

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY**

**DEPARTMENT OF ENVIRONMENTAL SCIENCE**

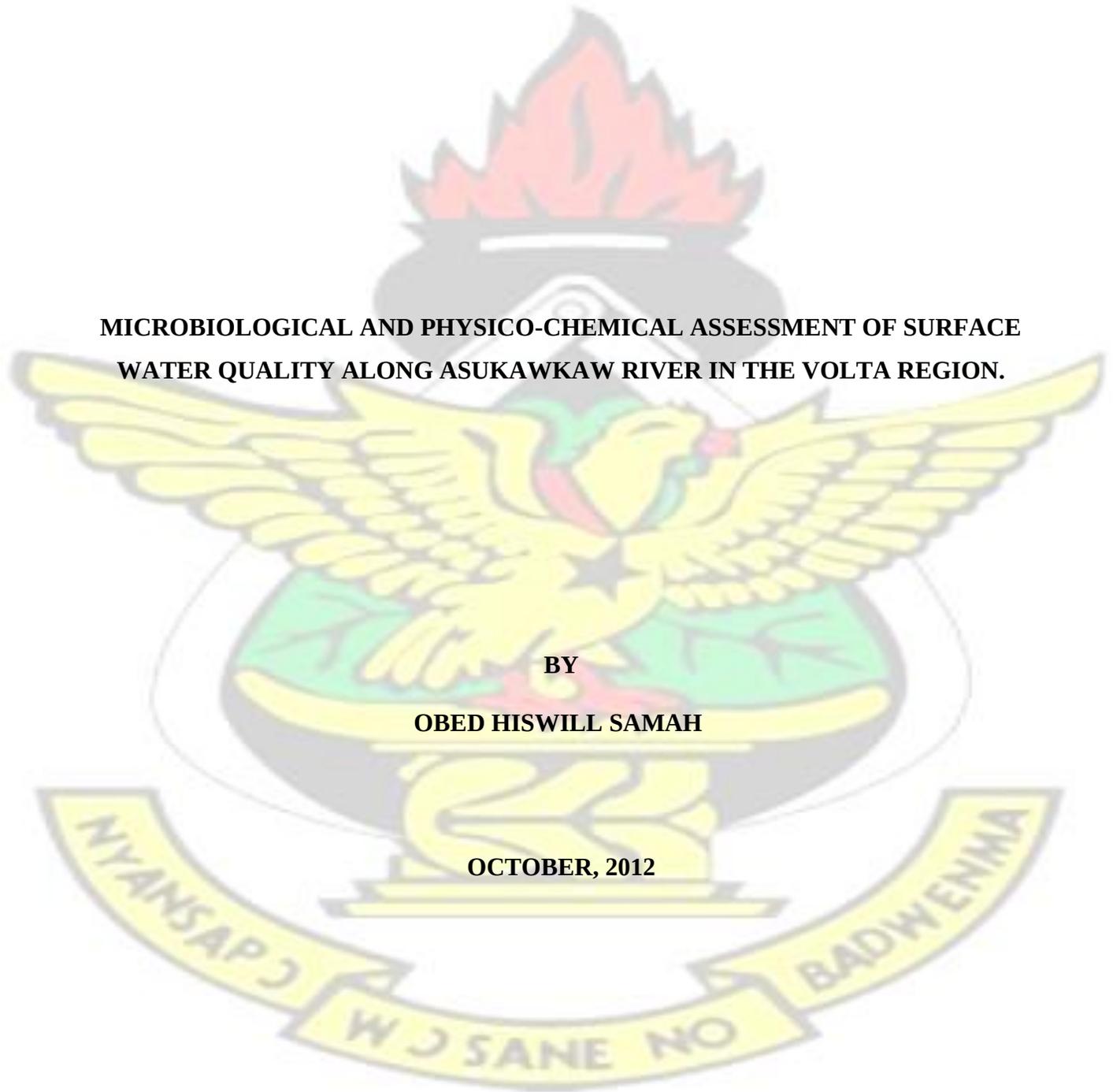
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**MICROBIOLOGICAL AND PHYSICO-CHEMICAL ASSESSMENT OF SURFACE  
WATER QUALITY ALONG ASUKAWKAW RIVER IN THE VOLTA REGION.**

**BY**

**OBED HISWILL SAMAH**

**OCTOBER, 2012**



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MICROBIOLOGICAL AND PHYSICO-CHEMICAL ASSESSMENT OF SURFACE  
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**A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED  
BIOLOGY, KWAME NKURUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,  
KUMASI, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE**

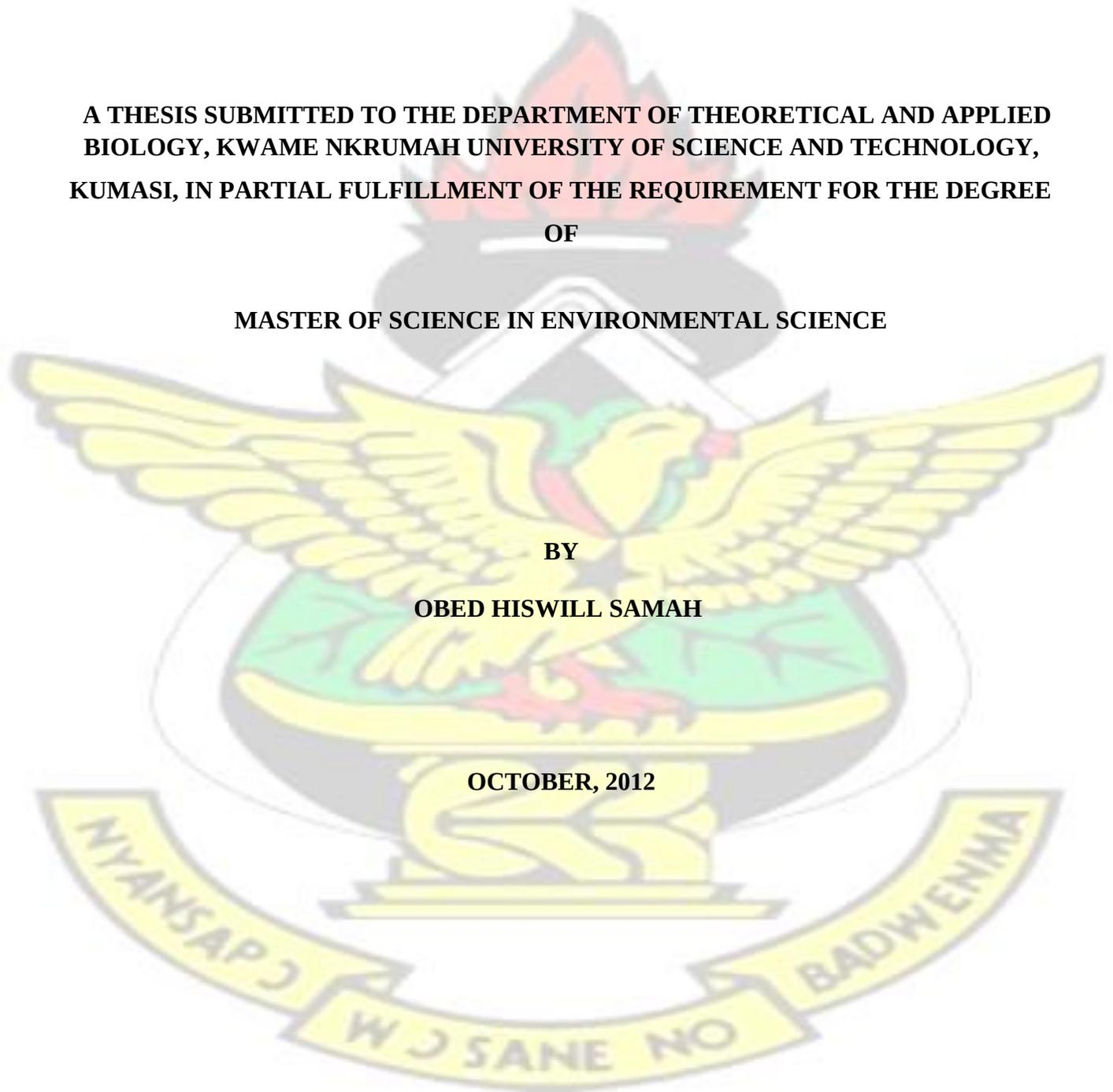
**OF**

**MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE**

**BY**

**OBED HISWILL SAMAH**

**OCTOBER, 2012**



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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, except where due acknowledgement has been made in text.

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(Head of Department) Signature Date

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## DEDICATION

This thesis is dedicated to my father Honorable Emmanuel Nelson Samah who has been my backbone in my achievements and for his enormous support in these hard times and throughout my life.

Thanks a lot and God richly bless you.



## ABSTRACT

This study (conducted between March and June, 2012), assessed the water quality of the Asukawkaw River in the Nkwanta South District of the Volta Region. Composite water samples drawn from some sections of the Asukawkaw river from five sampling points, Asukawkaw Upstream, Asukawkaw Downstream, Dodo Tamale, Dodo Bethel and Dodo Fie were analysed in the laboratory for temperature, pH, turbidity, conductivity, TDS, TSS alkalinity, and some selected nutrients ( $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ,  $\text{NO}_2^-$ ,  $\text{NO}_4^-$ ) some heavy metals (Fe, Pb Zn, Cd, and Cr) and total and faecal coliforms. The results indicated that turbidity, total iron, chromium, faecal coliforms and total coliforms were above the guidelines set by the WHO and the 2003 Ghana Raw Water Criteria and Guidelines for domestic use. With the exception of temperature and pH, all the other parameters experienced a general increase during the sampling regime due to the influence of rainfall with turbidity, conductivity and total dissolved solids recording high values. The nutrient concentrations observed in the water were slightly low and fell within the WHO standards except for  $\text{PO}_4^{2-}$  at Dodo Bethel and Asukawkaw Downstream. There were high levels of Fe, some considerable concentrations of Cr contamination at all the sampling points. All other heavy metal parameters were below detection limit (BDL). Pollution Load Index (PLI) assessment of the river for Fe, Pb, Cd, Zn, Cr and Al indicates an unpolluted water body. The mean total coliforms ranged between 497.50 TC/100ml and 1323.25TC/100ml while all the samples analyzed recorded 121.00 FC/100ml and 425.50FC/100ml for faecal coliforms.



