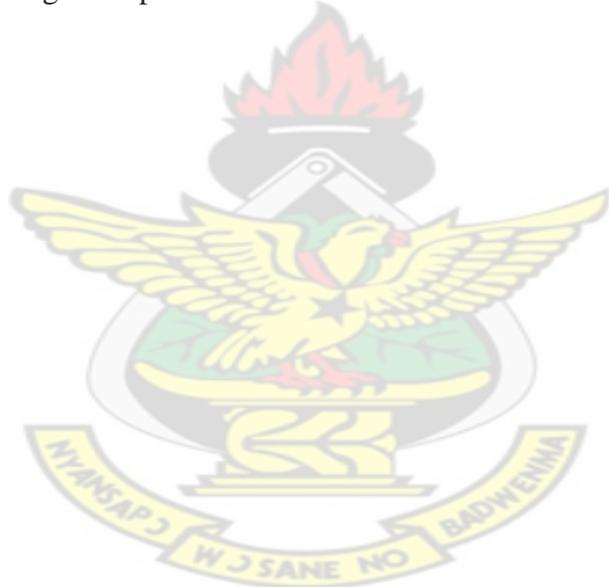


Figure 4.7 Mean Sulphate concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools.

Mean concentrations of sulphite are represented in Figure 4.8. Opoku Ware SHS had the highest value of 1721.20 ± 129.00 mg/l at 2 m sampling point followed by Prempeh College which recorded a value 1336.80 ± 155.00 mg/l at the same distance from the laboratory. The least value at 2 m was recorded at Asanteman SHS which was 1166.70 ± 125.00 mg/l. The concentrations of Sulphite also decreased with distance away from the source of generation. Between 2 m and 100 m, concentrations of Sulphite in all the schools reduced by about 50%. Finally, at 200 m, Sulphite concentration reduced significantly. At this point Kumasi Anglican SHS had the lowest concentration of 219.80 ± 20.00 mg/l and the highest value was 376.12 ± 29.00 mg/l at Opoku Ware SHS.



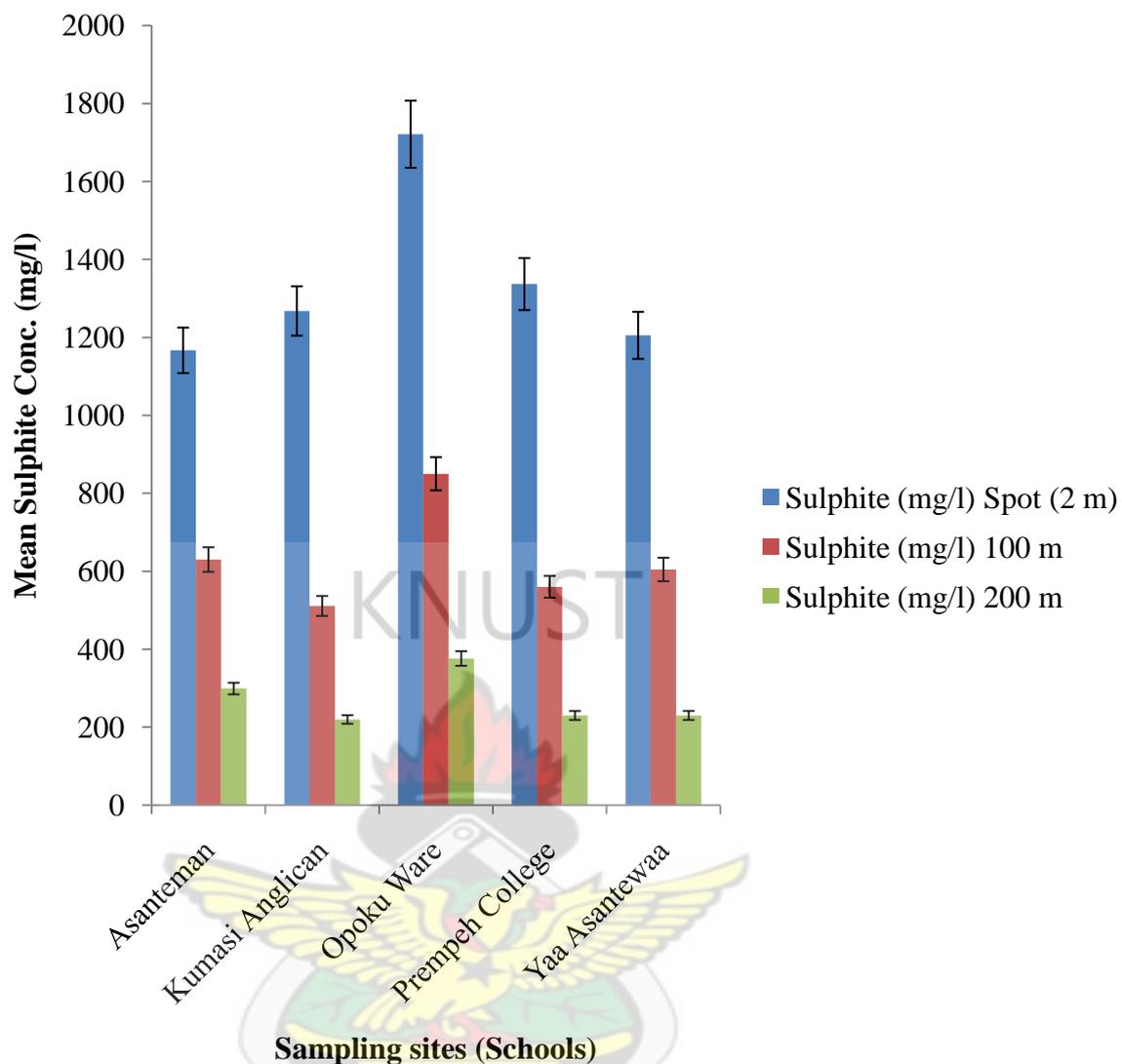


Figure 4.8 Mean Sulphite concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.9 below shows mean phosphate concentration in the samples. At 2 m sampling point, the highest phosphate concentration was found at Kumasi Anglican SHS with a value of 21.13 ± 1.60 mg/l and the least value was recorded at Yaa Asantewaa SHS with a value of 15.82 ± 1.70 mg/l. Between 2 m and 100 m there was reduction in phosphate concentration in all the schools. However, between 100 m and 200 m sampling points, only Asanteman SHS and Prempeh College had their

phosphate concentrations reduced. Mean phosphate concentration for Kumasi Anglican SHS increased from 9.39 ± 0.70 mg/l to 9.68 ± 1.3 mg/l representing 5% increase as the effluent moved from 100 m to 200 m away from the laboratory. Mean phosphate concentration of Opoku Ware SHS increased from 7.16 ± 0.50 mg/l to 20.12 ± 0.60 mg/l representing 181% increase over the same stretch of distance. That of Yaa Asantewaa SHS also increased from 6.27 ± 0.60 mg/l to 8.49 ± 0.20 mg/l which is about 26% increase in phosphate concentration at the same interval.

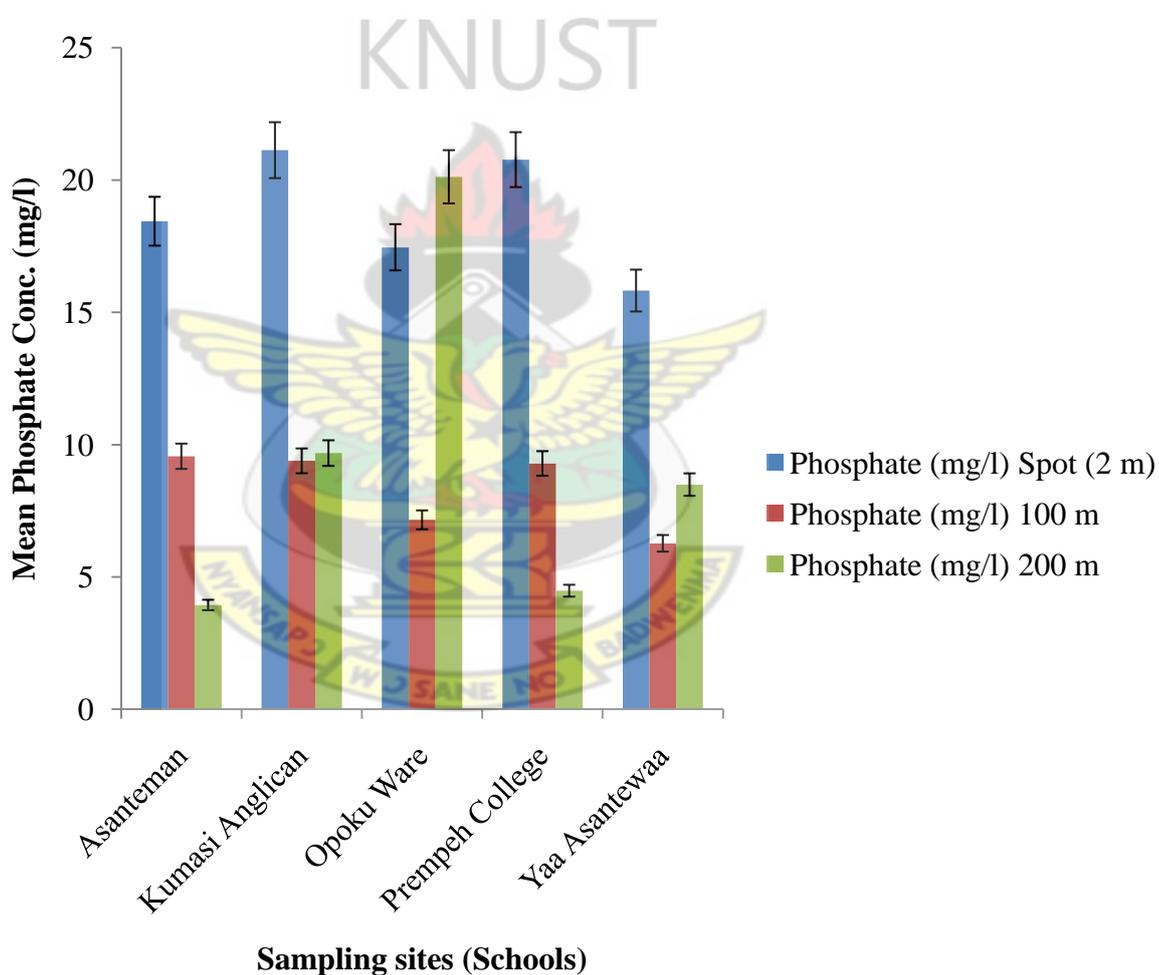


Figure 4.9 Mean Phosphate concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

The distribution of nitrite in the various samples with respect to distance from the point of discharge is represented in Figure 4.10. The highest nitrite concentration at the 2 m sampling point was recorded at Asanteman SHS with a value of 0.055 ± 0.004 mg/l, followed by Yaa Asantewaa SHS which recorded a value of 0.052 ± 0.004 mg/l. The lowest at that same distance from source was recorded at Opoku Ware SHS which was 0.031 ± 0.002 mg/l. The mean nitrite concentrations for all schools reduced as the effluents travel downstream. At 100 m distance, mean nitrite concentration recorded at Asanteman SHS was 0.033 ± 0.003 mg/l, 0.025 ± 0.003 mg/l at Kumasi Anglican SHS, 0.0098 ± 0.0008 mg/l at Opoku Ware SHS, 0.021 ± 0.003 mg/l at Prempeh College, and 0.026 ± 0.002 mg/l for Yaa Asantewaa SHS. At 200 m distance away from the laboratories the least mean nitrite concentration of 0.0043 ± 0.0005 mg/l was recorded at Opoku Ware SHS which represent about 56% reduction from that measured at 100 m away from the laboratory. At 200 m distance from the laboratory the highest value was measured at Asanteman SHS with a value of 0.0156 ± 0.001 mg/l which represent about 52% reduction from the value measured at the 100 m sampling point.