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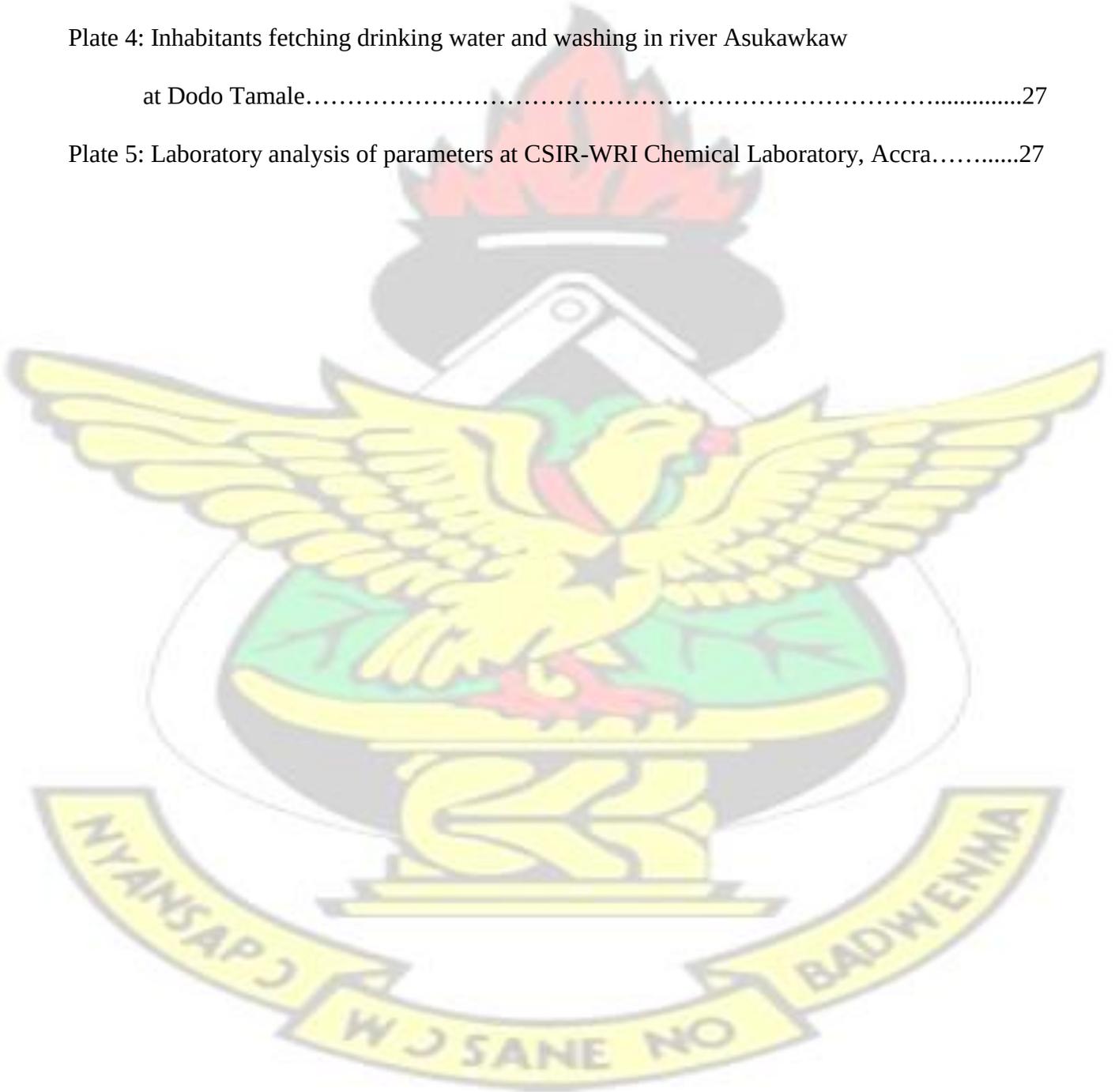
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## LIST OF ABBREVIATIONS

AAS	-	Atomic Absorption Spectrophotometer
ANOVA	-	Analysis of Variance
APHA	-	American Public Health Association
AWWA	-	American Water Works Association
BDL	-	Below Detection Limit
BOD	-	Biochemical Oxygen Demand
CCFB	-	Chuan Chya Food and Beverages
CLRSWC	-	Committee on Long-Range Soil and Water Conservation, National Research Council
COD	-	Chemical Oxygen Demand
CSIR	-	Council for Scientific and Industrial Research
CWQRB	-	California Water Quality Resources Board
CWSA	-	Community Water and Sanitation Agency
DDT	-	Dichlodiphenyltrichloroethane
DHHS	-	Department of Health and Human Services
EPA	-	Environmental Protection Agency
FAO	-	Food and Agricultural Organization
FFB	-	Fresh Fruit Bunch
GEF	-	Global Environment Facility
GoG	-	Government of Ghana
GWCL	-	Ghana Water Company Limited
IDPH	-	Illinois Department of Public Health
LI	-	Legislative Instrument
MCL	-	Maximum Contaminant Level
MDG's	-	Millennium Development Goals
NTU	-	Nephelometric Turbidity Unit
PAH	-	Polyaromatic Hydrocarbon
PCB's	-	Polychlorinated Biphenyls
TDS	-	Total Dissolved Solid
TSS	-	Total Suspended Solid
UNEP	-	United Nations Environment Programme
UNEP/GEMS	-	UNEP /Global Environment Monitoring System
USGS	-	United States Geological Services
WHO	-	World Health Organisation
WRC	-	Water Resources Commission

## CHAPTER ONE

### 1.0 BACKGROUND

The dramatic global industrialization, agricultural mechanization with modern agricultural practices, expansion of chemical industries and rapid development of cheap sources of energy variety had brought about stress on the ecosystem (Keller *et. al.*, 2002, Quilbe *et. al.*, 2004). The increased use of artificial fertilizers combined with the removal of natural vegetation for cultivation and urbanization has caused a world-wide trend of increasing nutrient and sediment loads in river systems (Berka *et. al.*, 2001; Gabrick and Bell, 2003).

The sources of pollution of water bodies are essentially natural through geological modification (dissolution from earth crust, earthquake) or anthropogenic through atmospheric deposition, industrial and domestic sewage, run-off from mechanized agricultural field and chemical wastes discharged into bodies of water (Fatoki *et. al.*, 2002, Olajire and Imeokparia, 2000).

The presence of impurities reduces the quality and uses to which water may be deployed. Water must therefore be analysed to determine its acceptability for the intended purpose (Familoni, 2005). Usually, pollution is associated with the presence of toxic substances or energy in large quantity more than what can be attenuated by the environment on the basis of natural degradative changes and therefore, there is a strong anthropocentric bias towards its determination (Macer, 2000). The ever-increasing pollution of the environment has been one of the greatest concerns for science and the general public in the last fifty years (Foudan and Kefatos, 2001; Salami and Adekola, 2002). Prolonged exposure has the potential to produce adverse effects in humans and other organisms which include the danger of acute toxicity, mutagenesis (genetic changes),

carcinogenesis, and teratogenesis (birth defects) for human and other organisms (Foudan and Kefatos, 2001).

Over 30 per cent of the rural population in Ghana do not have access to safe drinking water. Nationally, 22 per cent of the population still lack access to safe water (Allison, 2007). It has been estimated that lack of clean drinking water and sanitation services leads to water-related diseases globally and between five to ten million deaths occur annually, primarily of small children (Snyder and Merson, 1982).

An estimated 80% of all illnesses in developing countries are related to water and sanitation and 15% of all child deaths under the age of five years in developing countries result from diarrhoeal diseases (WHO, 2004; Thompson and Khan, 2003).

One of the goals of the United Nations Millennium Development Goals (MDG's) is to reduce persistent poverty and promote sustainable development worldwide especially in developing countries. Improvement of drinking water supply and sanitation is a core element of poverty reduction. The MDG target for water is to halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation. The WHO (2004) estimates that if these improvements were to be made in sub-Saharan Africa alone, 434,000 child deaths due to diarrhoea would be averted annually.

### **1.1 PROBLEM STATEMENT**

Nkwanta South District is deficient in quality source of drinking water (Larmie *et. al.*, 2009). Water treatment and supply to the populace is a challenge to local authorities making most people reliant on surface water as a source of drinking water. Indiscriminate use of agrochemicals for vegetable growing along some important water bodies puts the quality of drinking water into

question. Coupling this with the large scale oil palm plantation development in the district with its attendant agro and industrial chemical use and disposal along the Asukawkaw river, puts the quality of drinking water into question.

Potable water coverage in the district is just about 44% with a total of 266 boreholes with the remaining 56% depending on the Asukawkaw River and the Kpafia Stream (a tributary of Asukawkaw River) as the sources of drinking water (Larmie *et. al.*, 2009).

There is the need therefore to assess the quality of surface water in the district.

## **1.2 JUSTIFICATION**

Water quality monitoring is an essential tool used by environmental agencies to gauge the quality of surface water and to make management decisions for improving or protecting the intended uses. For many people in Ghana, water supply, sanitation, and safe disposal of waste remain the most important of all environmental problems. Control and sustainable management of watersheds are major issues in Ghana because of human activities. These include nutrient enrichment of surface waters by agricultural chemicals, soil degradation caused by deforestation, eutrophication, improper land management, abstraction of water for human consumption and irrigation.

The Asukawkaw river contributes up to about 40% of the total volume of water in the Volta lake (Moxon, 1968; GEF-UNEP, 2002.). Evaluations of Asukawkaw river water quality conditions are often limited in scope and spatial extent due to the length and size of the river, insufficient monitoring resources, and its multi-jurisdictional nature.

The Asukawkaw river is affected mainly by both domestic and agricultural activities. Pollution is generally slight and localized along the banks owing to indiscriminate disposal of untreated faecal

matter and garbage, because of lack of adequate sanitary and waste disposal facilities (WRC, 2000). Human activities in watersheds can increase nutrient loads carried into surface waters by runoff and enhance primary production (Sharpley & Menzel, 1987). The environmental issues arise from the improper management and control of domestic, municipal, agricultural, and industrial wastes which find their way into the water bodies, as well as from erosion in river catchments as a result of clearing for farming, timber, and extraction of firewood, among others (WRC, 2000).

The Asukawkaw river, which is an important source of water supply for the people in its catchment area, is being polluted with waste discharges and agricultural activities. The demand for adequate water to satisfy the ever increasing needs through conservation and regulation has necessitated the need to identify the various sources of contaminants carried into rivers by runoff. This then necessitated the assessment of the physico-chemical, microbiological and nutrient loads of the Asukawkaw river, to generate useful and convincing information in the design of socially optimal decisions for public intervention.

### **1.3 SIGNIFICANCE OF THE STUDY**

The results of the study will serve as baseline information on surface quality in terms of some selected physico-chemical, nutrient and microbiological parameters. The data obtained may also assist in advising local government authorities and central government on policy regarding regulation for potable water provision in the country and also advise on monitoring of surface water quality for both domestic and commercial use in the country.

## 1.4 OBJECTIVES

### Main objective

To determine the quality of drinking surface water in oil palm development areas in the Asukawkaw river portion of the Nkwanta South District of the Volta Region.

### Specific objectives:

The Specific objectives were to:

1. assess the microbiological quality of the drinking surface water samples.
2. determine the concentrations of the physico-chemical parameters of drinking water.
3. assess the levels of heavy metals (Fe, Pb, Zn, Cd, and Cr) in drinking surface water.
4. quantify surface water pollution by monitored heavy metals in the study area using Pollution Load Index, Geo-accumulation Index, Enrichment Ratio and Contamination Degree of drinking surface water samples.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. SOURCES OF CONTAMINATION OF SURFACE WATER IN AGRICULTURE

##### 2.1.1 Surface nutrient runoff

Surface runoff is the water flow that occurs when the soil is infiltrated to full capacity and excess water from rain, meltwater, or other sources flows over the land. This is a major component of the water cycle (Keith, 2004). When runoff generated either by rainfall or by the melting of snow, or glaciers flow along the ground, it can pick up soil contaminants including, but not limited to petroleum, pesticides, or fertilizers that become discharge or nonpoint source pollution. Ultimately these consequences translate into human health risk, ecosystem disturbance and aesthetic impact to water resources. Some of the contaminants that create the greatest impact to surface waters arising from runoff are petroleum substances, herbicides and fertilizers. In the case of surface waters, the impacts translate to water pollution, since the streams and rivers have received runoff carrying various chemicals or sediments.