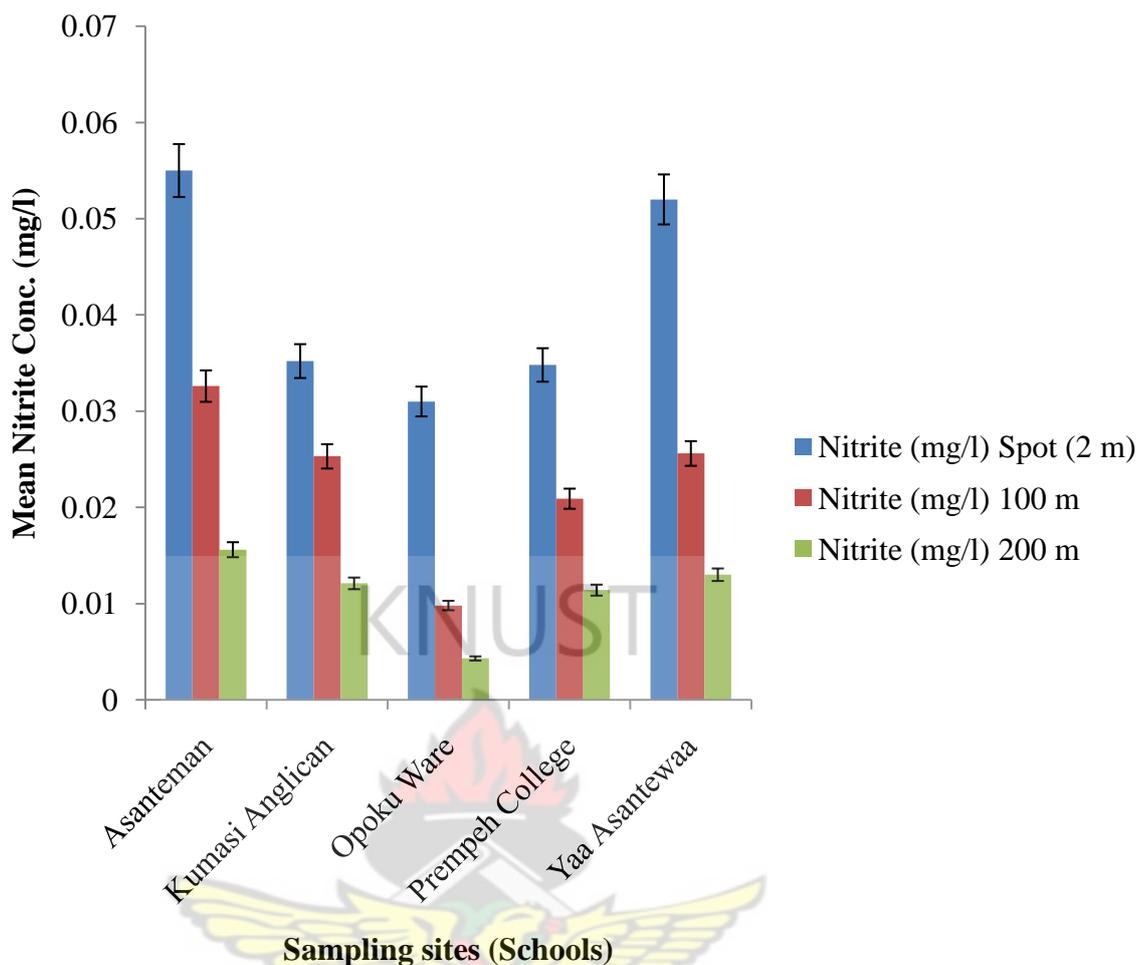


Figure 4.10 Mean nitrite concentrations of the effluents (in mg/l) from the chemistry laboratories of the schools

Mean concentrations of nitrates from the various sampling sites decreased as one moved away from the source of discharge as represented in Figure 4.11 below. The highest mean concentration of nitrite was recorded at Yaa Asantewaa SHS and the value was 94.72 ± 11.10 mg/l. The lowest was recorded at Opoku Ware SHS with a value of 13.56 ± 1.10 mg/l. At 100 m distance away from the laboratories, the value recorded at Asanteman SHS reduced by about 43%, that of Kumasi Anglican SHS by about 48%, that of Opoku Ware SHS was reduced by about 31%. Prempeh College had its value reduced by about 32% and that of Yaa Asantewaa SHS reduced by about 45%. At 200 m, the highest mean concentration was measured at Yaa

Asantewaa SHS (25.02 ± 2.50 mg/l) and the lowest value observed was at Opoku Ware SHS with a value of 4.66 ± 0.40 mg/l.

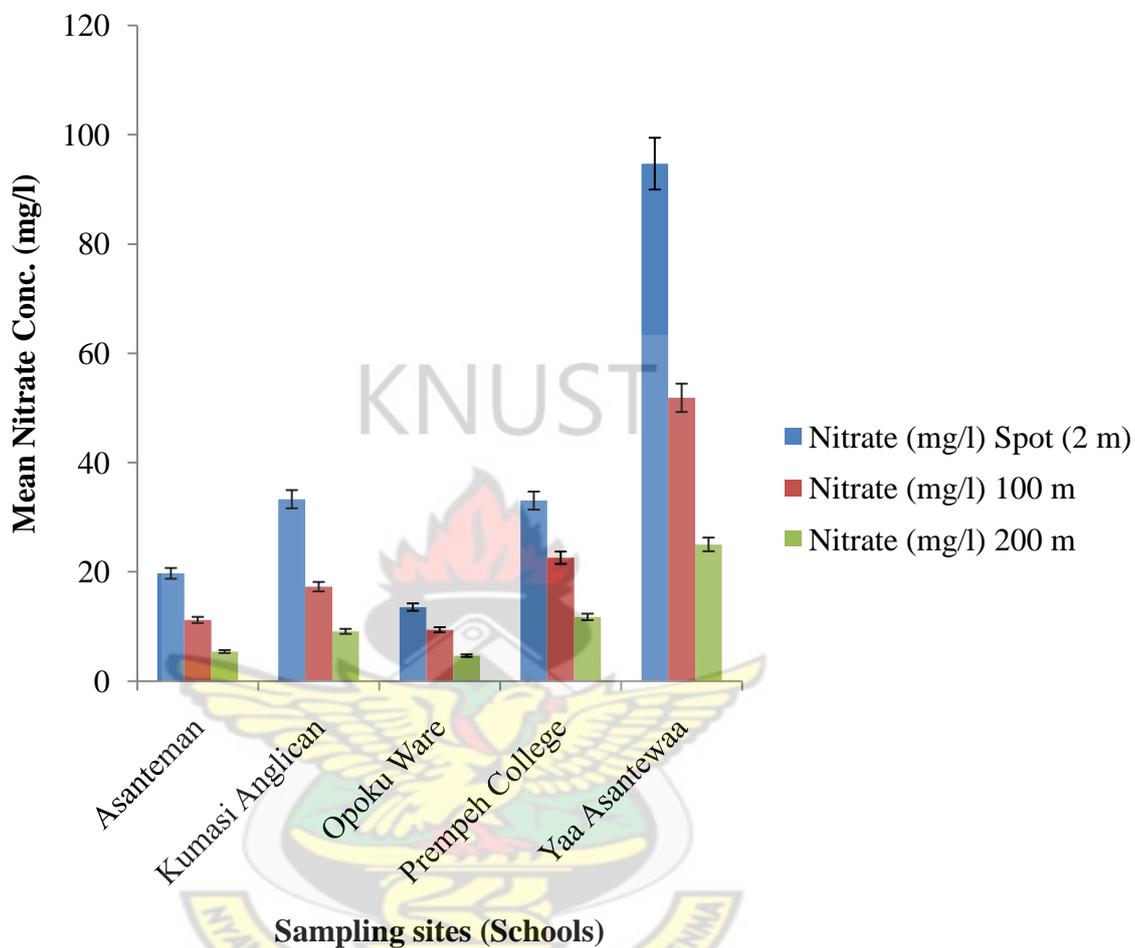


Figure 4.11 Mean Nitrate concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.12 shows the distribution of ammonia the effluent samples from the selected schools decrease as the effluents flow downstream. At the point of discharge of the effluents, that is up to 2 m from the laboratory, the school that recorded the highest ammonia concentration was Asanteman SHS with a value of 6.77 ± 0.60 mg/l followed by Kumasi Anglican SHS which recorded a value 4.40 ± 0.42 mg/l.

The least value measured was at Prempeh College (3.38 ± 0.51 mg/l). At 100 m distance away from the source, the concentration of ammonia at Asanteman SHS decreased by 31%, while that of Kumasi Anglican SHS decreased by about 51%, Prempeh College reduced by 39%, Opoku Ware SHS also reduced by about 36% and that of Yaa Asantewaa SHS by about 60%. At 200 m distance, Asanteman SHS recorded mean ammonia concentration of 1.10 ± 0.19 mg/l which was the highest among the schools from the samples taken at that distance. The lowest value was at Prempeh College (0.33 ± 0.02 mg/l), a reduction of about 84% from the level that was observed at 100 m from the point of discharge.

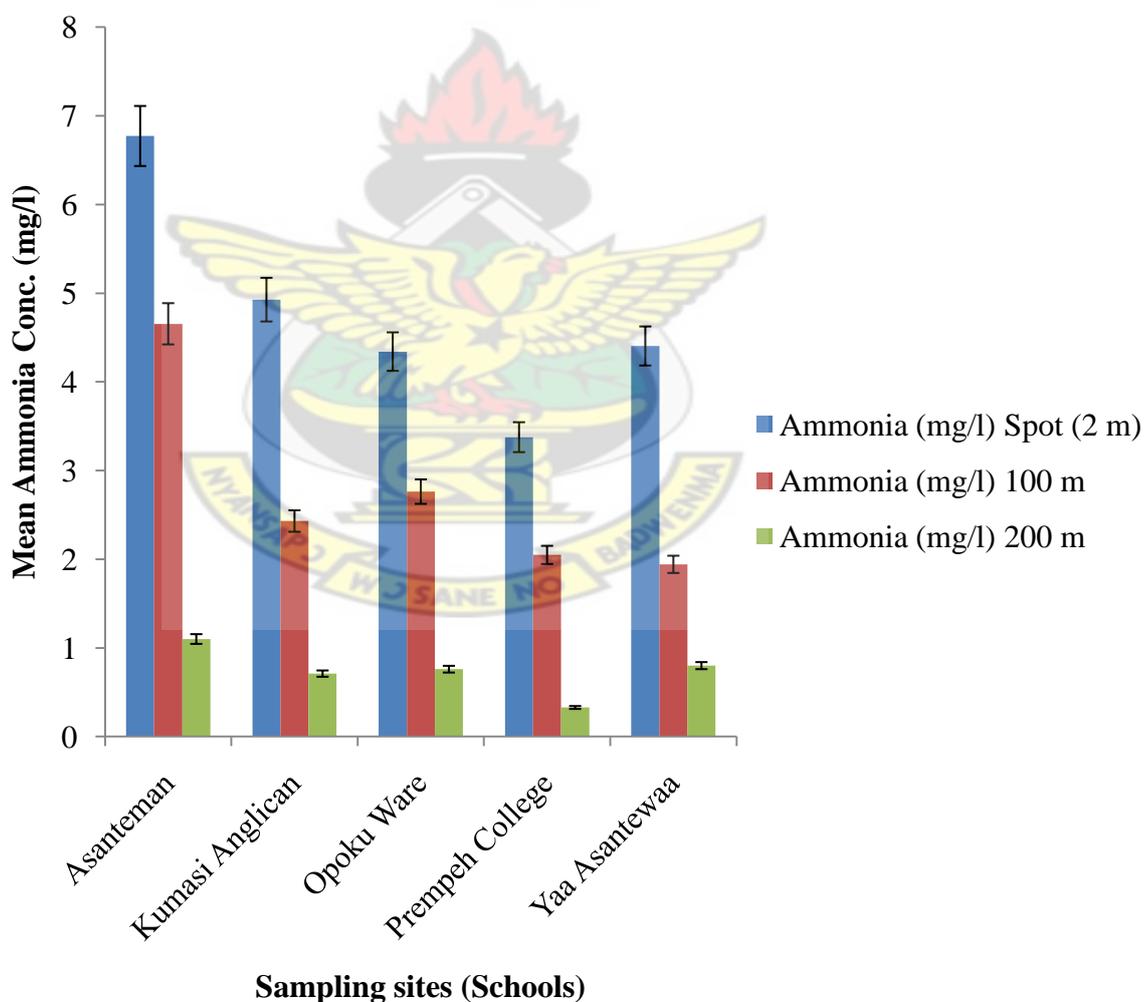


Figure 4.12 Mean Ammonia concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

4.3 The Concentrations of Metals that were Measured in the Samples

Figure 4.14 represents mean concentrations of aluminium from the various sampling points in the schools. In all the schools, the mean aluminium concentration decreased downstream. At 2 m distance away from the laboratory, Asanteman SHS recorded the highest aluminium concentration of 7.02 mg/l, followed by Kumasi Anglican SHS which recorded 6.93 ± 0.34 mg/l. Opoku Ware SHS recorded 4.57 ± 0.56 mg/l and the least concentration of aluminium was recorded at Yaa Asantewaa SHS (3.56 ± 0.30 mg/l). At 100 m distance the concentration recorded at Asanteman SHS was 3.59 ± 0.29 mg/l, which was about 49% reduction from the value recorded at 2 m sampling point. The concentration of aluminium at Kumasi Anglican SHS was 3.05 ± 0.19 mg/l representing about 56% reduction from the value recorded at 2 m sampling point. The concentration of aluminium recorded at Opoku Ware SHS at 100 m away from point of discharge was 2.10 ± 0.23 mg/l about 54% reduction, 3.41 ± 0.27 mg/l was recorded at Prempeh College, about 45% reduction and 1.71 ± 0.16 mg/l was recorded at Yaa Asantewaa SHS which was about 52% reduction from the values recorded at 2 m distance away from the laboratories. At the distance of 200 m away from the laboratories, the least aluminium concentration was recorded at Yaa Asantewaa SHS with a value of 0.52 ± 0.04 mg/l followed by Opoku Ware SHS (0.53 ± 0.03 mg/l), and the highest value was recorded at Prempeh College which was 1.18 ± 0.14 mg/l.

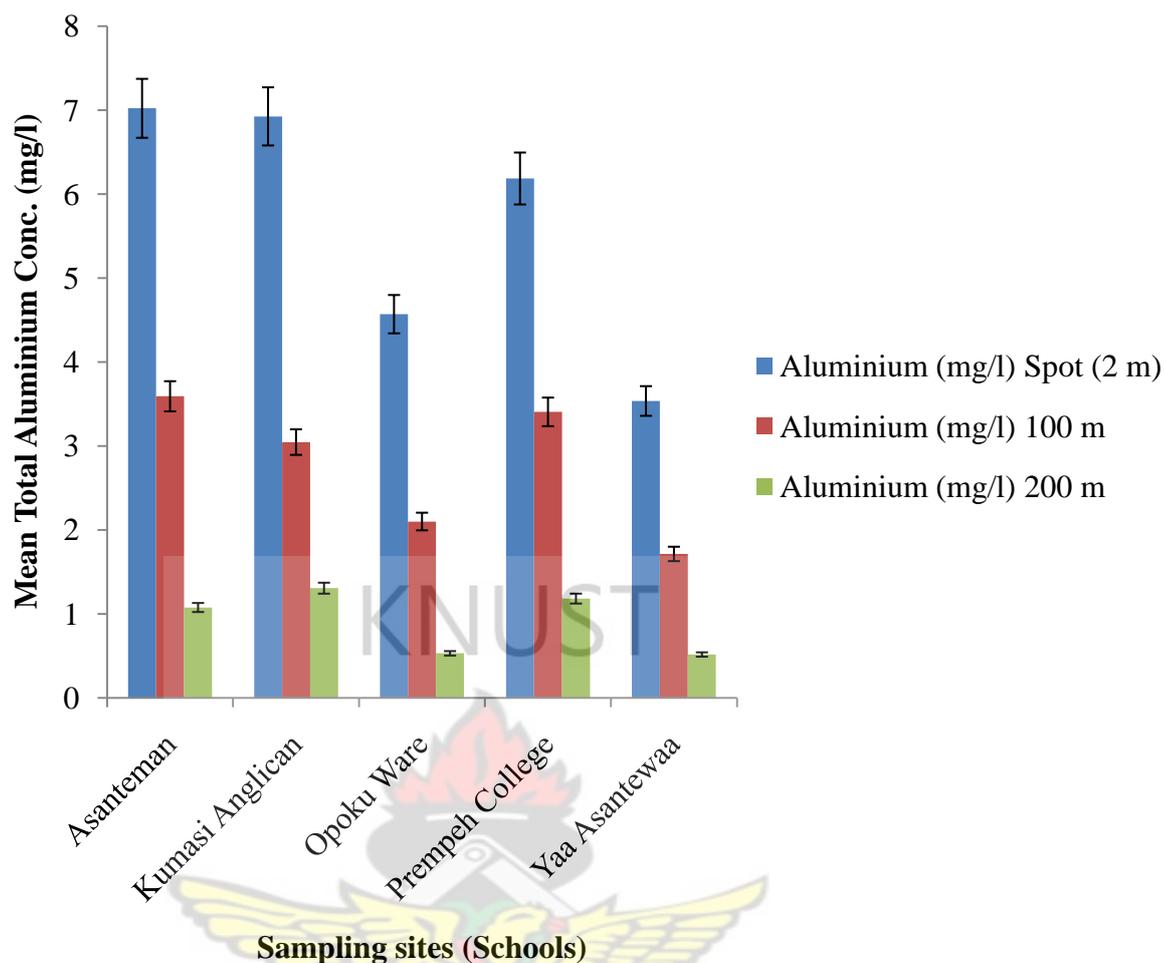


Figure 4.13 Mean Total Aluminium of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Calcium concentrations in the samples at different sampling points are represented in Figure 4.14. At 2 m sampling point, Yaa Asantewaa SHS recorded the highest value of 888.00 ± 78 mg/l, Kumasi Anglican SHS recorded 690.00 ± 75 mg/l, Opoku Ware SHS recorded 774.40 ± 80.00 mg/l, Prempeh College recorded 454.00 ± 61.00 mg/l and the lowest value was recorded at Asanteman which was 330.80 ± 24 mg/l. At 100 m Asanteman SHS recorded the lowest calcium concentration of 166.60 ± 13.00 mg/l. This value was about 50% less than that recorded at 2 m. Concentration of calcium at Kumasi Anglican SHS was 381.40 ± 41.00 mg/l, Yaa Asantewaa SHS recorded the highest calcium concentration of 657.00 ± 57.00 mg/l which was about

26% less than the previous value recorded at 2 m sampling point. At 200 m away from the laboratories, the lowest calcium concentration recorded was at Asanteman SHS with a value of 95.20 ± 6.00 mg/l, which is about 43% reduction from the previous measurement. The highest value recorded at 200 m was at Yaa Asantewaa SHS and the value was 318.00 ± 32.00 mg/l which was 52% less than the previous value recorded at 100 m from the source.

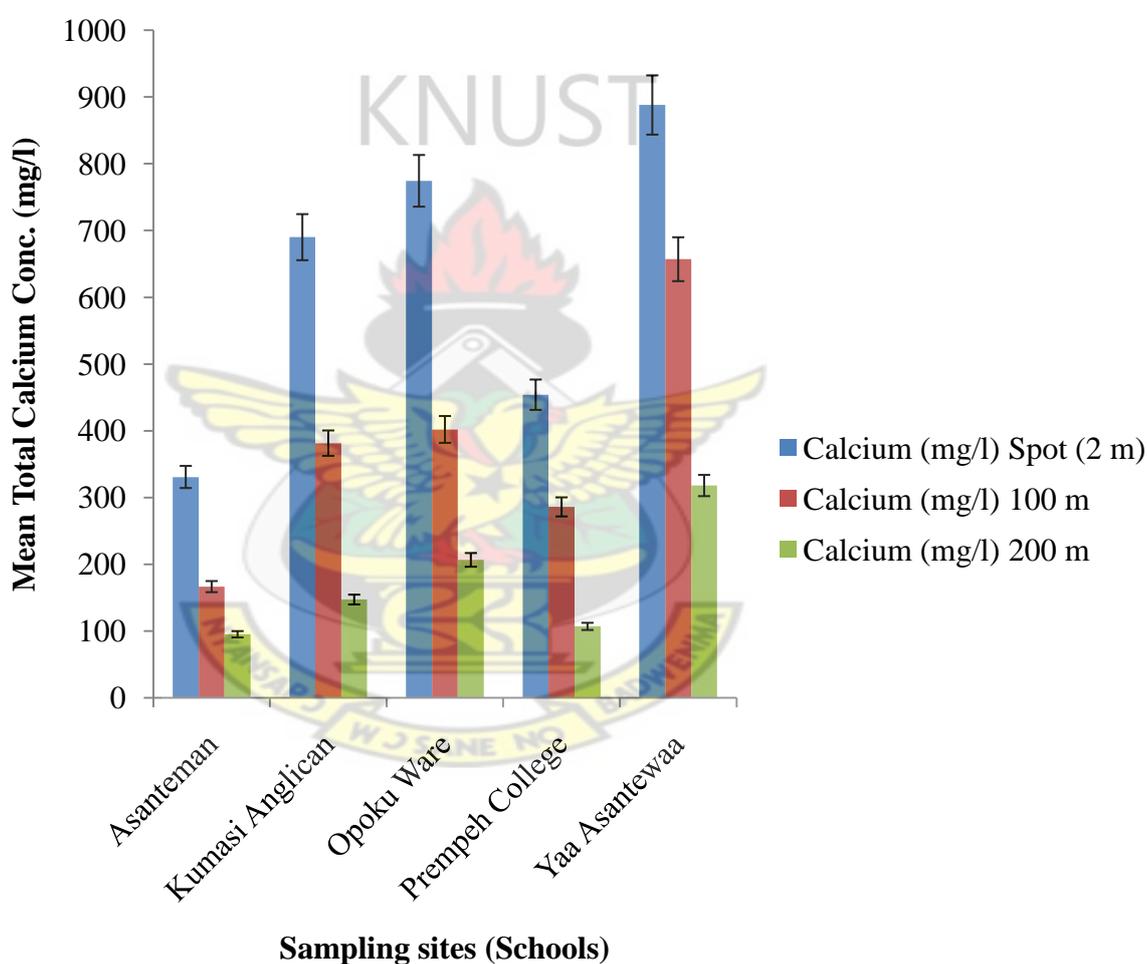


Figure 4.14 Mean Total Calcium Concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.15 below shows the mean copper concentrations. Asanteman SHS recorded the highest concentration of copper at the 2 m spot with a value of 40.06 ± 2.50 mg/l followed by Yaa Asantewaa SHS which was 31.54 ± 2.40 mg/l. At the same point Kumasi Anglican had a value of 20.70 ± 1.90 mg/l, 18.22 ± 2.60 mg/l was recorded at Opoku Ware SHS and 12.64 ± 1.10 mg/l was also recorded at Prempeh College which was the lowest value recorded at point 2 m. As the effluents flowed distance away from the laboratory, concentration of copper decreased. At 100 m sampling point, concentration of copper reduced to 19.18 ± 1.8 mg/l at Asanteman SHS, that of Kumasi Anglican SHS reduced to 9.38 ± 0.70 mg/l being about 55% reduction. The lowest value recorded 100 m distance away from the point of discharge was at Prempeh College which was 7.85 ± 0.80 mg/l. At 200 m sampling point, the concentration at Asanteman SHS was 8.26 ± 0.70 mg/l. Kumasi Anglican SHS recorded a value of 2.99 ± 0.30 mg/l. Opoku Ware SHS also had 2.68 ± 0.20 mg/l which was the lowest at 200 m sampling point. Prempeh College recorded 3.31 ± 0.30 mg/l and finally Yaa Asantewaa SHS recorded 6.50 ± 0.50 mg/l.

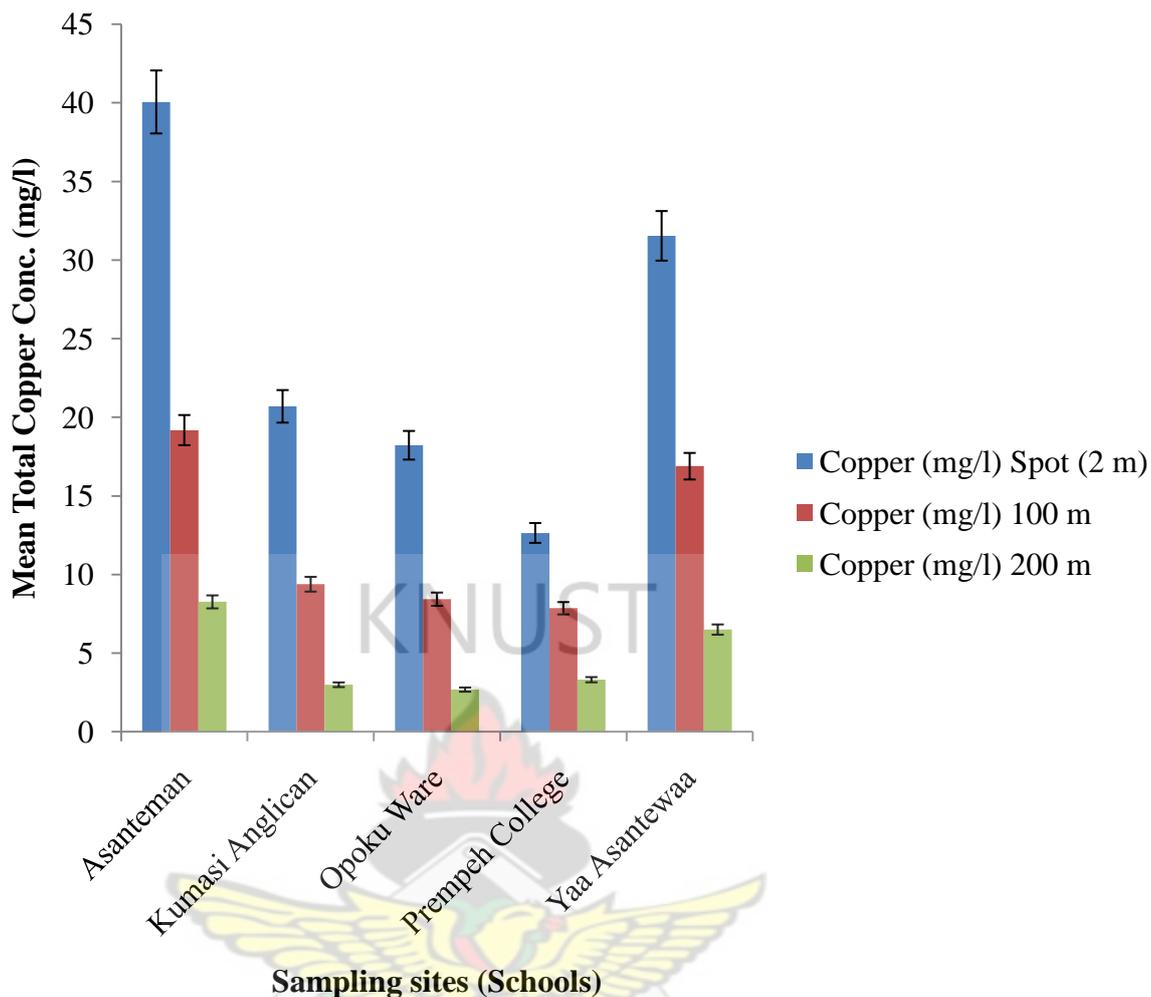
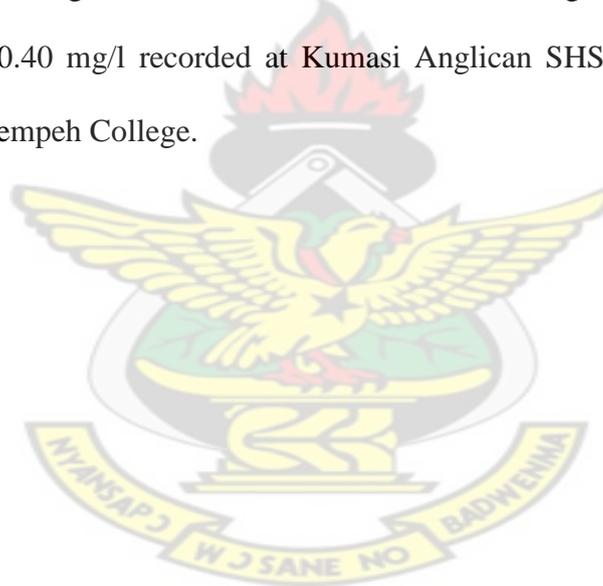


Figure 4.15 Mean Total Copper Concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.16 below shows mean iron concentrations of the effluents sampled from the various schools. At 2 m point of collection, the values of iron concentration obtained were 21.40 ± 2.30 mg/l at Opoku Ware SHS which was the lowest among the schools at this sampling point. Asanteman SHS recorded a value of 23.99 ± 2.40 mg/l. Kumasi Anglican SHS recorded a mean concentration of 27.97 ± 2.50 mg/l which was the highest value measured at this sampling point. Prempeh College recorded a value of 25.98 ± 2.40 mg/l, and Yaa Asantewaa SHS had 27.45 ± 2.90 mg/l. Fe concentrations in the effluents decreased at 100 m away from the point of

discharge in all the schools. Iron concentration at Asanteman SHS at this point was 9.85 ± 0.80 mg/l which was about 59% reduction from the value recorded at the 2 m sampling point, that of Kumasi Anglican SHS was 10.54 ± 0.90 mg/l representing approximately 63% reduction. Opoku Ware SHS recorded to 7.31 ± 0.40 mg/l being the lowest value of Fe in all the samples. At 100 m sampling point, the highest Fe concentration was recorded at Yaa Asantewaa SHS which was 14.70 ± 1.60 mg/l. At 200 m point of collection, the concentrations were lower than those measured at the 100 m sampling point. The highest value measured at this point was 5.68 ± 0.60 mg/l at Yaa Asantewaa SHS and the lowest value of Fe was at Opoku Ware SHS which was 1.85 ± 0.10 mg/l. Other values were 3.31 ± 0.30 mg/l recorded at Asanteman SHS, 3.88 ± 0.40 mg/l recorded at Kumasi Anglican SHS, and 3.76 ± 0.30 mg/l recorded at Prempeh College.