Pesticide runoff occurs when pesticides are carried outside of the intended area of application through water or soil erosion. Runoff often occurs as a result of over-watering and soil saturation. Surface runoff occurring within forests can supply lakes with high loads of mineral nitrogen and phosphorus leading to eutrophication. Runoff waters within coniferous forests are also enriched with humic acids and can lead to humification of water bodies (Klimaszyk *et. al.*, 2011).

### **2.1.2 Erosion and sedimentation**

Agriculture contributes greatly to soil erosion and sediment deposition through inefficient management of land cover (CLRSWC, 1993). It is estimated that agricultural land degradation is leading to an irreversible decline in fertility on about 6 million ha of fertile land each year (Dudal, 1981). The accumulation of sediments (i.e. sedimentation) in runoff water affects water quality in various ways (Hangsleben *et. al.*, 2006).

The nitrogen (N) and phosphorus (P) applied to agricultural land (via synthetic fertilizers, composts, manures, biosolids, etc.) can provide valuable plant nutrients. However, if not managed correctly, excess N and P can have negative environmental consequences. Excess N supplied by both synthetic fertilizers (as highly soluble nitrate) and organic sources such as manures (whose organic N is mineralized to nitrate by soil microorganisms) can lead to surface water contamination of nitrate. Nitrate-contaminated drinking water can cause blue baby syndrome. Methemoglobinemia, "Blue-Baby Disease," is an effect in which hemoglobin is oxidized to methaemoglobin, resulting in asphyxia (Pushard, 2005).

### **2.1.3 Volatilization and drift**

Pesticide drift occurs when spray particles are carried through the air outside of the intended treatment area. The occurrence of drift is affected by the size of aerial pesticide droplets, wind speed, and the distance between the target spray site and the actual spray nozzle. The negative impacts of pesticide spray drift can include contamination and/or damage of nearby crops, wild or domestic animals, insects including pollinators, and people. Surrounding bodies of water, such as streams and ponds, can also become contaminated, resulting in damage to fish and other wildlife.

## **2.2 Surface water quality and health**

For a healthy living, clean water is an absolute necessity. As a result of the contamination of water bodies with heavy metals, persistent organic pollutants, faecal material and nutrients, serious health problems have resulted with 80% of diseases in developing countries being water related (Feugo, 2008; UNEP, 2002). Chemicals causing health disorders may be naturally present in water bodies or may be introduced by human activities. Pesticides contain organophosphates and carbonates which damage the nervous system. Most pesticides contain carcinogenic substances well above safety levels which may result in cancer. High concentrations of nitrates in drinking water cause the blue body syndrome, a condition whereby a very restricted amount of oxygen reaches the brain resulting in death (US EPA, 1992).

## **2.3 PHYSICO-CHEMICAL INDICES OF WATER QUALITY**

### **2.3.1 Physical Parameters**

#### **2.3.1.1 pH**

The pH of drinking water represents the concentration of the free hydrogen ions in it or the measure of how acidic or basic that water is. Natural water often have a pH of 4-9 and most are slightly basic as a result of bicarbonate and carbonates of the alkali and alkaline earth metals.

The principal chemicals that produce acid precipitation are  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{CO}_2$ . Human activities are responsible for the production of these atmospheric pollutants. Acid rain is the word used for describing rainfall that has a pH level of less than 5.6 (Radojevic and Harrison, 1992). When acid waters come into contact with certain chemicals and metals, they often make them more toxic. For example, fish that can tolerate pH values as low as 4.8 will die at pH 5.5 if the water contains

0.9 mg/l of iron (USEPA, 2006). If acid rain water (environment) mixes with small amounts of certain metals such as Aluminum, Lead or Mercury, more contamination of the water occurs and health concerns far exceeding the usual dangers of these substances occurs. When analysts measure pH, they are determining the balance between these ions (USEPA, 2006).

### **2.3.1.2 Turbidity**

Turbidity is the measure of the fine suspended matter and its ability to impede light passing through water. Turbidity is mostly caused by colloidal matter, suspended matter such as clay, silts, finely divided organic and inorganic matter, soluble coloured organic compounds and plankton and other microscopic organisms. Turbidity expresses the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Correlation of turbidity with weight concentration of suspended matter is difficult because the size, shape and refractive index of the particle also affect the light scattering properties of the suspension.

It is measured in Nephelometric Turbidity Unit (NTU). The longer the dry period in between rainfall events, greater is the amount of turbidity in water (Shelton, 2000). The more the intensity of rainfall, the more efficient is the cleaning process and greater is the presence of pollutants in the runoff. Drinking water has turbidity level of 0 to 1 NTU.

### **2.3.1.3 Electrical Conductivity**

According to the California Water Quality Resources Board (CWQRB, 2005), conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions

or sodium, magnesium, calcium, iron, and aluminium cations. Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Compounds which dissociates easily in solution are good conductors while those which do not dissociate easily are poor conductors. Conductivity is also affected by temperature of measurement: the warmer the water, the higher the conductivity. The presence of mobile ions, their concentration, mobility, valency, and relative concentration also affect conductivity. For this reason, conductivity is reported as conductivity at 25°C. Conductivity is measured in microsiemens per centimetre ( $\mu\text{S}/\text{cm}$ ). Distilled water has conductivity in the range of 0.5 to 3  $\mu\text{S}/\text{cm}$ . Industrial waters can range as high as 10,000  $\mu\text{S}/\text{cm}$  (Pushard, 2005).

#### **2.3.1.4 Alkalinity**

Alkalinity is not a pollutant. It is the total measure of the substances in water that have "acid-neutralizing" ability. Alkalinity indicates a solution's power to react with acid and neutralize it (USEPA, 2006). The main sources of natural alkalinity are rocks that contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity (CWQRB, 2005).

As a general rule 30 to 100 mg/l calcium carbonate is desirable although up to 500 mg/l may be acceptable. Alkalinity is apparently unrelated to public health but is very important in pH control. Alum, gaseous chlorine and other chemicals are occasionally used in water treatment to acts as acids and therefore tend to depress pH.

Many waters are deficient in natural alkalinity and must be supplemented with lime ( $\text{CaO}$ ) or some other chemicals to maintain the pH in the desirable range to usually 6.5 to 8.5.

### **2.3.1.5 Total Dissolved Solids (TDS)**

It is a measure of the total ions in solution. In dilute solutions, TDS and EC are reasonably comparable and the TDS of a water sample based on the measured EC value can be calculated using the following equation:  $TDS (mg/l) = 0.5 \times EC (\mu S/cm)$ . The above relationship can also be used to check the acceptability of water chemical analyses. As the solution becomes more concentrated ( $TDS > 1000 \text{ mg/l}$ ,  $EC > 2000 \mu S/cm$ ), the proximity of the solution ions to each other depresses their activity and consequently their ability to transmit current, although the physical amount of dissolved solids is not affected. At high TDS values, the ratio TDS/EC increases and the relationship tends toward  $TDS = 0.9 \times EC$ .

TDS is the sum of all the materials dissolved in the water; it has many different mineral sources. Total dissolved solids (TDS) consist of mainly carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron, manganese and a few others. They do not include gases, colloids or sediments.

### **2.3.1.6 Total Suspended Solids (TSS)**

According to the CWQRB (2005), TSS provides an actual weight of the particulate material present in the sample. In water quality monitoring situations, a series of more labour intensive TSS measurements can be paired with relatively quick and easy turbidity measurements to develop a site-specific correlation. Once satisfactorily established, the correlation can be used to estimate TSS from more frequently made turbidity measurements, saving time and effort.

Because turbidity readings are somewhat dependent on particle size, shape, and colour, this approach requires calculating a correlation equation for each location (Shelton, 2000).

TSS of a water sample is determined by pouring a carefully measured volume of water (typically one litre; but less if the particulate density is high, or as much as two or three litres for very clean water) through a pre-weighed filter of a specified pore size, then weighing the filter again after drying to remove all water. The gain in weight is a dry weight measure of the particulates present in the water sample expressed in units derived or calculated from the volume of water filtered (typically milligrams per litre or mg/l) (Shelton, 2000).

### 2.3.1.7 Temperature

Temperature affects the speed of chemical reactions, the rate at which algae and aquatic plants photosynthesize, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic residents. Temperature is important in aquatic systems because it can cause mortality and it can influence the solubility of dissolved oxygen (DO) and other materials in the water column (e.g., ammonia). Water temperatures fluctuate naturally both daily and seasonally. The maximum daily temperature is usually several hours after noon and the minimum is around daybreak. Water temperature varies seasonally with air temperature (UNEP/GEMS, 2006).

Aquatic organisms often have narrow temperature tolerances. Thus, although water bodies have the ability to buffer against atmospheric temperature extremes, even moderate changes in water temperatures can have serious impacts on aquatic life, including bacteria, algae, invertebrates, and fish.

## 2.3.2 Nutrients contaminants in water

### 2.3.2.1 Nitrate and Nitrites

Nitrate is, together with phosphate, the main ingredient in fertilizers but can also come from sewage water. Nitrate, is potentially harmful if its concentration is high in water and serve as a good indicator of chemical polluted water (Peter, 1998). Since nitrate and nitrite are nutrients, their presence in high concentrations can nurture the growth of algae in the water and consequentially impair the water quality (Bastawy *et. al.*, 2006).

Nitrate ( $\text{NO}_3^-$ ) comes into water supplies through the nitrogen cycle rather than via dissolved minerals. It is one of the major ions in natural water. Most nitrates that occur in drinking water are as a result of contamination of water by feed lots and agricultural fertilizers. Nitrate is reduced to nitrite in the body.

According to the USEPA (2006), Nitrate is the more stable oxidized form of combined nitrogen in most environmental media. Nitrates occur naturally in mineral deposits (generally sodium or potassium nitrate), in soils, seawater, freshwater systems, the atmosphere, and in biota. Lakes and other static water bodies usually have less than 1.0  $\mu\text{g/L}$  of nitrate-nitrogen.

### 2.8.2.2 Phosphates

According to the USESB, (2003), Phosphates come from fertilizers, pesticides, industry, and cleaning compounds. Natural sources include phosphate-containing rocks and solid or liquid wastes. Phosphates enter waterways from human and animal wastes (the human body releases about a pound of phosphorus per year), phosphate-rich rocks, wastes from laundries, cleaning, industrial processes, and farm fertilizers. Phosphates also are used widely in power plant boilers to prevent corrosion and the formation of scale (United States Geographical Survey, 1970).

Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Ortho forms are produced by natural processes and are found in wastewater. Poly forms are used for treating boiler waters and in detergents; they can change to the ortho form in water. Organic phosphates are important in nature and also may result from the breakdown of organic pesticides which contain phosphates (USES, 2003). Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contains phosphates. They exist in solution as particles, loose fragments or in the bodies of aquatic organisms. Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate stimulates the growth of plankton and aquatic plants which provides food for fishes. It may not be toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates (USGS, 1970).