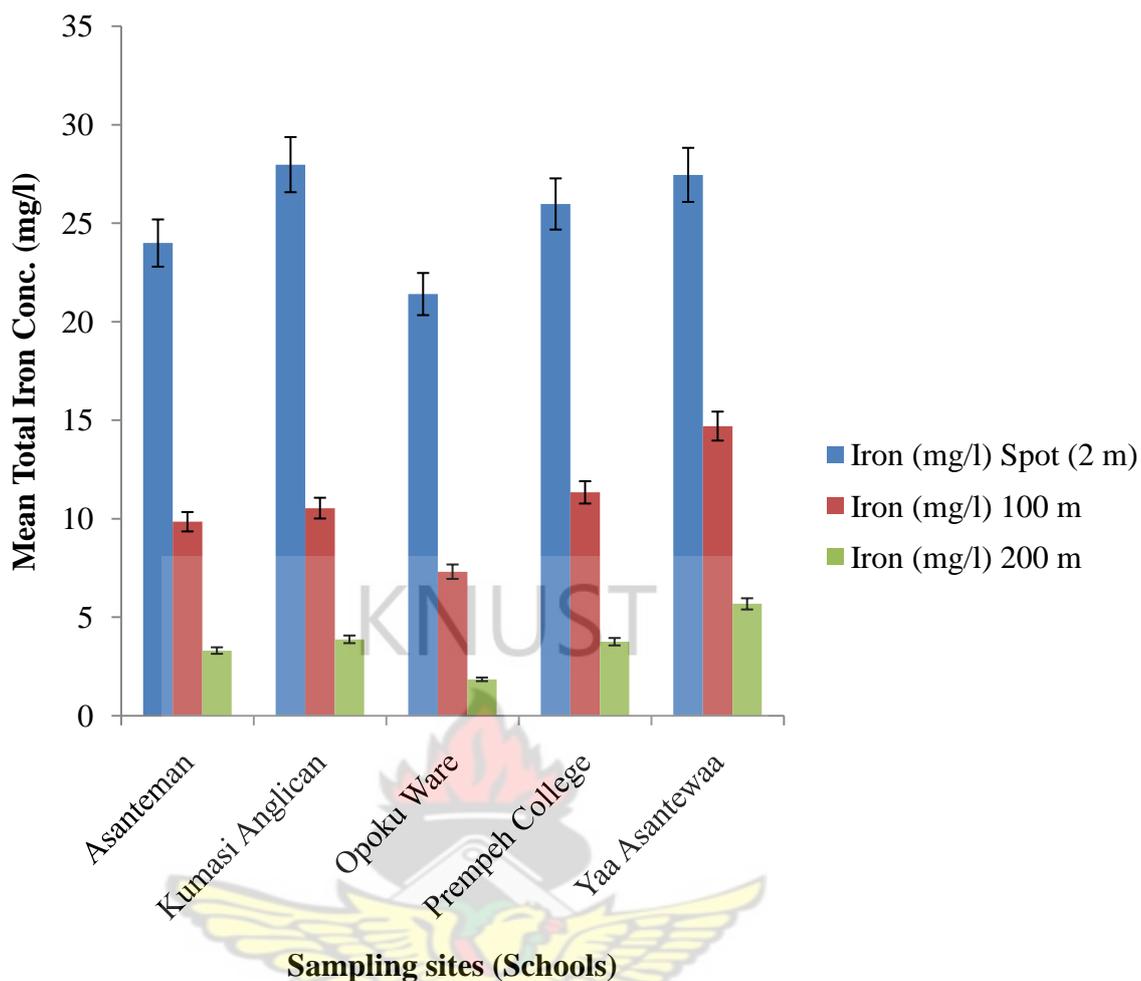


Figure 4.16 Mean Total Iron Concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

Figure 4.17 below represents the mean zinc concentrations measured in effluent samples from the five selected senior high schools. At the 2 m point of collection, the highest concentration was measured at Opoku Ware SHS and the value was 8.11 ± 0.62 mg/l and the least value was recorded at Kumasi Anglican SHS which was 4.45 ± 0.45 mg/l. The mean value for Asanteman SHS samples was 5.73 ± 0.60 mg/l. Prempeh College recorded 6.22 ± 0.49 mg/l while Yaa Asantewaa SHS recorded a mean value of 7.46 ± 0.56 mg/l. At the 100 m sampling point, the concentrations were lower than those measured at the 2 m spot. At 100 m point, the

value for Asanteman SHS was 3.48 ± 0.38 mg/l which was about 39% less than the previous value. Yaa Asantewaa SHS recorded a value of 2.95 ± 0.31 mg/l which was about 34% less than the value at the 2 m sampling point. Opoku Ware SHS recorded a mean value of 4.77 ± 0.38 mg/l which represented about 41% reduction from the value recorded at the 2 m point. Prempeh College recorded a mean value of 3.29 ± 0.28 mg/l which represented about 47% reduction from the previous value. At 200 m sampling point, Asanteman SHS recorded a value of 1.00 ± 0.06 mg/l and this was the least value recorded at the 200 m sampling point. The highest value was recorded at Opoku Ware SHS which was 1.80 ± 0.14 mg/l.

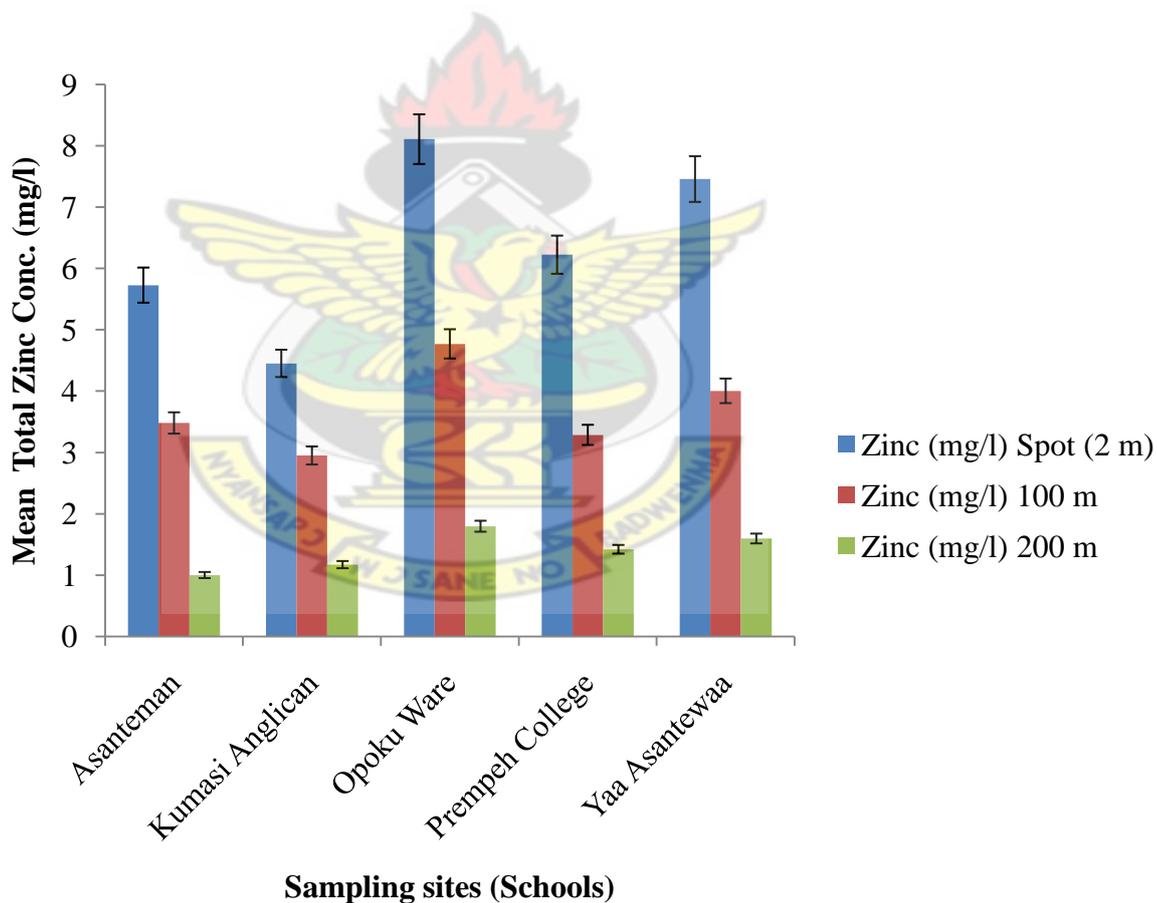


Figure 4.17 Mean Total Zinc Concentrations of the effluents (in mg/l) from the Chemistry Laboratories of the schools

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

In all the schools where the study was carried out, all the selected parameters for investigation were detected in each of the samples taken. This means the schools do similar practical work and therefore may use the same chemicals. Generally, the levels and the concentrations of the parameters decreased as the effluents moved downstream from the point of discharge (Appendix 4). This may be due to volatilisation, absorption and adsorption of the components in the effluents as the effluents move downstream (Geetha *et al.*, 2008). The study shows that the laboratories of the selected senior high schools generate effluents which contain a lot of components that can pollute the receiving water bodies.

The pH values were within the EPA Ghana maximum permissible level which is 6-9 for effluents discharged into natural water bodies. This can be explained by the fact that most of the practical exercises are simple acid-base reactions which produce wastes that are generally neutral. Again, it can be mentioned that accidental spillage of strong acids and bases is minimal since this could have affected the pH of the effluent significantly. There was no significant difference with regard to pH at the different schools and at the different sampling points. $p = 0.43$ at 2 m sampling point (Appendix 5A), $p = 0.47$ (Appendix 5B) at 100 m sampling point, and $p = 0.80$ at 200 m sampling point (Appendix 5C). In all these cases, $p > 0.05$.

The mean electrical conductivity (EC) values measured in all the schools and at the sampling points were above the EPA Ghana maximum permissible limit of 1500

$\mu\text{S}/\text{cm}$. Even Yaa Asantewaa SHS that had the lowest conductivity at 200 m sampling point was 2796 $\mu\text{S}/\text{cm}$. This can be due to the fact that all the schools use a variety of chemicals at a given time for practical work most of which are inorganic that ionises easily in water. An example is the use of di-Ammonium Iron (II) Sulphate $\{[\text{Fe}(\text{NH}_4)_2\text{SO}_4]\}$ for qualitative inorganic analysis. This compound contains two cations- (Fe^{2+} and NH_4^+) and one anion (SO_4^{2-}). The bench reagents that may be used in the identification are NaOH, BaCl_2 , HCl, and $\text{K}_3[\text{Fe}(\text{CN})_6]$. This might have accounted for the high EC encountered in the effluents from all the schools. There was no significant difference in conductivity of the effluents generated by the schools. At 2 m, $p = 0.97$ (Appendix 5A), at 100 m, $p = 0.84$ (Appendix 5B) and $p = 0.77$ at 200 m (Appendix 5C).

In all the schools, temperature increases as the effluents moved downstream. This may be due to the fact that, as the effluent move downstream on a normal day, the ambient temperature will naturally have effect on that of the effluent in the drain. There was no significant difference in the temperature among the schools and at all sampling points because the $p > 0.05$. The highest temperature of 28.26 $^{\circ}\text{C}$ was recorded at the 200 m sampling point at Kumasi Anglican SHS and the lowest was recorded at 2 m sampling point at Asanteman SHS (24.64 $^{\circ}\text{C}$) Figure 4.3 and Appendix 4.