### **2.8.2.3 Sulphate**

Sulphates ( $\text{SO}_4^{2-}$ ) occur in almost all natural waters. Most sulphate compounds originate from the oxidation of sulphate ores, the presence of the shale and the existence of industrial waste.

Minerals that contain sulphate include magnesium sulphate (Epsom salt), sodium sulphate and calcium sulphate (gypsum). A high concentration of sulphate in drinking water causes a laxative effect when combined with calcium and magnesium, the two most common components of water hardness. Bacteria which attack and reduce sulphates cause hydrogen sulphide gas to form. Sulphate has a suggested level of 250 mg/l in the secondary drinking water standards published by the (USEPA, 1994).

Sulphate ( $\text{SO}_4^{2-}$ ) ion is precipitated in an acetic acid medium with barium chloride to form barium sulphate. Light absorbance of barium sulphate suspension by a UV-visible spectrophotometer at

420nm is used to determine the sulphate concentration. This is done by comparison with the calibration curve (APHA, 1992).

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### **2.8.3 Heavy metals in water**

#### **2.8.3.1 Iron**

According to Antonovics *et. al.*, (1971), metallic iron occurs in the free state and is widely distributed and ranked in abundance among the entire elements in the earth's crust, next to aluminium. The principal ore of iron is hermatite. Other important ores are goethite, magnetite, siderite and bog iron (limonite) (Ralph, 1998). The combination of naturally occurring organic materials and iron can be found in shallow wells and surface water. This type of iron is usually yellow or brown but may be colourless (IDPH, 1999).

#### **2.8.3.2 Lead**

Except in related cases lead is probably not a major problem in drinking water although they potentially exist in cases where old lead pipes is still used. Lead can be reduced considerably with a water softener activated carbon; filtration can also reduce lead to a certain extent. Reverse osmosis can remove 94 to 98% of the lead in drinking water at the point-of use (Manahan, 1994).

#### **2.8.3.3 Zinc**

In natural surface waters the concentration of zinc is usually below 10µg/l and in groundwater 10-40µg/l. in tap water the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings. The most corrosive waters are those of low pH.

Zinc imparts an undesirable astringent taste to water. Test indicates that 5% of a population could distinguish between zinc-free water and water containing zinc at a level of 4 mg/l as zinc sulphate (UNEP/WHO, 1996).

Dwarfism related to zinc deficiency has been reported in Turkey, Morocco and Portugal, the United States as well as China (Watkins *et. al.*, 1993).

#### **2.8.3.4 Cadmium**

Cadmium is found in very low concentrations in most rocks, as well as in coal and petroleum. Mostly cadmium is found in combination with zinc (WHO, 1992). Cadmium uses include electroplating, nickel-cadmium batteries, paint and pigments, and plastic stabilizers (WHO, 1992). It is introduced into the environment from mining smelting and industrial operations, including electroplating, reprocessing cadmium scrap, and incineration of cadmium containing plastics. The remaining cadmium emissions are from fossil fuel use, fertilizer application, and sewage sludge disposal. Cadmium may enter drinking water as a result of corrosion of galvanized pipe. Landfill leachates are also an important source of cadmium in the environment (Wester *et. al.*, 1992). Acute and chronic exposure to cadmium in animals and humans results in kidney dysfunction, hypertension, anaemia, and liver damage (Wester *et. al.*, 1992). Because of cadmium's potential adverse health effects and widespread occurrence in raw waters, it is regulated (Weast, 1974).

Cadmium may enter aquatic systems through weathering and erosion of soils and bedrock, atmospheric decomposition of direct discharges from industrial operations, leakage from landfills and contaminated sites and the dispersive use of sludge and fertilizers in agriculture. Much of the cadmium entering fresh waters from industrial sources may be rapidly adsorbed by particulate

matter and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO, 1992).

Rivers containing excess cadmium can contaminate surrounding land, either through irrigation for agricultural purposes, dumping of dredged sediments or flooding. It has also been demonstrated that rivers can transport cadmium for considerable distance up to 50 km from the source (WHO, 1992).

#### **2.8.3.5 Chromium**

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases (Sheldon, 2000).

Chromium enters the environment through a number of routes and in many forms (CWQRB, 2005). In air, chromium compounds are present mostly as fine dust particles which eventually settle over land and water. Fish do not accumulate much chromium in their bodies from water (Andrews *et. al.*, 1989). Individuals can be exposed to Chromium through; eating food containing chromium (III), breathing contaminated workplace air or skin contact during use in the workplace, drinking contaminated well water and living near uncontrolled hazardous waste sites containing chromium or industries that use chromium (Van-Gronsveld, 1995).

The World Health Organization (WHO) has determined that chromium (VI) is a human carcinogen (Thornton, 1996). The Department of Health and Human Services (DHHS) has determined that certain chromium (VI) compounds are known to cause cancer in humans. It is likely that health effects seen in children exposed to high amounts of chromium will be similar to the effects seen in adults (Stokinger, 1981).

## 2.4 MICROBIOLOGICAL PARAMETERS OF WATER QUALITY

### 2.4.1 Total Coliform and Faecal Coliform

#### Total Coliform

These bacteria are used as an indicator of the microbiological quality of water. Their detection in drinking water indicates that, the source is probably environmental, and faecal contamination is not likely. Total coliform bacteria is the most common pollution in rainfall and runoff water (Hill, *et. al.*, 2006) and direct heating to temperature of 65°C or above, reduces total coliform in naturally contaminated river water (Fjendbo, *et. al.*, 1998). Total coliforms are used as indicators to measure the degree of pollution and sanitary quality of river water

#### Faecal Coliform

The faecal coliform group is indicative of organisms originating in the intestinal tract of humans and some animals (Thomann and Mueller, 1987). In a study in Louisiana, a river during summer, a strong correlation between high water caused by rain, runoff and increase levels of bacteria (Hill, *et. al.*, 2006). The presence of faecal coliform in a drinking water sample often indicates recent faecal contamination, reflecting a greater risk that pathogens are present than if only total coliform bacteria are detected.

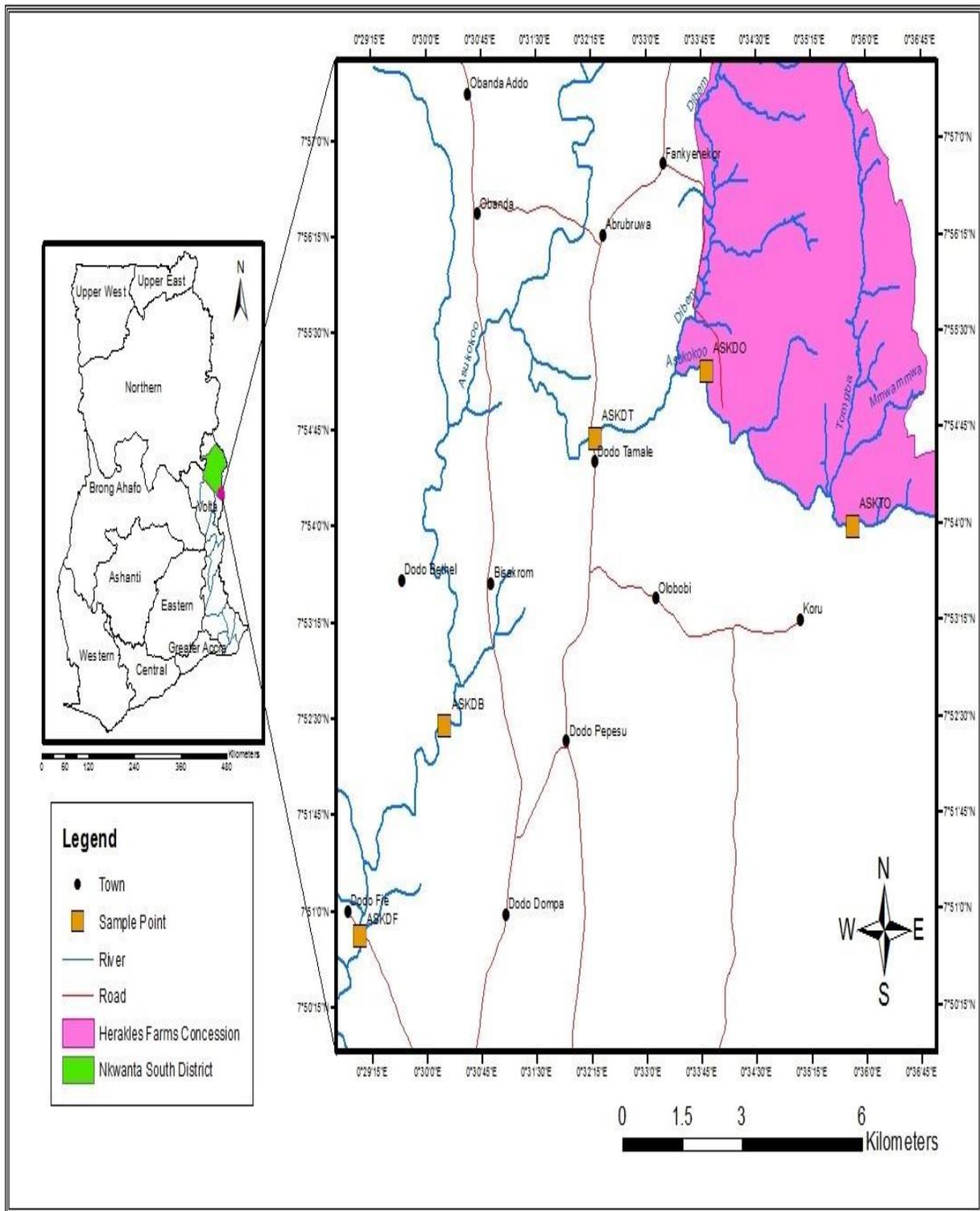
## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1 STUDY AREA

The research was conducted in the Nkwanta South District of the Volta Region (Figure 3.1). The District is one of the eighteen Administrative Districts of the Volta region. It is located in the northern part of the Region. The district is bounded to the North by the Nanumba District of the Northern Region and Nkwanta North, to the South by the Kadjebi District, to the East by the Republic of Togo and to the West by the newly created Krachi East District ([www.ghanadistricts.gov.gh](http://www.ghanadistricts.gov.gh)).

The Asukawkaw River (*literally translated 'red river'*), is perennial and flows along the northern and western borders of the project site. It serves as the administrative boundary between the Nkwanta South and the Kadjebi Districts, extending from Togo. The major inlet tributaries of the Asukawkaw river are the Wawa, Menu and Dibem Rivers. The Asukawkaw River originates in the Togo highlands and has a total catchment of 4,780 km<sup>2</sup>, 2,230 km<sup>2</sup> of which is within Ghana (GEF-UNEP, 2002). The river has a total length of 127.13 km from source to mouth. About 69.6% (88.51 km) of this length is within Ghana.



Map 1: Map showing project location in Ghana and sampling locations along Asukawkaw river

### **3.1.2 Socio-economic conditions**

Nkwanta South District is basically rural with over 76% of the population living in rural areas and in scattered settlements (Larmie *et. al.*, 2009).