All the schools had their alkalinity levels greater than the EPA Ghana maximum permissible limits of 150.00 mg/l set for Paints and Chemical Industries. This was in agreement with findings of Fakayode (2005) that total alkalinity of industrial effluents exceeded the level permissible for discharge into surface water. Even Yaa

Asantewaa SHS that had the least recorded mean alkalinity of 442.00 mg/l which was still higher than the set value. The high levels of alkalinity may be due to the fact that the effluents contained high concentrations of CO_3^{2-} (carbonate), HCO_3^- (bicarbonate) and OH^- (hydroxide) which are ions commonly found in most of the compounds used for practical work in these schools. High level of alkalinity has also been found to deteriorate both surface and ground water (Jain *et al.*, 2006). The alkalinity generally decreased downstream in all the cases, although the values recorded were very high in all the schools. At all the sampling points $p > 0.05$. This makes no significant difference among the schools. At the source, Asanteman SHS had the highest mean total alkalinity of 9330.00 mg/l and Yaa Asantewaa SHS had the least which was 3146.00 mg/l (Figure 4.5).

Values for hardness obtained in all the samples taken were considerably high though there is no EPA Ghana limit for effluent hardness. The high levels may be due to the high levels of calcium and sulphate measured. The high levels of hardness may also be due to magnesium, bicarbonates, and carbonates that may be present. The hardness was due to the presence of high level of carbonate and dissolved sulphates. This agrees with the findings of Jain *et al.*, (2006) who found that hardness of water was mainly due to high levels of calcium, magnesium, carbonates and sulphates in the water. The levels of hardness generally decreased downstream except that of Opoku Ware SHS where it increased between the 100 m and the 200 m sampling points. At 100 m away from the laboratory, the mean total hardness was 4942.00 mg/l and this increased to 11912.00 mg/l at 200 m. In all the cases, there was no significant difference between the schools and the various sampling points since $p > 0.05$ (Appendices 5A, 5B and 5C).

In spite of the remarkable reduction in the mean concentrations of Cl^- at different sampling points of the various schools, the levels of chloride in all the effluents were greater than the EPA Ghana maximum permissible level which is 250.00 mg/l. There was no significant difference in the chloride concentration among the five schools as $p > 0.05$ (Appendices 5A, 5B and 5C). Fakayode (2005) also found that the level of chloride in industrial effluent into the Alaro River exceeded the effluent guideline for discharge into surface water. Since the levels of chloride were high, they could inhibit the growth of plants, bacteria and fish in the receiving water bodies (APHA, 1992; Bosnic *et al.*, 2000). This high chloride content in the effluent also has a corrosive effect on metal pipes (UNEP/WHO, 1996).

For phosphate, there was no significant difference in the schools and the sampling points since $p > 0.05$. All the schools had the concentrations of phosphate reduced downstream except Opoku Ware SHS and Yaa Asantewaa SHS where the levels increased downstream between 100 m and 200 m sampling points. All the five schools however had remarkable reduction in the concentration of phosphate in their effluents between 2 m and 100 m sampling points. Despite the reduction of phosphate concentration as the effluent flowed downstream, no school could meet the EPA Ghana maximum permissible level of phosphate which is 2.00 mg/l. This was in agreement with Ugochukwu and Leton (2004) who found that the level of phosphate in effluent from an oil service industry they studied was above the International Effluent Quality Standards as well as the Federal Ministry of Environment (FMENV) Standards. Phosphorus is a plant nutrient that can trigger plant growth when introduced into an aquatic environment (Nkegbe *et al.*, 2005). Nitrogen and phosphorus interact to produce large standing crops of algae (Mason, 2002). When

added singly, phosphorus caused increase in standing crops of algae, whereas nitrogen alone did not elicit a response (Mason, 2002). This shows that phosphorus controls the growth of phytoplankton hence its limitation reduces the problem of eutrophication. A 0.01 mg/l phosphorus concentration is high enough to cause eutrophication in a natural water body (Nkegbe *et al.*, 2005). These high phosphate concentrations in all the effluents can therefore cause a serious problem in nearby water bodies when the effluents join the water bodies.

Nitrite is the only parameter whose mean concentrations were relatively low in all the samples taken. EPA Ghana has no limit of nitrite released into a fresh water body. Though the concentrations were low, there was no significant difference among the schools as $p > 0.05$ in all the schools and at all sampling points. The relatively low concentration may be due to its instability and its ability to change easily into its more stable form of nitrate (UNEP/WHO, 1996). This may also account for relatively higher concentrations of nitrate than nitrite in all the effluents. This may be the reason why in natural waters nitrite is normally present in low concentrations (UNEP/WHO, 1996) and not usually found in drinking water (Bruce, 2008).

Generally, mean nitrate concentrations were low even at the source. With the exception of Yaa Asantewaa SHS, all the four other schools had nitrate concentrations lower than the EPA Ghana maximum permissible limit of 50 mg/L for effluent discharge into natural water bodies. Although mean concentrations of nitrate decreased downstream, that of Yaa Asantewaa SHS still remained relatively high downstream (even at 200 m). The high concentration of nitrate causes

eutrophication when phosphates are available at a concentration of 0.1 mg/l (Nkegbe *et al.*, 2005). Nitrates also stimulate growth of algae and other plants, which later decay and increase biochemical oxygen demand as they decompose (APHA, 1992).

For sulphate and sulphite, despite the high levels of sulphate in the effluents, the levels in all the schools were below the EPA maximum limit of 200 mg/l. Even Prempeh College that generated the highest from the source had 198 mg/l. The levels of the two parameters decreased downstream. This was in agreement with Chimwanza *et al* 2006, who said that concentration of sulphate decreases downstream especially when diluted downstream with water. The low levels of sulphates may be attributed to the precipitation of sulphates with metal ions (Chinhanga, 2010). There was remarkable reduction in sulphate and sulphite levels in all the schools as the effluents move from the point of discharge. There was no significant difference in the sulphite and sulphate concentration among the schools at $p > 0.05$.

With the exception of Asanteman SHS, all the schools had mean ammonia concentration lower than the EPA level of 1.00 mg/l. The reduction in ammonia-nitrogen concentrations downstream may be due to the dissolved oxygen. In the presence of oxygen, ammonia is oxidised to nitrate ions. There was no significant difference in the generation of ammonia by the schools at all sampling sites and all the schools, $p > 0.05$ (Appendices 5A, 5B and 5C).

Calcium ions in large concentrations cause water hardness. The presence of calcium ions might have caused the high levels of total hardness of the effluents. In any case,

the levels of calcium reduced with distance away from the point of discharge. The reduction may be due to precipitation of calcium ions from the effluent (Banerjee, 2008). The level of calcium in all the effluents analysed was high. There was no significant difference among the schools and at the various sampling points as regards the generation of calcium at $p > 0.05$ (Appendices 5A, 5B and 5C).

In the case of aluminium (Al), mean concentration was below the EPA Ghana maximum limit for Al discharge into fresh water bodies. The $p > 0.05$ for all schools and at all sampling points. This means there was no significant difference among the schools and at all the sampling points (Appendices 5A, 5B and 5C). Continuous generation of Al in the effluents may accumulate in plants and cause health problems for animals that consume these plants. Al ions react with proteins in the gills of fish and embryos of frogs to reduce their number in lakes and rivers (ATSDR, 1990).

The concentration of iron (Fe) reduced downstream. In all the schools and at all the sampling points, $p > 0.05$ (Appendices 5A, 5B and 5C). This means that there was no significant difference in the generation of Fe in the effluents. High levels of Fe affect the taste and colour of drinking water (Mosley *et al.*, 2004). Iron gives a bitter taste to water and changes the colour of water. This colouration can stain cooking utensils (Schafer *et al.*, 2008). EPA Ghana however has no permissible limit for iron discharge into fresh water bodies.

Generally mean concentration of copper decreased as the effluents moved downstream from the point of discharge. At the 200 m sampling point, the concentrations of copper at Asanteman SHS and Yaa Asantewaa SHS were above

the EPA Ghana limit of 5 mg/l for copper. In all the schools and at all the sampling points, $p > 0.05$ (Appendices 5A, 5B and 5C). This means statistically there was no significant difference in the generation of copper in the schools and the various sampling points. The high concentration of copper could be harmful to human. Ingestion of high level can lead to nausea, vomiting and diarrhoea. Very high doses of copper could damage liver and kidney (Wong, 1988). High levels of copper have been found to have toxic effect on aquatic life even when concentration is as low as 0.3 mg/L (Bosnic *et al.*, 2000).

The concentration of zinc (Zn) also decreased downstream. The mean concentration of Zn measured in all the schools and at all the sampling points was below the EPA Ghana maximum permissible limit of 10 mg/l. In all the schools and at all the sampling points, $p > 0.05$ (Appendices 5A, 5B and 5C). This means statistically there was no significant difference in the generation of zinc in the schools and the various sampling points. Acidity of water can be increased by high concentration of zinc (USEPA, 1995). This is due to hydrolysis of zinc ion in water to produce excess hydroxonium (H_3O^+) ion. Water soluble zinc compounds can contaminate ground water (Zu *et al.*, 2006).

5.2 Conclusion.

All the parameters selected for the study were found in reasonable quantities in all the samples taken for analysis. That means if more parameters were selected, there was the likelihood that their presence would be established. It may be concluded here that the selected senior high schools use a lot of different chemicals for their practical lessons.

The study has also shown that, distance plays an important role in effluent behaviour. As the effluents flow downstream most of the parameters studied decreased in their levels. It can be concluded here that not all the effluents generated drains to contaminate a water body. Some are lost on their way.

It was also found that the concentrations of phosphate were high in all the schools. In the presence of nitrates, when these effluents containing high concentrations of phosphate are allowed into nearby water bodies, they can cause eutrophication and harm aquatic life. This can therefore cause pollution.

In the case of the metals, only copper at Asanteman SHS and Yaa Asantewaa SHS were above the EPA Ghana maximum permissible limit at the 200 m sampling point. Although the levels of the metals found at 200 m in most of the schools were below the maximum permissible limits as prescribed by EPA Ghana for discharge into natural water bodies, continuous release of the effluents from the laboratories may bioaccumulate in the fish in the receiving streams as the drains of all these schools head towards natural water bodies.

Therefore if these practices are not checked and managed they can cause harm to aquatic life.

5.3 Recommendations.

Generally, chemicals are poisonous to life depending on the quantity taken into the body over a period of time. Improved guidance with management practices, treatment methods and acceptable discharge locations and methods are thus considered necessary.

The following recommendations are therefore made from the outcome of the research:

1. The Ministry of Education, Ghana Education Service and the EPA Ghana should formulate policies and come out with an alternative method for the schools to discard waste chemicals from their chemistry laboratories.
2. Since the study was done in only five senior high schools in Kumasi, it is recommended that more research should be carried out in more senior high schools and schools outside Kumasi. The scope of such a study should embrace the Polytechnics, the Universities and the research institutions such as Council for Scientific and Industrial Research where more toxic compounds are used for experiments.



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APPENDICES

Appendix IA: Results of effluent sampled from the selected SHS in the month of November 2010 from a distance of 2 m from the point of discharge.

PARAMETERS	SAMPLING SITES				
	A _{1A}	K _{1A}	P _{1A}	W _{1A}	Y _{1A}
pH	10.25	3.69	7.41	10.38	9.14
Conductivity(μS/cm)	199200	140800	20000	225600	19320
Temperature(°C)	26.8	25.0	27.1	27.2	26.7
Total Hardness	14840	5330	2200	21040	6210
Total Alkalinity	15000	4000	2000	19160	6400
Calcium	200	1640	1520	400	1080
Aluminium	14.10	9.10	5.00	14.30	7.50
Zinc	15.50	11.60	4.60	13.00	13.40
Ammonium	13.00	12.48	12.48	13.00	10.79
Iron	62.70	62.70	62.70	62.70	62.70
Copper	66.60	27.80	19.50	65.40	53.40
Chloride	6500	4800	3500	6000	5400
Sulphate	270	320	320	300	360
Sulphite	2646	3478	3780	3478	2281
Phosphate	43.00	42.60	42.60	43.00	40.30
Nitrite	0.005	0.005	0.05	0.05	0.10
Nitrate	28.20	83.60	88.00	29.00	88.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;
W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix IB: Results of effluent sampled from the selected SHS in the month of December 2010 from a distance of 2 m from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{2A}	K _{2A}	P _{2A}	W _{2A}	Y _{2A}
pH	9.38	9.03	9.27	9.26	9.33
Conductivity(μS/cm)	16550	9370	9520	14470	9650
Temperature(°C)	22.70	23.80	23.40	23.00	23.90
Total Hardness	50	100	200	160	140
Total Alkalinity	23000	118	2500	6600	2200
Calcium	4.00	20.00	60.00	32.00	40.00
Aluminium	1.41	1.03	1.03	1.35	1.58
Zinc	1.34	0.56	0.42	1.34	0.69
Ammonium	0.86	0.57	0.82	0.40	1.03
Iron	6.27	5.67	5.00	6.27	6.27
Copper	4.48	2.68	1.92	4.00	7.00
Chloride	4700	1250	1600	4300	1750
Sulphate	26.00	28.00	24.00	32.00	38.00
Sulphite	179.60	356.00	359.10	378.00	245.70
Phosphate	4.30	4.23	4.09	4.23	4.30
Nitrite	0.050	0.001	0.002	0.020	0.030
Nitrate	3.52	1.89	1.10	3.74	1.98

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix IC: Results of effluent sampled from the selected SHS in the month of January 2011 from a distance of 2 m from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{3A}	K _{3A}	P _{3A}	W _{3A}	Y _{3A}
pH	10.25	7.80	9.20	8.50	9.30
Conductivity(μ S/cm)	7220	19430	13330	16440	33000
Temperature($^{\circ}$ C)	24.30	26.30	23.20	28.00	25.00
Total Hardness	2500	180	7750	1800	220
Total Alkalinity	3200	16000	22000	350	1580
Calcium	450	380	90	170	1920
Aluminium	2.80	7.90	6.00	1.30	1.40
Zinc	4.90	1.80	10.50	11.80	13.00
Ammonium	12.00	0.88	1.68	6.50	0.50
Iron	13.60	38.50	7.99	13.85	5.80
Copper	30.80	6.50	3.90	10.400	16.50
Chloride	2200	2500	6000	7500	2800
Sulphate	120	190	240	60	100
Sulphite	2438	1820	185	600	649
Phosphate	13.50	9.60	38.90	25.60	3.90
Nitrite	0.10	0.05	0.02	0.005	0.02
Nitrate	8.40	39.00	70.30	14.70	285.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix ID: Results of effluent sampled from the selected SHS in the month of February 2011 from a distance of 2 m from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{4A}	K _{4A}	P _{4A}	W _{4A}	Y _{4A}
pH	5.25	4.60	2.90	9.26	10.40
Conductivity(μ S/cm)	22050	17400	180000	13880	9220
Temperature($^{\circ}$ C)	26.90	27.30	24.50	25.00	23.30
Total Hardness	360	1980	3500	10800	6400
Total Alkalinity	2700	1820	12000	2020	1900
Calcium	360	80	250	1830	1220
Aluminium	6.40	9.80	9.10	1.40	1.20
Zinc	1.90	6.30	3.60	1.30	4.60
Ammonium	2.00	6.90	1.40	0.80	6.20
Iron	9.60	2.50	38.60	13.40	57.00
Copper	38.40	50.80	9.40	6.40	20.00
Chloride	4000	3620	5400	1550	4500
Sulphate	80	270	185	65	120
Sulphite	280	300	380	1700	650
Phosphate	6.40	30.90	16.80	10.80	4.60
Nitrite	0.02	0.10	0.10	0.05	0.01
Nitrate	26.00	6.40	3.20	18.90	26.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix IE: Results of effluent sampled from the selected SHS in the month of March 2011 from a distance of 2 m from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{5A}	K _{5A}	P _{5A}	W _{5A}	Y _{5A}
pH	6.90	10.40	9.30	8.40	8.03
Conductivity(μ S/cm)	30780	27750	9020	10100	64040
Temperature($^{\circ}$ C)	22.50	29.40	27.30	25.80	26.30
Total Hardness	1250	6500	6000	5250	4600
Total Alkalinity	2750	1980	950	1400	3650
Calcium	640	1330	350	1440	180
Aluminium	10.40	6.80	9.80	4.50	6.00
Zinc	5.00	2.00	12.00	13.10	5.60
Ammonium	6.00	3.80	0.50	1.00	3.50
Iron	27.80	30.50	15.60	10.80	5.50
Copper	60.00	15.70	28.50	4.90	60.80
Chloride	5600	1420	1620	3750	1000
Sulphate	240	39	180	120	18
Sulphite	290	385	1980	2450	2200
Phosphate	25.00	18.30	1.45	3.65	26.00
Nitrite	0.10	0.02	0.002	0.03	0.10
Nitrate	32.50	35.60	2.60	1.45	72.60

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 2 A: Results of effluent sampled from the selected SHS in the month of November 2010 from a distance of 100 m away from the point of discharge

PARAMETERS	SAMPLING SITES				
	A _{1B}	K _{1B}	P _{1B}	W _{1B}	Y _{1B}
pH	9.80	5.49	7.80	8.45	8.33
Conductivity(μ S/cm)	141300	98240	12000	151300	10000
Temperature($^{\circ}$ C)	26.90	26.00	28.30	28.10	26.90
Total Hardness	8400	2360	1400	14040	8780
Total Alkalinity	6300	1500	900	12120	2100
Calcium	85	900	900	250	1280
Aluminium	6.40	2.80	2.00	6.10	3.00
Zinc	10.00	8.00	2.30	8.60	6.90
Ammonium	6.10	6.40	7.45	6.00	5.00
Iron	16.00	12.10	22.10	12.00	32.40
Copper	22.50	12.30	12.10	25.00	20.80
Chloride	2000	1300	1000	1000	1600
Sulphate	130	140	130	100	190
Sulphite	1430	1210	1250	1244	1140
Phosphate	21.00	12.10	13.00	10.10	10.10
Nitrite	0.002	0.002	0.02	0.01	0.05
Nitrate	12.00	32.50	58.40	24.00	53.40

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 2 B: Results of effluent sampled from the selected SHS in the month of December 2010 from a distance of 100 m away from the point of discharge

PARAMETERS	SAMPLING SITES				
	A _{2B}	K _{2B}	P _{2B}	W _{2B}	Y _{2B}
pH	7.34	8.22	7.35	8.15	6.20
Conductivity(μ S/cm)	9430	2500	4580	8890	3550
Temperature($^{\circ}$ C)	26.80	27.40	26.20	24.40	25.30
Total Hardness	30	60	120	120	75
Total Alkalinity	14250	75	1800	3500	1150
Calcium	3.00	12.00	35.00	20.00	25.00
Aluminium	1.01	0.73	0.53	1.00	0.22
Zinc	1.00	0.25	0.23	0.65	0.32
Ammonium	0.57	0.372	0.212	0.210	0.31
Iron	2.15	1.00	2.10	1.27	3.12
Copper	2.42	1.26	0.67	2.05	4.20
Chloride	2200	750	900	2100	970
Sulphate	14.00	14.00	13.00	18.00	20.00
Sulphite	85.00	124.70	172.80	151.60	132.60
Phosphate	2.30	2.23	2.09	2.23	2.30
Nitrite	0.020	0.0005	0.0012	0.0120	0.010
Nitrate	2.40	1.25	0.70	2.12	1.50

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;
W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 2 C: Results of effluent sampled from the selected SHS in the month of January 2011 from a distance of 100 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{3B}	K _{3B}	P _{3B}	W _{3B}	Y _{3B}
pH	8.40	6.80	7.20	7.10	8.50
Conductivity(μ S/cm)	3102	8110	8115	9420	16000
Temperature($^{\circ}$ C)	27.10	25.10	25.70	27.80	26.50
Total Hardness	1200	120	2410	940	220
Total Alkalinity	1500	7500	8200	195	980
Calcium	225	190	65	120	1110
Aluminium	1.55	2.00	2.00	0.90	0.65
Zinc	2.10	1.10	4.50	6.80	7.50
Ammonium	12.00	0.88	1.68	6.50	0.50
Iron	6.0	20.10	2.90	7.80	1.10
Copper	16.0	4.25	2.30	7.50	9.15
Chloride	440	1600	2400	3500	1900
Sulphate	100	110	140	45	70
Sulphite	1280	850	98	250	220
Phosphate	9.20	3.50	20.40	14.00	1.95
Nitrite	0.050	0.03	0.012	0.0022	0.013
Nitrate	5.00	25.00	50.30	9.20	146.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa

Appendix 2 D: Results of effluent sampled from the selected SHS in the month of February 2011 from a distance of 100 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{4B}	K _{4B}	P _{4B}	W _{4B}	Y _{4B}
pH	6.55	6.65	4.9	7.26	8.4
Conductivity(μ S/cm)	5000	4050	23000	2500	9220
Temperature($^{\circ}$ C)	28.00	27.80	25.00	26.70	25.90
Total Hardness	195	855	1800	6500	2800
Total Alkalinity	950	1000	7200	1400	1000
Calcium	190	65	250	980	750
Aluminium	2.00	5.70	6.00	0.70	0.80
Zinc	1.10	4.00	1.90	0.60	2.40
Ammonium	1.40	3.40	0.70	0.50	2.10
Iron	5.10	1.10	20.10	9.10	33.80
Copper	20.00	20.10	5.00	5.00	12.10
Chloride	2800	2120	2900	880	2800
Sulphate	65	180	135	40	90
Sulphite	175	180	170	1250	230
Phosphate	2.30	18.00	10.40	7.60	2.00
Nitrite	0.011	0.080	0.070	0.023	0.005
Nitrate	18.00	4.20	2.00	11.00	18.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 2 E: Results of effluent sampled from the selected SHS in the month of March 2011 from a distance of 100 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{5B}	K _{5B}	P _{5B}	W _{5B}	Y _{5B}
pH	7.00	8.20	7.35	7.60	8.10
Conductivity(μ S/cm)	18000	16300	5010	6500	33010
Temperature($^{\circ}$ C)	25.00	28.10	28.00	26.90	27.50
Total Hardness	750	3500	3500	3110	2800
Total Alkalinity	1450	1980	430	650	1850
Calcium	330	740	180	640	120
Aluminium	7.00	4.00	6.50	1.80	3.90
Zinc	3.20	1.40	7.50	7.20	2.90
Ammonium	3.20	1.10	0.20	0.60	1.80
Iron	20.00	18.40	9.50	6.40	3.10
Copper	35.00	9.00	19.20	2.60	38.20
Chloride	3200	930	1000	2220	750
Sulphate	139	25	110	75	15
Sulphite	180	190	1110	1355	1300
Phosphate	13.00	11.10	0.55	1.85	15.00
Nitrite	0.080	0.014	0.0012	0.0016	0.050
Nitrate	18.60	23.50	1.55	0.68	40.40

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 3 A: Results of effluent sampled from the selected SHS in the month of November 2010 from a distance of 200 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{1C}	K _{1C}	P _{1C}	W _{1C}	Y _{1C}
pH	7.80	6.45	7.55	8.40	8.20
Conductivity(μ S/cm)	65000	30040	3000	62100	3000
Temperature($^{\circ}$ C)	28.00	30.00	27.30	28.50	27.90
Total Hardness	2110	980	650	55000	980
Total Alkalinity	2200	490	370	5300	900
Calcium	55	380	270	135	430
Aluminium	1.50	0.50	0.20	1.10	1.00
Zinc	2.00	2.00	1.20	2.80	2.40
Ammonium	0.10	0.40	0.45	1.00	0.80
Iron	2.00	2.10	3.10	2.00	12.50
Copper	4.00	3.00	4.10	6.00	7.20
Chloride	650	450	200	180	350
Sulphate	55	65	65	40	75
Sulphite	550	550	450	480	350
Phosphate	6.00	4.30	4.00	15.60	3.20
Nitrite	0.0012	0.0012	0.013	0.004	0.0215
Nitrate	2.00	15.20	22.00	10.00	27.10

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 3 B: Results of effluent sampled from the selected SHS in the month of December 2010 from a distance of 200 m away from the point of discharge

LABEL	A _{2C}	K _{2C}	P _{2C}	W _{2C}	Y _{2C}
PARAMETERS	S A M P L I N G S I T E S				
	A _{2C}	K _{2C}	P _{2C}	W _{2C}	Y _{2C}
pH	7.35	8.36	7.40	8.00	7.20
Conductivity(μS/cm)	3000	700	1500	2270	980
Temperature(°C)	26.90	27.80	25.80	29.40	27.30
Total Hardness	25	45	90	80	100
Total Alkalinity	5000	65	600	1200	480
Calcium	6.00	6.00	25.00	13.00	10.00
Aluminium	0.03	0.13	0.21	0.30	0.15
Zinc	0.50	0.15	0.20	0.33	0.10
Ammonium	0.20	0.170	0.11	0.15	0.80
Iron	0.55	0.50	1.10	0.15	1.40
Copper	1.30	0.65	0.35	1.00	2.25
Chloride	900	250	200	850	270
Sulphate	10.00	9.00	6.00	10.00	10.00
Sulphite	55.00	99.00	110.20	80.60	70.50
Phosphate	1.40	1.20	1.00	1.10	1.50
Nitrite	0.012	0.00035	0.0002	0.0010	0.0050
Nitrate	1.90	0.65	0.20	1.02	1.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 3 C: Results of effluent sampled from the selected SHS in the month of January 2011 from a distance of 200 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{3C}	K _{3C}	P _{3C}	W _{3C}	Y _{3C}
pH	8.20	6.40	8.20	7.70	7.50
Conductivity(μ S/cm)	1600	3400	3320	3600	5000
Temperature($^{\circ}$ C)	27.60	26.30	27.20	27.40	26.70
Total Hardness	380	95	970	300	220
Total Alkalinity	430	2000	3600	100	430
Calcium	160	110	40	85	800
Aluminium	0.65	1.20	0.90	0.50	0.33
Zinc	0.90	0.60	2.10	3.20	3.50
Ammonium	3.00	0.38	0.59	2.20	1.30
Iron	2.00	6.20	1.10	3.10	0.60
Copper	7.00	1.19	1.10	2.20	3.05
Chloride	120	700	1000	1200	800
Sulphate	165	75	60	30	50
Sulphite	700	250	45	120	140
Phosphate	6.20	32.80	12.10	6.00	0.85
Nitrite	0.0250	0.021	0.007	0.0014	0.007
Nitrate	3.00	18.00	35.10	6.00	65.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School;