Agriculture and animal husbandry employs about 81.5 of the total population who are economically active with other profession employing the remaining 18.5% (Larmie *et. al.*, 2009).

There are nine health facilities in the Districts. The staffing position at all the health facilities in the area is not encouraging. Malaria is the commonest disease in the area.

Potable water coverage in the area is just about 44% with a total of 266 boreholes. There are 1,972 household latrines with sanitation coverage of less than 20% ([www.ghanadistricts.org](http://www.ghanadistricts.org)).

## **3.2 EXPERIMENTAL METHODS**

### **3.2.1 Sampling areas**

A total of five sampling areas were considered for sampling. Three sampling areas were chosen based on accessibility, the site serving as drinking water fetching areas and located south of the oil palm development concession. The presence of agricultural activities was also taken into consideration. These areas were Dodo Tamale/Asukawkaw Brewaniase, Dodo Bethel and Dodo Fie community all within the Nkwanta South District. Consideration was also given to the Herakles' environmental departments sampling areas for bi-annual water quality monitoring sampling as in Map 1. All the communities selected as sampling sites lie south of the concession.

These communities mainly practice subsistence farming which is mostly not too close to the river and with less agricultural activity. These three communities are densely populated with fewer boreholes as sources of water in Dodo Tamale and none at Dodo Bethel and Dodo Fie, therefore

most households in Dodo Tamale fetch river water to augment their water needs whilst those in Dodo Bethel and Dodo Fie depend solely on the Asukawkaw river for domestic use.

### **3.2.2 Preparation of sampling containers**

In order to obtain accurate results from the sampling programme, sampling procedures were adopted to eliminate or minimise potential contamination of the samples. Sample containers were soaked in 4M nitric acid overnight and were washed with distilled water, rinsed with de-ionized water and dried in a drying cabinet. Some of the dry containers were selected, filled with distilled water and the pH tested, when it was between 6 to 7 then it was ready for use, otherwise the sampling container was washed and the pH tested again. This served as quality control (Anon, 2000).

Sample bottles of volume 1 litre were rinsed with water from the respective sampling sites, thrice, before actual sample collection was undertaken.

Glass sample bottles of volume 1 litre for bacteriological analyses were washed thoroughly with soap and hot water and then rinsed with hot water to remove traces of washing compound and finally rinsed with distilled water. The bottles were then sterilized in the Gallenkamp autoclave at a temperature of 170°C for three (3) hours, with an Aluminum foil placed around the cover. An indicator tape was placed across the foil. A black strip on the indicator tape signified proper sterilization of the bottle.

### **3.2.3 Sample containers labelling**

Samples collected from the Asukawkaw upstream (Tomgbah) area were labelled as follows; ATO1, ATO2, ATO3 and ATO4 for first, second, third and fourth samplings respectively and they

served as the controls and downstream samples were labelled as ADO1, ADO2, ADO3, and ADO4. Those sampled from the Dodo Tamale (Asukawkaw Brewaniase) area were coded as follows; ADT1, ADT2, ADT3, ADT4. Those sampled from the Dodo Bethel areas were also coded as follows; ADB1, ADB2, ADB3, ADB4. Samples collected from Dodo Fie were coded as ADF1, ADF2, ADF3, and ADF4 to represent first, second, third and fourth samplings respectively.

### **3.2.4 Sampling**

Sampling was done between the months of March and June, 2012. The selected sampling points were Asukawkaw Zongo (Asukawkaw Downstream), Dodo Tamale (Asukawkaw Brewaniase), Dodo Bethel, and Dodo Fie. Also surface water was collected from Tomgbah (Asukawkaw Upstream), of the oil palm project area and used as control. The samples were collected in the early hours of daybreak when women and children were fetching water for domestic purposes.

A total of 60 samples were collected from 5 selected communities along the Asukawkaw River in the Nkwanta South District. For each sampling area, three water samples each for physico-chemical, microbiological and heavy metals were collected from the same drinking water drawing locations within each community within a period of four months, namely, March, April, May and June.

### **3.2.5 Preparation of samples**

Surface water samples for physico-chemical analyses were collected at depths 20–30 cm directly into clean 1 litre plastic bottles. Temperature, pH and Conductivity were measured *in situ*, using a potable Eijkeljamp 18.21 Multiparameter Analyser.

Samples for bacteriological analyses were collected into sterilized plain glass bottles. All samples were stored in an icebox at 4°C to prevent possible alteration of parameters by light and also to ensure that the microorganisms remained viable though dormant and transported to the CSIR-Water Research Institute's laboratory in Accra for analysis.

The samples for heavy metal determination were acidified with concentrated Nitric acid to a pH of 2 and kept in the refrigerator; this was done to prevent the precipitation of metals (APHA, 1992; Anon, 2000).



Plate 1: River Asukawkaw at Dodo Tamale



Plate 2: Taking readings in-situ at Dodo Bethel



Plate 3: GARMIN GPSmap 60CSx used for taking sampling site coordinates



Plate 4: Inhabitants fetching drinking water and washing in river Asukawkaw at Dodo Tamale



Plate 5: Laboratory analysis of parameters at CSIR-WRI Chemical laboratory, Accra

### **3.3 Methodology**

#### **3.3.1 Measurement of pH**

The pH meter with a glass combination electrode and automatic temperature compensation probe was calibrated with buffers at pH 4.7 and 10 at 25°. The pH and temperature values of the sample aliquot were recorded upon reading.

#### **3.3.2 Determination of Temperature**

This was determined on site at the time of analysis. An aliquot of 50 ml of sample was measured into a 100 ml beaker and the Mercury- filled temperature cell was immersed in the solution. The reading on the thermometer was then recorded.

#### **3.3.3 Determination of Conductivity**

The conductivity was determined by means of a Field conductivity meter attached to the portable Eijkeljamp 18.21 Multiparameter Analyser. The conductivity meter and beaker were rinsed with a portion of the sample. Then the beaker was filled completely. The cell was then inserted into the beaker. The temperature control was adjusted to that of the sample and the probe was then inserted into the vessel and the conductance read.

All the Laboratory Analysis were done according to standard procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF, 2001).

### **3.3.4 Determination of Turbidity by Nephelometric method**

A Nephelometric turbidimeter with sample cells, HACH model: 2100P was used. Samples in 1 litre plastic bottles were analysed on the field. The meter was calibrated and the knob was adjusted to read 0.1 before use.

The sample was agitated vigorously and poured into the cell to at least two-thirds full. The appropriate range was selected, when the red light came on, the knob was moved to the next range till it was stable, and then the turbidity value was read.

### **3.3.4 Total Dissolved Solids (TDS)**

A 50 ml well-mixed sample of the river water was measured into a beaker. The WTW TDS / Conductivity meter probe was immersed in the sample and its conductivity recorded (APHA/AWWA/WEF, 2005).

### **3.3.5 Determination of Total Suspended Solids (TSS) by Absorbance Method**

The Spectrometer was set to a wavelength of 630 nm. The sample was shaken to ensure even distribution of dissolved solids and 25 ml aliquot was taken and put in the sample holder. The results were displayed digitally in mg/l (APHA/AWWA/WEF, 2005).

### **3.3.6 Determination of Alkalinity**

A 50 ml sample was measured into a conical flask. Two drops of methyl orange indicator was added and the resulting mixture titrated against the standard 0.1M HCl solution to the first permanent pink colour at pH 4.5 (APHA/AWWA/WEF, 2005).

The following equation was used in the calculation

$$\text{Alkalinity mg(CaCO}_3\text{)/L} = \frac{A \times N \times 50,000}{1 \text{ml sample}}$$

Where      A= ml of acid used      N= Normality of standard acid used

### 3.4 ANIONS ANALYSED

#### 3.4.1 Sulphate Determination by Turbidimetric method

One hundred millilitres (100 ml) of water sample was measured into a 250 ml Erlenmeyer flask. Five millilitres (5 ml) of conditioning reagent was added and mixed by stirring. One gramme (1 g) of barium chloride crystals was added while stirring and timed for 60 seconds. The Absorbance was then determined at 420 nm on the spectrophotometer within 5 minutes. The concentration was then read directly from the calibration curve on the computer screen

(APHA/AWWA/WEF, 2005).

#### 3.4.2 Phosphate determination.

One drop of phenolphthalein indicator was added to 100 ml of sample. The sample was discharged by adding an acid, dropwise until it turned pink. 4 ml of molybdate reagent I and 10 drops of stannous chloride reagent I was added and mixed thoroughly. Absorbance was then read after 10 minutes at a wavelength of 690 nm on the T60 UV spectrophotometer. The photometer was zeroed with a blank solution (APHA/AWWA/WEF, 2005).

### **3.4.3 Determination of Nitrate by Hydrazine reduction method**

10.0 ml of the sample was pipetted into a test tube and 1.0 ml of 1.3M NaOH was added and gently mixed, followed by 1.0 ml of reducing mixture and gently mixed. The mixture was heated for 10 minutes at 60°C in a water bath and allowed to cool at room temperature. 1.0 ml of colour developing reagent was added to the mixture and shaken and the absorbance read at 520 nm using a T60 UV Visible Spectrophotometer. The method detection limit was 0.005 mg/l (APHA/AWWA/WEF, 2005).

### **3.4.4 Nitrite Determination**

An aliquot of 2 ml of 0.1 M NaOH solution and 1 ml of colour developing reagent was added to the sample. The mixture was allowed to stand for 20 minutes. The nitrite concentration was determined at wavelength 540 nm of absorbance using a T60 UV Visible Spectrophotometer. A blank analysis was performed with all the reagents without sample for all the analysis (APHA/AWWA/WEF, 2005).

### **3.5 HEAVY METALS DETERMINATION**

The measurement of heavy metals: Fe, Pb, Zn, Cr, and Cd was done by the Atomic Absorption Spectrophotometry (AAS)-Direct Aspiration method (APHA/AWWA/WEF, 2005). In AAS, a sample solution is aspirated into a flame and atomized. A light beam is directed through the flame, into a monochromator and onto a detector that measure the amount of light absorbed by the element in the flame. Because each metal has its own characteristic absorption wavelength, a source lamp composed of that metal was used.

### 3.5.1 Iron Concentration

The sample aliquot was digested in nitric acid, diluted appropriately, then aspirated and the absorbance was **measured spectrometrically at 248.3 nm** with the aid of an Agilent 240 FS Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame (APHA/AWWA/WEF, 2005).

### 3.5.2 Lead Concentration

The sample was preserved in the field with nitric acid. The sample aliquot was then digested in nitric acid. The digest was aspirated and the absorbance **measured spectrometrically at 283.3 nm** with the aid of an Agilent 240 FS Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame. The instrument's detection limit was 0.05 mg/l (APHA/AWWA/WEF, 2005).

### 3.5.3 Zinc Concentration

The sample was preserved in the field with nitric acid. The sample aliquot was then digested in nitric acid. The digest was aspirated and the absorbance **measured spectrometrically at 213.8 nm** with the aid of an Agilent 240 FS Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-propane oxidizing flame.

Instrument's detection limit was 0.005 mg/l (APHA/AWWA/WEF, 2005).

### 3.5.4 Cadmium

A sample was preserved in the field with nitric acid. The shaken sample aliquot is digested with nitric acid. The digest is aspirated into the flame and the absorbance is measured

spectrophotometrically at **228.8 nm** using an Agilent 240 FS Atomic Absorption Spectrophotometer and compared to identically-prepared standard and blank solutions, using an air-acetylene oxidizing flame. The method detection limit is 0.01 mg/l (APHA/AWWA/WEF, 2005).

### **3.5.5 Chromium**

A sample was preserved in the field with nitric acid. The sample aliquot was digested at pH of 1.6 (usual pH if sample is preserved with 0.2% nitric acid) with nitric acid then bromine water was added to the sample aliquot and warmed on water bath until the colour disappeared. The sample aliquot was aspirated and the absorbance measured at a wavelength of **358.0 nm** using an Agilent 240 FS Atomic Absorption Spectrophotometer and compared to identically-prepared chromium standard and blank solutions, using a C<sub>2</sub>H<sub>2</sub>-air reducing flame (APHA/AWWA/WEF, 2005).

## **3.6 BACTERIOLOGICAL ANALYSES**

The membrane filtration method was used in the determination of two parameters, namely; Total Coliform and Faecal Coliform.

### **3.6.1 Total Coliform determination**

A one hundred millilitre (100 ml) portion of the water sample was filtered through 47 mm membrane filters of 0.45µm pore size. The membrane filter was incubated on M-Endo agar (Wagtech Int.) and alternatively on Mac Conkey Agar at 37°C for 24 hours. Total coliform was

detected as dark-red colonies with a metallic (golden) sheen on the M-Endo agar; and also as all bacteria colonies with yellow ring around them on the Mac Conkey Agar. The total number of colonies appearing was counted for each plate.

### **3.6.2 Faecal Coliform determination**

100 ml portion of the water sample was filtered through 47 mm membrane filters of 0.45 $\mu$ m pore size. The membrane filter was incubated on M-FC agar at 44°C for 24 hours. Faecal coliform was detected as blue colonies on the M-FC agar. The total numbers of colonies appearing were counted for each plate.

### **3.6.3 Procedure for bacteriological analyses**

The samples were removed from storage and allowed to cool to room temperature and the incubation chamber for the analyses was cleaned with ethanol to prevent contamination. The porous plate of the membrane filtration unit and the membrane filter forceps were sterilised by being applied with 98% alcohol which was burnt off in a Bunsen flame. The sterile forceps were then used to transfer the sterile membrane filter onto the porous plate of the membrane filtration unit with the grid side up and a sterile meshed funnel placed over the receptacle and locked in place. The required volume of surface water sample (100 ml) was added to the membrane filtration unit using the funnel measure. The flame from the Bunsen burner was kept on throughout the whole analyses and the forceps was flamed intermittently to keep it sterile. The sample was filtered through the membrane filter under partial pressure created by a syringe fitted to the filtration unit. The filtrate was discarded and the funnel unlocked and removed. The sterile forceps were then used to transfer the membrane filter onto a sterile labelled Petri dish containing the appropriate growth medium (**M.F.C agar for faecal coliform and M. Endo agar for Total coliform**). The

membrane filter was placed on the medium by rolling action to prevent air bubbles from forming at the membrane-medium interface. The Petri dishes were incubated upside down at the appropriate temperatures, (37°C for total coliforms and 44°C for faecal coliforms) for 24 hours. After incubation, typical colonies were identified and counted. The colonies were counted three times with the aid of a colony counter and the mean was recorded

(APHA/AWWA/WEF, 2005).

### **3.7 STATISTICAL ANALYSES AND CALCULATION OF POLLUTION INDICES**

#### **3.7.1 Statistical analyses**

The data obtained in this study were subjected to descriptive statistical analyses using Microsoft Excel software and transported to SPSS (version 16 for Windows, year 2003). Descriptive summary statistics such as range, mean concentration, standard deviation as well as charts and graphs of surface water data were generated. The mean values were compared with the water quality criteria of World Health Organization (WHO). Analysis of variance (ANOVA) was used to examine the apparent differences in observed data between the different sampling locations in the River. Significant difference was tested at 95% confidence level. The result of the ANOVA is incorporated in the results section (Chapter 4). Also, possible relationships between analysed physico-chemical parameters and nutrient-nutrient parameters in the Asukawkaw river water samples were investigated using the Spearman's correlation coefficient,  $r$ ,  $p < 0.05$  and  $0.01$  significant levels. All tests were two-tailed.

#### **3.7.2 Nutrient loads computations**

The results of nutrients and TDS in mg/l were converted into loads using mean discharges and concentrations measured. The formula used is outlined by Tilrem (1979) as:

$$Q_{s,n} = KC_s Q_w,$$

where  $Q_{s,n}$  = loads in  $t \text{ day}^{-1}$ ,  $K = 0.0864$ ,  $C_s$  = mean concentration in  $\text{mg/l}$ , and  $Q_w$  = Water discharge in  $\text{m}^3\text{s}^{-1}$ . The mean discharges over a 12-year period at the various sampling points in the Asukawkaw river were used in the computation of the loads to  $\text{kg day}^{-1}$  for TDS, sulphate, phosphate, nitrate and nitrite.

### 3.7.3 Calculation of metal pollution indices

The pollution Load Index (PLI), Geoaccumulation Index (Igeo), Enrichment Factor (EF) and Contamination degree ( $C_d$ ) were computed for heavy metal loads in surface water samples using Microsoft Excel 2007 version.

#### 3.7.3.1 Pollution Load Index

Surface water pollution status of the study area was quantified using the Pollution Index Factor (PIF) approach by Freitas and Nobre (1997) and Nyarko *et. al.*, (2004). The equation used is given by;

$$CF \text{ or PIF} = C_s / C_c,$$

where  $C_s$  is the average concentration of element/metal in the sample, and  $C_c$  is the Background value or world average shale value for water and sediments.

#### **Pollution Load Index (PLI) Calculation.**

Tomlinson *et. al.*, (1980) and Cabrera *et. al.*, (1999) method was used in computing the overall pollution load indices (PLI's) of surface water samples for the sampling points and communities. The PLI was evaluated using the equations below:

For sampling points:

$$\text{PLI sampling site} = (\text{CF}_{\text{Fe}} \times \text{CF}_{\text{Pb}} \times \text{CF}_{\text{Zn}} \times \text{CF}_{\text{Cr}} \times \text{CF}_{\text{Cd}} \times \text{CF}_{\text{Al}})^{1/6}$$

$$\text{PLI} = n\sqrt{(\text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \dots \times \text{CF}_n)} \quad n = \text{number of metals}$$

where n = number of sampling points for a community, CF = Contamination factor

### 3.7.3.2 Geoaccumulation Index ( $I_{\text{geo}}$ )

Geoaccumulation Index ( $I_{\text{geo}}$ ) approach was used to quantify the degree of anthropogenic contamination in Asukawkaw river. The  $I_{\text{geo}}$  for each element was calculated using the formula:

$$I_{\text{geo}} = \text{Log}_2 (C_n / 1.5 \times B_n),$$

where  $I_{\text{geo}}$  is the Geoaccumulation Index,  $C_n$  is the measured element concentration in surface water sample, and  $B_n$  is the geochemical background value in world average shale or the world surface rock average given by Martin and Meybeck (1979).

The factor 1.5 is incorporated/introduced in the relationship to minimise or account for possible variations in background values/data due to lithogenic effect.

### 3.7.3.3 Enrichment Factor (EF)

The Enrichment Factor (EF) in drinking surface water samples was computed for elements at each sampling point using:

$$\text{EF} = [(C_n / C_{\text{Fe}})_{\text{sample}}] / [(C_n / C_{\text{Fe}})_{\text{shale}}],$$

where  $(C_n/C_{Fe})$  sample is the ratio of the concentration of the element of concern ( $C_n$ ) to that of Fe ( $C_{Fe}$ ) in surface water sample, and  $(C_n/C_{Fe})$  shale is the same ratio in world average shale value.

#### 3.7.3.4 Contamination Degree ( $C_d$ )

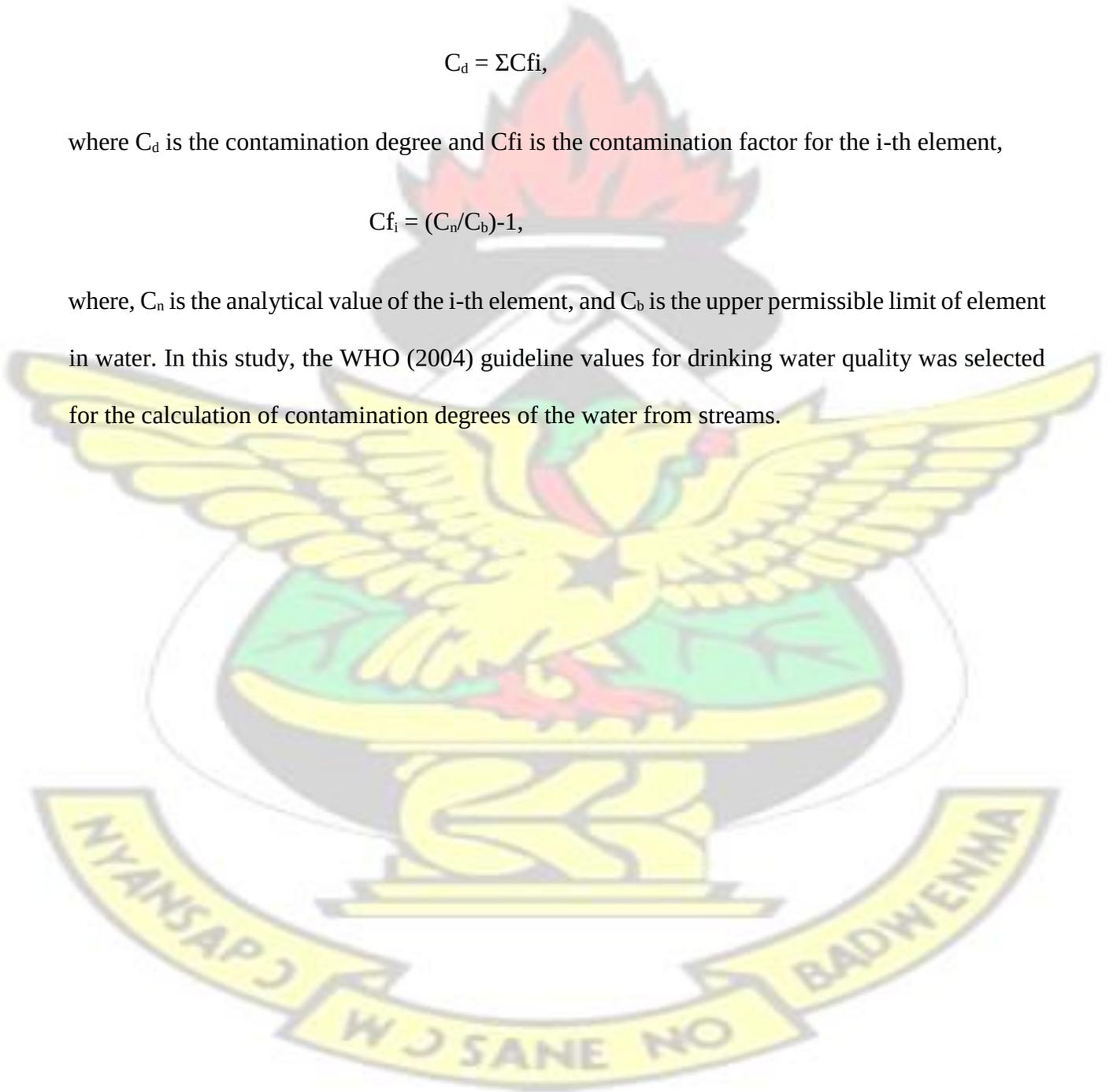
To assess the excessive values of monitored elements in water samples, the Teng *et. al.*, (2004) approach was followed using the equation:

$$C_d = \sum Cfi,$$

where  $C_d$  is the contamination degree and  $Cfi$  is the contamination factor for the  $i$ -th element,

$$Cfi = (C_n/C_b)-1,$$

where,  $C_n$  is the analytical value of the  $i$ -th element, and  $C_b$  is the upper permissible limit of element in water. In this study, the WHO (2004) guideline values for drinking water quality was selected for the calculation of contamination degrees of the water from streams.