Y=Yaa Asantewaa SHS

Appendix 3 D: Results of effluent sampled from the selected SHS in the month of February 2011 from a distance of 200 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{4C}	K _{4C}	P _{4C}	W _{4C}	Y _{4C}
pH	6.70	7.30	6.90	7.40	8.10
Conductivity(μ S/cm)	2200	2000	11200	900	3000
Temperature($^{\circ}$ C)	28.50	28.30	26.00	26.90	26.10
Total Hardness	160	300	980	3200	1000
Total Alkalinity	330	380	4000	650	340
Calcium	135	40	130	600	300
Aluminium	1.10	2.80	3.50	0.25	0.30
Zinc	0.40	2.10	0.70	0.25	1.10
Ammonium	0.80	2.00	0.38	0.22	0.60
Iron	3.00	0.60	8.00	2.00	12.20
Copper	9.00	8.50	2.00	3.10	5.00
Chloride	1000	1030	1100	350	1250
Sulphate	30	85	60	25	50
Sulphite	90	90	95	800	90
Phosphate	1.10	6.00	5.00	2.20	0.90
Nitrite	0.005	0.030	0.036	0.014	0.0035
Nitrate	11.00	2.00	1.10	6.00	10.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y = Yaa Asantewaa SHS

Appendix 3 E: Results of effluent sampled from the selected SHS in the month of March 2011 from a distance of 200 m away from the point of discharge

PARAMETERS	S A M P L I N G S I T E S				
	A _{5C}	K _{5C}	P _{5C}	W _{5C}	Y _{5C}
pH	7.50	8.20	7.65	7.60	7.00
Conductivity(μS/cm)	1500	1200	700	450	2000
Temperature(°C)	25.50	28.90	28.90	26.80	28.90
Total Hardness	180	900	950	980	1010
Total Alkalinity	600	800	90	200	60
Calcium	120	200	70	200	50
Aluminium	2.10	1.90	1.10	0.50	0.80
Zinc	1.20	1.00	2.90	2.40	0.88
Ammonium	1.40	0.60	0.11	0.23	0.50
Iron	9.00	10.00	5.50	2.00	1.70
Copper	20.00	1.60	9.00	1.10	15.00
Chloride	900	330	220	850	270
Sulphate	75	15	60	20	9
Sulphite	100	110	450	400	500
Phosphate	5.00	4.10	0.30	0.70	6.00
Nitrite	0.035	0.008	0.0007	0.0009	0.0280
Nitrate	9.20	9.70	0.38	0.29	22.00

ALL PARAMETERS ARE IN mg/l EXCEPT OTHERWISE STATED

NB: A=Asanteman SHS; K=Kumasi Anglican SHS; P=Prempeh College;

W=Opoku Ware School; Y=Yaa Asantewaa SHS

Appendix 4 Mean values of the parameters measured in the effluents pH

School	Spot (2 m)	100 m	200 m
Asanteman	8.41 ± 2.20	7.82 ± 1.30	7.51 ± 0.60
Kumasi Anglican	7.10 ± 2.90	7.07 ± 1.20	7.34 ± 1.30
Opoku Ware	9.16 ± 0.80	7.71 ± 0.60	7.82 ± 0.40
Prempeh College	7.62 ± 2.80	6.92 ± 1.20	7.54 ± 0.50
Yaa Asantewaa	9.24 ± 0.80	7.91 ± 1.00	7.60 ± 0.50
lsd	2.78	1.40	0.80

Conductivity (µS/cm)

School	Spot (2 m)	100 m	200 m
Asanteman	55160.00 ± 809.00	35366.00 ± 595.00	14660.00 ± 281.00
Kumasi Anglican	42950.00 ± 550.00	25840.00 ± 408.00	7468.00 ± 13.00
Opoku Ware	56098.00 ± 947.00	35722.00 ± 647.00	13864.00 ± 270.00
Prempeh College	46374.00 ± 748.00	10541.00 ± 757.00	3944.00 ± 42.00
Yaa Asantewaa	27046.00 ± 228.00	14356.00 ± 113.00	2796.00 ± 14.00
lsd	92717.00	57729.00	24333.00

Temperature (° C)

School	Spot (2 m)	100 m	200 m
Asanteman	24.64 ± 2.10	26.76 ± 1.10	27.30 ± 1.20
Kumasi Anglican	26.36 ± 2.20	26.88 ± 1.30	28.26 ± 1.40
Opoku Ware	25.80 ± 2.00	26.78 ± 1.50	27.80 ± 1.10
Prempeh College	25.10 ± 2.00	26.64 ± 1.40	27.04 ± 1.20
Yaa Asantewaa	25.04 ± 1.50	26.42 ± 0.90	27.38 ± 1.10
lsd	2.58	1.64	1.58

Total Hardness (mg/l)

School	Spot (2 m)	100 m	200 m
Asanteman	3800.00 ± 62.00	2115.00 ± 35.00	571.00 ± 8.70
Kumasi Anglican	2818.00 ± 29.00	1379.00 ± 15.00	464.00 ± 4.50
Opoku Ware	7810.00 ± 84.00	4942.00 ± 57.00	11912.00 ± 241.00
Prempeh College	3930.00 ± 30.00	1846.00 ± 12.00	728.00 ± 3.80
Yaa Asantewaa	3514.00 ± 19.00	2935.00 ± 35.00	662.00 ± 4.60
lsd	6924.90	4599.60	14246.00

Total Alkalinity (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	9330.00 ± 93.00	4890.00 ± 57.00	1712.00 ± 20.00
Kumasi Anglican	4783.60 ± 64.00	2411.00 ± 29.00	747.00 ± 7.5.00
Opoku Ware	5906.00 ± 78.00	3573.00 ± 49.00	1490.00 ± 22.00
Prempeh College	7890.00 ± 91.00	3706.00 ± 37.00	1732.00 ± 19.00
Yaa Asantewaa	3146.00 ± 20.00	1416.00 ± 52.00	442.00 ± 3.00
lsd	9760.60	5246.30	2123.50

Calcium (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	330.80 ± 24.00	166.60 ± 13.00	95.20 ± 6.00
Kumasi Anglican	690.00 ± 75.00	381.40 ± 41.00	147.20 ± 15.00
Opoku Ware	774.40 ± 80.00	402.00 ± 40.00	206.60 ± 23.00
Prempeh College	454.00 ± 61.00	286.00 ± 35.00	107.00 ± 10.00
Yaa Asantewaa	888.00 ± 72.00	657.00 ± 57.00	318.00 ± 32.00
lsd	884.35	524.84	258.78

Aluminium (mg/l)

School	Spot (2 m)	100 m	200 m
Asanteman	7.02 ± 0.53	3.59 ± 0.29	1.08 ± 0.79
Kumasi Anglican	6.93 ± 0.43	3.05 ± 0.19	1.31 ± 0.11
Opoku Ware	4.57 ± 0.56	2.10 ± 0.23	0.53 ± 0.03
Prempeh College	6.19 ± 0.35	3.41 ± 0.27	1.18 ± 0.14
Yaa Asantewaa	3.54 ± 0.30	1.71 ± 0.16	0.52 ± 0.04
lsd	5.68	3.05	1.16

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Zinc (mg/l)

School	Spot (2 m)	100 m	200 m
Asanteman	5.73 ± 0.6	3.48 ± 0.38	1.00 ± 0.06
Kumasi Anglican	4.45 ± 0.45	2.95 ± 0.31	1.17 ± 0.09
Opoku Ware	8.11 ± 0.62	4.77 ± 0.38	1.80 ± 0.14
Prempeh College	6.22 ± 0.49	3.29 ± 0.28	1.42 ± 0.11
Yaa Asantewaa	7.46 ± 0.56	4.00 ± 0.31	1.60 ± 0.13
lsd	7.14	4.42	1.46

Ammonia (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	6.77 ± 0.56	4.65 ± 0.46	1.10 ± 0.19
Kumasi Anglican	4.93 ± 0.49	2.43 ± 0.25	0.71 ± 0.07
Opoku Ware	4.34 ± 0.54	2.76 ± 0.32	0.76 ± 0.09
Prempeh College	3.38 ± 0.51	2.05 ± 0.31	0.33 ± 0.02
Yaa Asantewaa	4.40 ± 0.42	1.94 ± 0.19	0.80 ± 0.03
lsd	6.71	4.21	0.99

Iron (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	23.99 ± 2.40	9.85 ± 0.80	3.31 ± 0.30
Kumasi Anglican	27.97 ± 2.50	10.54 ± 0.90	3.88 ± 0.40
Opoku Ware	21.40 ± 2.30	7.31 ± 0.40	1.85 ± 0.10
Prempeh College	25.98 ± 2.40	11.34 ± 0.90	3.76 ± 0.30
Yaa Asantewaa	27.45 ± 2.90	14.70 ± 1.60	5.68 ± 0.60
lsd	33.21	13.58	5.12

Copper (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	40.06 ± 2.50	19.18 ± 1.80	8.26 ± 0.70
Kumasi Anglican	20.70 ± 1.90	9.38 ± 0.70	2.99 ± 0.30
Opoku Ware	18.22 ± 2.60	8.43 ± 0.90	2.68 ± 0.20
Prempeh College	12.64 ± 1.10	7.85 ± 0.80	3.31 ± 0.30
Yaa Asantewaa	31.54 ± 2.40	16.89 ± 1.30	6.50 ± 0.50
lsd	28.85	13.46	6.03

Chloride (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	4600.00 ± 16.40	2128.00 ± 10.60	714.00 ± 3.60
Kumasi Anglican	2718.00 ± 15.00	1340.00 ± 5.50	552.00 ± 3.20
Opoku Ware	4620.00 ± 22.60	1940.00 ± 10.70	686.00 ± 4.10
Prempeh College	3624.00 ± 20.60	1640.00 ± 9.40	544.00 ± 4.60
Yaa Asantewaa	3090.00 ± 18.40	1604.00 ± 8.10	588.00 ± 4.30
lsd	2481.50	1194.40	527.46

Sulphate (mg/l)

School	Spot (2 m)	100 m	200 m
Asanteman	147.20 ± 10.00	89.60 ± 5.10	67.00 ± 6.00
Kumasi Anglican	169.40 ± 13.00	93.80 ± 7.20	49.80 ± 3.50
Opoku Ware	115.40 ± 11.00	55.60 ± 3.20	25.00 ± 1.10
Prempeh College	189.80 ± 11.00	105.60 ± 5.30	50.20 ± 2.40
Yaa Asantewaa	127.20 ± 14.00	77.00 ± 7.00	38.80 ± 2.80
lsd	156.79	76.28	47.25

KNUST

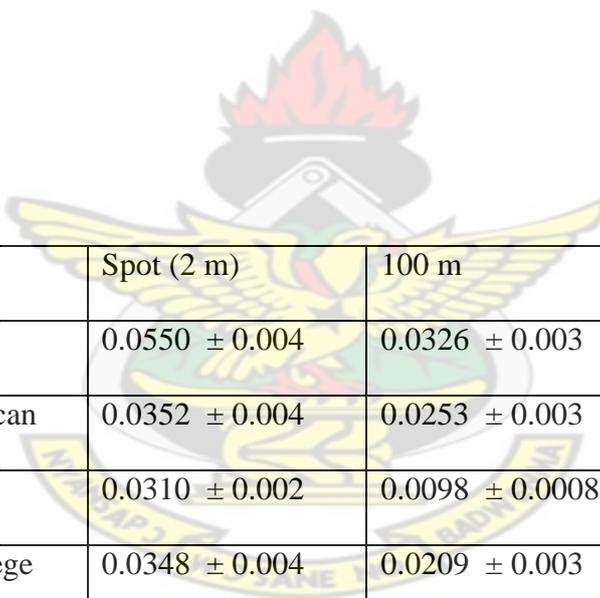
Sulphite (mg/l)

School	Spot (2 m)	100 m	200 m
Asanteman	1166.70 ± 125.00	630.00 ± 66.00	299.00 ± 30.00
Kumasi Anglican	1267.80 ± 139.00	510.94 ± 49.00	219.80 ± 20.00
Opoku Ware	1721.20 ± 129.00	850.12 ± 60.00	376.12 ± 29.00
Prempeh College	1336.80 ± 155.00	560.16 ± 57.00	230.04 ± 20.00
Yaa Asantewaa	1205.10 ± 96.00	604.52 ± 57.00	230.10 ± 19.00
lsd	1720.50	765.17	318.83

Phosphate (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	18.44 ± 1.50	9.56 ± 0.80	3.94 ± 0.20
Kumasi Anglican	21.13 ± 1.60	9.39 ± 0.70	9.68 ± 1.30
Opoku Ware	17.46 ± 1.70	7.16 ± 0.50	20.12 ± 0.60
Prempeh College	20.77 ± 1.90	9.29 ± 0.80	4.48 ± 0.50
Yaa Asantewaa	15.82 ± 1.70	6.27 ± 0.60	8.49 ± 0.20
lsd	22.28	9.03	9.17

KNUST



Nitrite (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	0.0550 ± 0.004	0.0326 ± 0.003	0.0156 ± 0.001
Kumasi Anglican	0.0352 ± 0.004	0.0253 ± 0.003	0.0121 ± 0.001
Opoku Ware	0.0310 ± 0.002	0.0098 ± 0.0008	0.0043 ± 0.0005
Prempeh College	0.0348 ± 0.004	0.0209 ± 0.003	0.0114 ± 0.001
Yaa Asantewaa	0.0520 ± 0.004	0.0256 ± 0.002	0.0130 ± 0.001
lsd	0.0518	0.0349	0.0160

Nitrate (*mg/l*)

School	Spot (2 m)	100 m	200 m
Asanteman	19.72 ± 1.30	11.20 ± 0.70	5.42 ± 0.40
Kumasi Anglican	33.30 ± 3.20	17.29 ± 1.40	9.11 ± 0.80
Opoku Ware	13.56 ± 1.10	9.40 ± 0.90	4.66 ± 0.40
Prempeh College	33.04 ± 4.20	22.59 ± 2.90	11.76 ± 1.60
Yaa Asantewaa	94.72 ± 11.10	51.86 ± 5.60	25.02 ± 2.50
lsd	73.91	38.91	18.23