## CHAPTER FOUR

### RESULTS

#### 4.1 PHYSICO-CHEMICAL PARAMETERS OF THE ASUKAWKAW RIVER WATER

A summary of the results of physico-chemical analyses has been presented in Table 2. Where possible, these values have been placed alongside natural background levels for tropical surface waters and WHO guideline values (Burton & Liss, 1976; Jorgensen, 1979; Stumm & Morgan, 1981; WHO, 2004).

The mean pH for the entire sampling regime ranged from pH  $7.29 \pm 0.52$  to pH  $7.62 \pm 0.21$  with the highest of pH  $7.62 \pm 0.21$  recorded at Dodo Tamale and the lowest of  $7.29 \pm 0.52$  at Dodo Bethel (Table 2). No statistically significant difference was found in the observed pH ranges at each site and the variation in pH due to change in sampling location was also not significant ( $p=0.745$ ).

The temperatures of the water samples were normal. The average temperature ranged from  $24.03 \pm 0.60$  °C at Asukawkaw downstream (ATO) to  $26.50 \pm 0.32$  °C at Dodo Fie (ADF) (Table 2). Samples from ATO and ADF showed noticeable variation in temperature. These values are within the temperature ranges experienced in the river.

The Mean electrical conductivity values of water samples collected in the river varied between  $63.10 \pm 4.51$  and  $168.98 \pm 82.73$   $\mu\text{S}/\text{cm}$ . The highest EC of  $168.98 \pm 82.73$   $\mu\text{S}/\text{cm}$  (Table 2) was obtained for the Dodo Fie samples, the downstream sampling point and the lowest of  $63.10 \pm 4.51$   $\mu\text{S}/\text{cm}$  was obtained for the Asukawkaw upstream samples (Table 2).

Turbidity values ranged from a minimum of  $17.02 \pm 4.74$  to a maximum of  $23.02 \pm 3.41$  NTU. These values were recorded for ADB and ATO respectively. The background levels for turbidity vary from 0.00–5.00 NTU (WRC, 2003). These values grossly exceeded their background levels for drinking water (WHO, 2003). There was no significant difference ( $p < 0.05$ ) between all the sampling points.

Mean Total Dissolved Solids (TDS) concentrations ranged from  $32.90 \pm 0.70$  to  $111.88 \pm 54.36$  mg/l for the Asukawkaw River with the highest values recorded at Dodo Tamale and the lowest at Asukawkaw upstream (Table 2). The total dissolved solids were within the WHO acceptable limits of 1000 mg/l. There was statistically significant difference ( $p < 0.05$ ) between the mean concentrations of all the sampling points.

Total Suspended Solids mean values for the Asukawkaw river ranged from  $6.88 \pm 2.02$  mg/l recorded at ADF to  $13.75 \pm 3.60$  mg/l for the ATO samples. There was no statistically significant difference ( $p < 0.05$ ) among the various sampling points.

Mean total alkalinity ranged from  $12.68 \pm 1.37$  at ADF to  $16.05 \pm 2.42$  ATO for the Asukawkaw river and were within the WHO limit of 200 mg/l (Table 4.2). There was no statistically significant difference ( $p < 0.05$ ) among the mean concentrations for the various sampling points.

Table 1: Names of sampling sites, sample-collection codes and their geographical locations.

<b>SAMPLE LOCATION</b>	<b>COD</b>	<b>GPS COORDINATES</b>
------------------------	------------	------------------------

ASUKAWKAW UPSTREAM	ATO	N 7° 53' 58.8" E 0° 35' 48.9"
ASUKAWKAW DOWNSTREAM	ADO	N 7° 55' 04.0" E 0° 03' 50.0"
DODO TAMALE	ADT	N 7° 54' 40.6" E 0° 32' 18.0"
DODO BETHEL	ADB	N 7° 52' 26.3" E 0° 30' 14.5"
DODO FIE	ADF	N 7° 50' 48.7" E 0° 29' 04.7"

Table 2: Some physico-chemical qualities of the water samples from indicated sampling points

Location		pH	Temperature (°C)	EC (µS/cm)	Turbidity (NTU)	TDS (mg/l)	TSS (mg/l)	Total Alkalinity (mg/l)
SAMP WHO LING VALUES POINT		<b>6.5-8.5</b>	-	<b>1500</b>	<b>5.00</b>	<b>1000</b>	-	<b>200.00</b>
ATO	Mean	7.38	24.03	63.10	23.02	32.90	13.75	12.68
	Std. Deviation	±0.24	±0.60	±4.51	±3.41	±0.70	±3.60	±1.37
	Range	7.02-7.53	23.6-24.9	58.7-69.1	18.6-26.67	32.3-33.70	9.00-17.00	11.2-14.2
ADO	Mean	7.62	24.33	76.43	19.88	35.15	10.25	14.13
	Std. Deviation	±0.21	±0.15	±22.78	±5.18	±1.76	±3.20	±1.73
	Range	7.47-7.92	24.2-24.5	59.4-110.00	15.2-26.32	32.7-36.9	7.00-13.10	12.80-16.6
ADT	Mean	7.47	24.83	141.70	19.38	111.88	11.50	14.28
	Std. Deviation	±0.26	±0.41	±69.64	±5.07	±54.36	±5.10	±1.46
	Range	7.10-7.760	24.3-25.3	60.40-222.0	13.1-24.43	33.2-156.7	5.00-16.00	12.6-16.00
ADB	Mean	7.29	25.25	155.65	17.02	99.75	9.25	15.65
	Std. Deviation	±0.52	±0.39	±65.34	±4.74	±45.10	±2.75	±2.68
	Range	7.47-7.63	24.8-25.7	63.3-214.0	12.2-21.96	35.6-133.2	6.00-12.00	13.8-19.6
ADF	Mean	7.40	26.50	168.98	18.04	107.88	6.88	16.05
	Std. Deviation	±0.46	±0.32	±82.73	±4.89	±49.78	±2.02	±2.42
	Range	7.50-7.69	26.2-26.9	64.80-266.10	12.10-22.42	34.8-141.6	4.50-9.00	

of the Asukawkaw River and the corresponding WHO limits.

#### 4.1.1 Interrelations of physico-chemical parameters in surface water samples

The Spearman's correlation matrix for levels of physico-chemical parameters in the water samples is presented in Table 3. There was strong negative correlation between Total alkalinity-TSS, Total alkalinity-Temperature and Total alkalinity-Turbidity with  $r$  values of (-0.898), (-0.635) and (-0.822) respectively at the 0.01 levels. Turbidity showed strong positive correlation with temperature ( $r=0.532$ ,  $p < 0.05$ ) at the 0.05 level and with TSS ( $r=0.897$ ,  $p < 0.01$ ) at  $< 0.01$  level. TDS exhibited a strong positive correlation with EC with  $r$  values of 0.821. TSS showed significant negative correlation with temperature ( $r = -0.821$ ,  $p < 0.01$ ) (Table 3). There was no significant correlation observed in the physical parameters with the pH's. Temperature-EC and temperature-TDS also had weak correlations. There were also no significant correlations between EC and Turbidity, TSS and total alkalinity respectively. TDS showed weak correlation with Turbidity, TSS and Total Alkalinity.

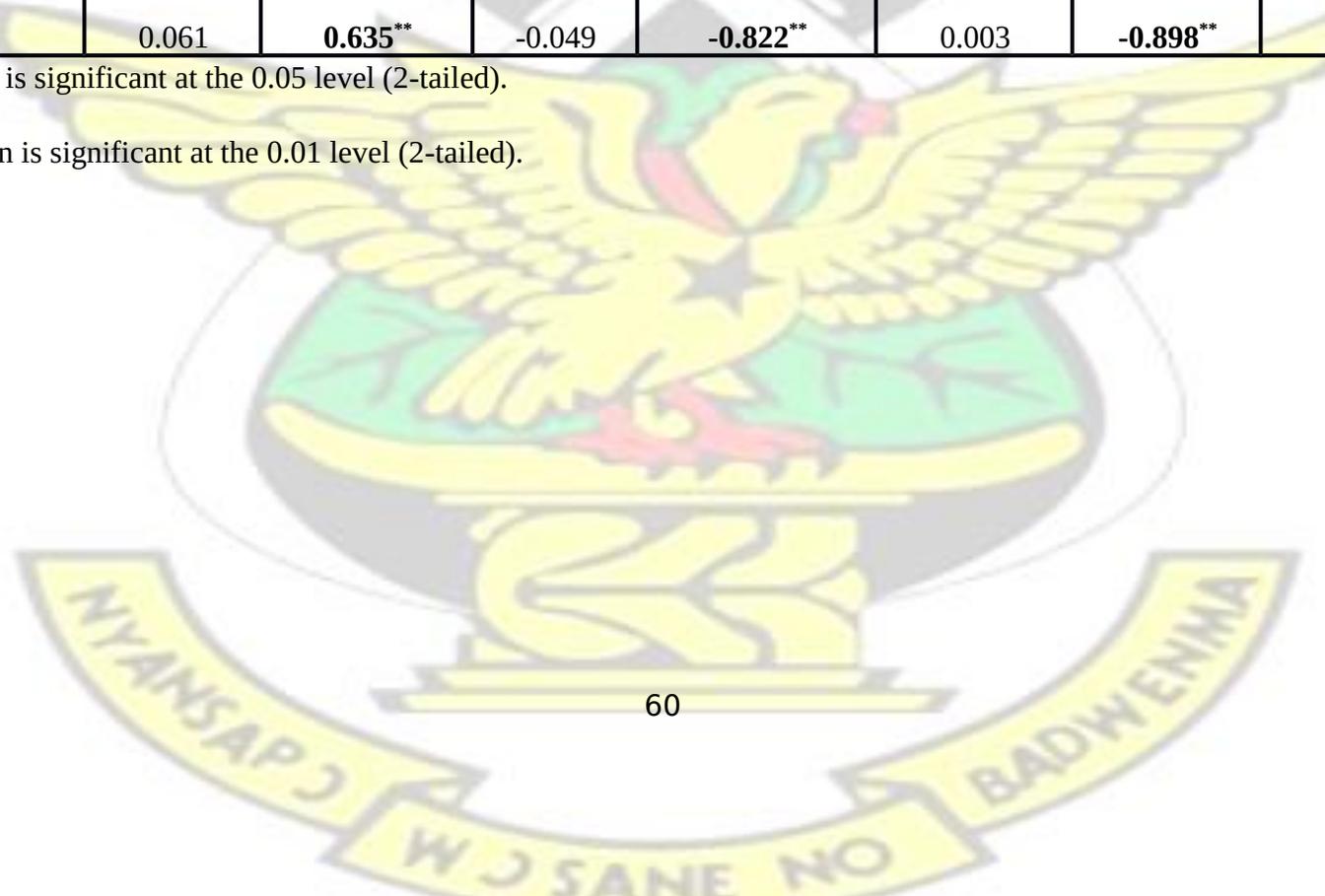


Table 3: Correlation matrix for physico-chemical parameters of surface water samples of the Asukawkaw river.