KNUST



Appendix 5A ANOVA TABLES FOR
EFFLUENTS FROM CHEMISTRY
LABORATORIES AT SPOT (2 m)

Completely Randomized AOV for pH

Source	DF	SS	MS	F	P
schools	4	17.663	4.41572	1.00	0.4327
Error	20	88.677	4.43387		
Total	24	106.340			
Grand Mean		8.3052	CV 25.35		

Completely Randomized AOV for Conductivity

Source	DF	SS	MS	F	P
schools	4	2.767E+09	6.918E+08	0.14	0.9653
Error	20	9.878E+10	4.939E+09		
Total	24	1.015E+11			
Grand Mean		45526	CV 154.37		

Completely Randomized AOV for Temperature

Source	DF	SS	MS	F	P
schools	4	9.3904	2.34760	0.61	0.6572
Error	20	76.4160	3.82080		
Total	24	85.8064			
Grand Mean		25.388	CV 7.70		

Completely Randomized AOV for Hardness

Source	DF	SS	MS	F	P
schools	4	7.747E+07	1.937E+07	0.70	0.5991
Error	20	5.510E+08	2.755E+07		
Total	24	6.285E+08			
Grand Mean		4374.4	CV 119.99		

Completely Randomized AOV for Alkalinity

Source	DF	SS	MS	F	P
schools	4	1.203E+08	3.009E+07	0.55	0.7014
Error	20	1.095E+09	5.474E+07		
Total	24	1.215E+09			
Grand Mean		6211.1	CV 119.12		

Completely Randomized AOV for Calcium

Source	DF	SS	MS	F	P
schools	4	1057396	264349	0.59	0.6749
Error	20	8986720	449336		
Total	24	1.004E+07			
Grand Mean		627.44	CV 106.83		

Completely Randomized AOV for Aluminium

Source	DF	SS	MS	F	P
schools	4	47.166	11.7915	0.64	0.6429
Error	20	370.925	18.5463		
Total	24	418.091			
Grand Mean		5.6480	CV 76.25		

Completely Randomized AOV for Zinc

Source	DF	SS	MS	F	P
schools	4	41.569	10.3921	0.35	0.8378
Error	20	586.258	29.3129		
Total	24	627.826			
Grand Mean		6.3940	CV 84.68		

Completely Randomized AOV for Ammonium

Source	DF	SS	MS	F	P
schools	4	31.464	7.8660	0.30	0.8716
Error	20	516.789	25.8394		
Total	24	548.253			
Grand Mean		4.7637	CV 106.71		

Completely Randomized AOV for Iron

Source	DF	SS	MS	F	P
schools	4	145.6	36.395	0.06	0.9934
Error	20	12673.5	633.674		
Total	24	12819.1			
Grand Mean	25.361	CV 99.26			

Completely Randomized AOV for Sulphite

Source	DF	SS	MS	F	P
schools	4	993742	248436	0.15	0.9626
Error	20	3.402E+07	1700819		
Total	24	3.501E+07			
Grand Mean	1339.5	CV 97.36			

Completely Randomized AOV for Copper

Source	DF	SS	MS	F	P
schools	4	2429.7	607.423	1.27	0.3147
Error	20	9566.6	478.332		
Total	24	11996.3			
Grand Mean	24.631	CV 88.79			

Completely Randomized AOV for Phosphate

Source	DF	SS	MS	F	P
schools	4	100.35	25.087	0.09	0.9852
Error	20	5703.24	285.162		
Total	24	5803.59			
Grand Mean	18.722	CV 90.20			

Completely Randomized AOV for Chloride

Source	DF	SS	MS	F	P
schools	4	1.497E+07	3742474	1.06	0.4030
Error	20	7.076E+07	3537910		
Total	24	8.573E+07			
Grand Mean	3730.4	CV 50.42			

Completely Randomized AOV for Nitrite

Source	DF	SS	MS	F	P
schools	4	0.00244	0.00061	0.40	0.8093
Error	20	0.03078	0.00154		
Total	24	0.03322			
Grand Mean	0.0416	CV 94.31			

Completely Randomized AOV for Sulphate

Source	DF	SS	MS	F	P
schools	4	18425	4606.3	0.33	0.8571
Error	20	282473	14123.6		
Total	24	300898			
Grand Mean	149.80	CV 79.33			

Completely Randomized AOV for Nitrate

Source	DF	SS	MS	F	P
schools	4	20955.4	5238.85	1.67	0.1965
Error	20	62764.8	3138.24		
Total	24	83720.2			
Grand Mean	38.867	CV 144.13			

Appendix 5B

ANOVA TABLES FOR EFFLUENTS FROM CHEMISTRY LABORATORIES AT 100 m

Completely Randomized AOV for pH

Source	DF	SS	MS	F	P
schools	4	4.1473	1.03681	0.92	0.4703
Error	20	22.4732	1.12366		
Total	24	26.6204			
Grand Mean		7.4856	CV 14.16		

Completely Randomized AOV for Alkalinity

Source	DF	SS	MS	F	P
schools	4	3.528E+07	8820548	0.56	0.6958
Error	20	3.163E+08	1.581E+07		
Total	24	3.516E+08			
Grand Mean		3199.2	CV 124.30		

Completely Randomized AOV for Conductivity

Source	DF	SS	MS	F	P
schools	4	2.717E+09	6.793E+08	0.35	0.8376
Error	20	3.830E+10	1.915E+09		
Total	24	4.101E+10			
Grand Mean		24365	CV 179.59		

Completely Randomized AOV for Calcium

Source	DF	SS	MS	F	P
schools	4	657904	164476	1.04	0.4117
Error	20	3165250	158263		
Total	24	3823154			
Grand Mean		378.60	CV 105.08		

Completely Randomized AOV for Temperature

Source	DF	SS	MS	F	P
schools	4	0.6216	0.15540	0.10	0.9812
Error	20	31.0880	1.55440		
Total	24	31.7096			
Grand Mean		26.696	CV 4.67		

Completely Randomized AOV for Aluminium

Source	DF	SS	MS	F	P
schools	4	13.602	3.40047	0.63	0.6438
Error	20	107.201	5.36006		
Total	24	120.803			
Grand Mean		2.7716	CV 83.53		

Completely Randomized AOV for Hardness

Source	DF	SS	MS	F	P
schools	4	3.941E+07	9852942	0.81	0.5331
Error	20	2.431E+08	1.215E+07		
Total	24	2.825E+08			
Grand Mean		2643.4	CV 131.89		

Completely Randomized AOV for Zinc

Source	DF	SS	MS	F	P
schools	4	10.098	2.5245	0.22	0.9213
Error	20	224.522	11.2261		
Total	24	234.620			
Grand Mean		3.6980	CV 90.60		

Completely Randomized AOV for Ammonia

Source	DF	SS	MS	F	P
schools	4	24.356	6.0889	0.60	0.6677
Error	20	203.365	10.1683		
Total	24	227.721			
Grand Mean		2.7674	CV 115.23		

Completely Randomized AOV for Sulphate

Source	DF	SS	MS	F	P
schools	4	7245.0	1811.26	0.54	0.7069
Error	20	66864.4	3343.22		
Total	24	74109.4			
Grand Mean		84.320	CV 68.57		

Completely Randomized AOV for Iron

Source	DF	SS	MS	F	P
schools	4	143.21	35.803	0.34	0.8493
Error	20	2120.23	106.012		
Total	24	2263.44			
Grand Mean		10.750	CV 95.78		

Completely Randomized AOV for Sulphite

Source	DF	SS	MS	F	P
schools	4	340742	85185	0.25	0.9043
Error	20	6727753	336388		
Total	24	7068495			
Grand Mean		631.15	CV 91.89		

Completely Randomized AOV for Copper

Source	DF	SS	MS	F	P
schools	4	558.52	139.631	1.34	0.2892
Error	20	2081.36	104.068		
Total	24	2639.88			
Grand Mean		12.348	CV 82.62		

Completely Randomized AOV for Phosphate

Source	DF	SS	MS	F	P
schools	4	45.838	11.4596	0.24	0.9095
Error	20	936.928	46.8464		
Total	24	982.766			
Grand Mean		8.3320	CV 82.15		

Completely Randomized AOV for Chloride

Source	DF	SS	MS	F	P
schools	4	1892896	473224	0.58	0.6823
Error	20	1.639E+07	819580		
Total	24	1.828E+07			
Grand Mean		1730.4	CV 52.32		

Completely Randomized AOV for Nitrite

Source	DF	SS	MS	F	P
schools	4	0.00142	3.548E-04	0.51	0.7312
Error	20	0.01400	7.000E-04		
Total	24	0.01542			
Grand Mean		0.0228	CV 115.90		

Completely Randomized AOV for Nitrate

Source	DF	SS	MS	F	P
schools	4	5942.3	1485.57	1.71	0.1877
Error	20	17395.0	869.75		
Total	24	23337.3			
Grand Mean		22.468	CV 131.26		

Appendix 5C
ANOVA TABLES FOR
EFFLUENTS FROM CHEMISTRY
LABORATORIES AT 200 m

Completely Randomized AOV for pH

Source	DF	SS	MS	F	P
schools	4	0.59798	0.14949	0.41	0.8006
Error	20	7.32428	0.36621		
Total	24	7.92226			
Grand Mean		7.5624	CV 8.00		

Completely Randomized AOV for Conductivity

Source	DF	SS	MS	F	P
schools	4	6.053E+08	1.513E+08	0.44	0.7748
Error	20	6.804E+09	3.402E+08		
Total	24	7.409E+09			
Grand Mean		8546.4	CV 215.81		

Completely Randomized AOV for Temperature

Source	DF	SS	MS	F	P
schools	4	4.5896	1.14740	0.80	0.5411
Error	20	28.7920	1.43960		
Total	24	33.3816			
Grand Mean		27.556	CV 4.35		

Completely Randomized AOV for Hardness

Source	DF	SS	MS	F	P
schools	4	5.115E+08	1.278E+08	1.10	0.3853
Error	20	2.332E+09	1.166E+08		
Total	24	2.844E+09			
Grand Mean		2867.4	CV 376.59		

Completely Randomized AOV for Alkalinity

Source	DF	SS	MS	F	P
schools	4	7030076	1757519	0.68	0.6149
Error	20	5.181E+07	2590666		
Total	24	5.884E+07			
Grand Mean		1224.6	CV 131.44		

Completely Randomized AOV for Calcium

Source	DF	SS	MS	F	P
schools	4	166061	41515.3	1.08	0.3932
Error	20	769529	38476.4		
Total	24	935590			
Grand Mean		174.80	CV 112.22		

Completely Randomized AOV for Aluminium

Source	DF	SS	MS	F	P
schools	4	2.7864	0.69659	0.90	0.4828
Error	20	15.4898	0.77449		
Total	24	18.2762			
Grand Mean		0.9220	CV 95.45		

Completely Randomized AOV for Zinc

Source	DF	SS	MS	F	P
schools	4	2.0423	0.51058	0.42	0.7941
Error	20	24.4676	1.22338		
Total	24	26.5100			
Grand Mean		1.3964	CV 79.21		

Completely Randomized AOV for Ammonium

Source	DF	SS	MS	F	P
schools	4	1.5212	0.38030	0.67	0.6226
Error	20	11.4099	0.57049		
Total	24	12.9311			
Grand Mean		0.7396	CV 102.12		

Completely Randomized AOV for Iron

Source	DF	SS	MS	F	P
schools	4	37.655	9.4136	0.63	0.6495
Error	20	300.810	15.0405		
Total	24	338.465			
Grand Mean		3.6960	CV 104.93		

Completely Randomized AOV for Sulphite

Source	DF	SS	MS	F	P
schools	4	89031	22257.7	0.38	0.8195
Error	20	1168068	58403.4		
Total	24	1257099			
Grand Mean		271.01	CV 89.17		

Completely Randomized AOV for Copper

Source	DF	SS	MS	F	P
schools	4	124.229	31.0571	1.49	0.2436
Error	20	417.625	20.8812		
Total	24	541.853			
Grand Mean		4.7476	CV 96.25		

Completely Randomized AOV for Phosphate

Source	DF	SS	MS	F	P
schools	4	147.55	36.8876	0.76	0.5617
Error	20	967.06	48.3529		
Total	24	1114.61			
Grand Mean		5.1420	CV 135.23		

Completely Randomized AOV for Chloride

Source	DF	SS	MS	F	P
schools	4	122824	30706	0.19	0.9397
Error	20	3196920	159846		
Total	24	3319744			
Grand Mean		616.80	CV 64.82		

Completely Randomized AOV for Nitrite

Source	DF	SS	MS	F	P
schools	4	0.00036	8.993E-05	0.61	0.6604
Error	20	0.00295	1.475E-04		
Total	24	0.00331			
Grand Mean		0.0113	CV 107.69		

Completely Randomized AOV for Sulphate

Source	DF	SS	MS	F	P
schools	4	4829.0	1207.24	0.94	0.4605
Error	20	25650.4	1282.52		
Total	24	30479.4			
Grand Mean		46.160	CV 77.58		

Completely Randomized AOV for Nitrate

Source	DF	SS	MS	F	P
schools	4	1359.12	339.779	1.78	0.1726
Error	20	3819.21	190.960		
Total	24	5178.32			
Grand Mean		11.194	CV 123.45		