	pH (units)	Temp.(°C)	E.C.	Turbidity (NTU)	TDS (mg/l)	TSS (mg/l)	Total Alkalinity
pH (units)	<b>1.000</b>						
Temperature (°C)	0.050	<b>1.000</b>					
Electrical conductivity	0.105	0.385	<b>1.000</b>				
Turbidity (NTU)	0.100	<b>-0.532*</b>	-0.023	<b>1.000</b>			
TDS (mg/l)	0.260	0.381	<b>0.0821**</b>	0.083	<b>1.000</b>		
TSS (mg/l)	-0.055	<b>-0.626**</b>	0.002	<b>.0897**</b>	0.048	<b>1.000</b>	
Total Alkalinity	0.061	<b>0.635**</b>	-0.049	<b>-0.822**</b>	0.003	<b>-0.898**</b>	<b>1.000</b>

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

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



## 4.2 CONCENTRATIONS OF NUTRIENTS IN WATER SAMPLES FROM THE ASUKAWKAW RIVER

The mean concentrations of the nutrients ( $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{2-}$ ,  $\text{NO}_3^-$ , and  $\text{NO}_2^-$ ) in the Asukawkaw river are reported in Table 4.

Mean Sulphate concentrations in the analysed samples ranged from  $6.33 \pm 1.30$  mg/l to  $51.39 \pm 32.08$  mg/l with the lowest value of  $6.33 \pm 1.30$  mg/l recorded at Asukawkaw downstream whilst the highest mean concentration ( $51.39 \pm 32.08$  mg/l) was recorded at Dodo Tamale (Table 4). There was statistically significant difference ( $p=0.012$ ) between the mean concentrations of the various sampling points. The sulphate values for all samples analysed were within the WHO permissible level of 250 mg/l.

Mean phosphate concentration in the samples varied between  $0.36 \pm 0.16$  and  $0.71 \pm 0.36$  mg/l (Table 4). The highest mean concentration was recorded at Dodo Bethel and the lowest at Dodo Fie. There was no statistically significant differences ( $p=0.216$ ) in the mean of phosphate concentrations between the five sampling points. Phosphate concentrations in the samples were however, above the WHO permissible limit of 0.5 mg/l except for ADF which recorded a value of 0.36 mg/l.

From Table 4, the mean nitrate concentration in the surface water samples ranged from  $0.096 \pm 0.10$  mg/l to  $0.129 \pm 0.12$  mg/l. Samples from Asukawkaw downstream had the highest level of nitrate recording  $0.129 \pm 0.12$  mg/l and the lowest recorded from Asukawkaw Dodo

Tamale, with mean value of  $0.096 \pm 0.10$  mg/l. The variations in mean concentrations from sampling points were not statistically significant ( $p=0.991$ ). These values were within the acceptable limit of 3.00 mg/l prescribed by the WHO.

The mean level of nitrite in the samples analysed for the entire period ranged from  $0.053 \pm 0.05$  mg/l to  $0.099 \pm 0.07$  mg/l (Table 4). The highest value of  $0.099 \pm 0.07$  mg/l was recorded at Dodo Fie and Asukawkaw upstream recorded the lowest value of  $0.053 \pm 0.05$  mg/l. Variations were not statistically significant ( $p=0.943$ ). The values were however within the WHO permissible limit of 3.00 mg/l.

Table 4: Mean, range and standard deviation values of analysed nutrient parameters

Sampling points		Sulphate (mg/l)	Phosphate (mg/l)	Nitrate-N (mg/l)	Nitrite-NO <sub>2</sub> (mg/l)
WHO LIMIT		<b>250.00</b>	<b>0.5</b>	<b>3.00</b>	<b>3.00</b>
ATO	Mean	8.38	0.45	0.099	0.053
	Std. Deviation	$\pm 2.78$	$\pm 0.20$	$\pm 0.10$	$\pm 0.05$
	Range	4.60-11.00	0.15-0.59	0.001-0.210	0.008-0.123
ADO	Mean	6.33	0.59	0.129	0.09
	Std. Deviation	$\pm 1.30$	$\pm 0.14$	$\pm 0.12$	$\pm 0.07$
	Range	4.90-7.43	0.45-0.77	0.001-0.260	0.008-0.171
ADT	Mean	51.39	0.44	0.096	0.06
	Std. Deviation	$\pm 32.08$	$\pm 0.15$	$\pm 0.10$	$\pm 0.05$
	Range	3.60-63.14	0.23-0.57	0.001-0.190	0.012-0.132
ADB	Mean	22.36	0.71	0.107	0.06
	Std. Deviation	$\pm 13.42$	$\pm 0.36$	$\pm 0.10$	$\pm 0.07$
	Range	2.60-31.70	0.18-0.93	0.001-0.210	0.013-0.158
ADF	Mean	24.22	0.36	0.099	0.07
	Std. Deviation	$\pm 13.30$	$\pm 0.16$	$\pm 0.10$	$\pm 0.07$
	Range	4.36-32.60	0.13-0.49	0.001-0.200	0.011-0.165

#### 4.2.1 Correlations between mean nutrient concentrations from all the sampling points

Possible Nutrient-Nutrient relationships were investigated using the Spearman's correlation coefficient,  $r$ ,  $p < 0.05$  and 0.01 significant levels to ascertain whether they have any relationship

apart from occurring in the river. The mean nutrient concentrations for the four nutrient parameters for the sampling locations were used. The Spearman's correlation matrix for nutrient levels in the water samples is presented in Table 5. The Table indicates that nitrate correlated positively with sulphate ( $r=0.506$ ) at the  $p=0.05$  significant level and phosphate ( $r=0.612$ ) at the  $p=0.01$  significant level. As shown in Table 5 there was a weak correlation between Phosphate and Sulphate ( $r=0.376$ ). Nitrite and Sulphate ( $r=0.449$ ,  $p=0.05$ ), nitrite and phosphate ( $r=0.457 < p=0.01$ ), had weak positive correlations at the 0.05 levels and nitrite and phosphate ( $r=0.16 < p=0.01$ ) Nitrate ( $r=0.944$ ) showed strong correlation at the 0.05 level.

Table: 5 Correlation matrix of r-values of mean nutrient data for all sampling stations within the Asukawkaw River

	Sulphate (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)
Sulphate (mg/l)	1.000			
Phosphate (mg/l)	0.376	1.000		
Nitrate (mg/l)	<b>0.506*</b>	<b>0.612**</b>	1.000	
Nitrite (mg/l)	<b>0.449*</b>	<b>0.457*</b>	<b>0.944**</b>	1.000

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

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

Table 6: Mean loads ( $Q_{s,n}$ ) of selected chemical parameters of Asukawkaw River ( $\text{kg day}^{-1}$ )

SAMPLING POINT	$Q_w / \text{m}^3\text{s}^{-1}$	K	TDS	$\text{SO}_4^{2-} (\text{mg/l})$	$\text{P-PO}_4^{3-} (\text{mg/l})$	$\text{NO}_3^- (\text{mg/l})$	$\text{NO}_2^-$ (The loads of all
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the nutrients were generally low with the exception of sulphate and TDS which showed a slight increase in mean loads. From Table 6, the mean loads of TDS were highest at

			(mg/l)	)	mg/l)	l)	
ATO	12.15	0.0864	34.539	8.797	0.472	0.104	0.05
ADO	12.15	0.0864	36.899	6.645	0.619	0.135	0.09
ADT	12.15	0.0864	117.447	53.947	0.462	0.101	0.06
ADB	12.15	0.0864	104.714	23.473	0.753	0.112	0.06
ADF	12.15	0.0864	113.248	25.425	0.378	0.104	0.07
<b>Q<sub>s,n</sub>/kg day<sup>-1</sup></b>			<b>81.3754</b>	<b>23.6574</b>	<b>0.5368</b>	<b>0.1112</b>	<b>0.06</b>

ADT (117.447 kg day<sup>-1</sup>) and the least mean load was recorded at ATO (34.539kg day<sup>-1</sup>). SO<sub>4</sub><sup>2-</sup> values were in the range of 6.645 kg day<sup>-1</sup> at ADO to 53.947 ADT. P-PO<sub>4</sub><sup>3-</sup> values ranged from 0.378 at ADF to 0.753 at ADB. The mean loads of NO<sub>3</sub><sup>-</sup> also ranged from 0.101 kg day<sup>-1</sup> to 0.135 kg day<sup>-1</sup> at ADT and ADO respectively. The mean NO<sub>2</sub><sup>-</sup> loads varied from 0.052 at ATO to 0.095 kg day<sup>-1</sup> at ADO.

#### 4.3 HEAVY METAL CONCENTRATIONS OF ANALYSED WATER SAMPLES IN ASUKAWKAW RIVER

The mean Iron concentration in water samples from the five sampling points varied from 1.04±0.02 mg/l to 1.26±0.03 mg/l (Table 7). Iron levels were highest at Dodo Tamale and the lowest recorded at Dodo Bethel. These mean variations between the sampling points was significant (p=0.000). The values were above the acceptable limit of 0.30 mg/l prescribed by WHO.

The mean level of Chromium in the water samples analysed for the entire sampling period ranged from 0.52±0.25 to 0.63±0.25 mg/l (Table 7). The highest value of 0.63±0.25mg/l was recorded at Asukawkaw Upstream and the lowest value of 0.52±0.25 mg/l was recorded at Dodo Tamale (Table 7). There was no statistically significant differences (p= 0.928) between the observed values at the sampling points. The values were above the acceptable limit of 0.3 mg/l prescribed by WHO.

The Pb, Zn and Cd concentrations in the water samples from the river were all below the detection limits (BDL).

Table 7: Results for Heavy metal analyses; including their means, SD's, and range of River Asukawka

Sampling points		Fe mg/l	Pb mg/l	Zn mg/l	Cd mg/l
ATO	Mean	1.15	BDL	BDL	BDL
	Std. Deviation	±0.03			
	Range	1.11-1.17			
ADO	Mean	1.23	BDL	BDL	BDL
	Std. Deviation	±0.03			
	Range	1.20-1.26			
ADT	Mean	1.26	BDL	BDL	BDL
	Std. Deviation	±0.03			
	Range	1.23-1.29			
ADB	Mean	1.04	BDL	BDL	BDL
	Std. Deviation	±0.02			
	Range	1.01-1.06			
ADF	Mean	1.25	BDL	BDL	BDL
	Std. Deviation	±0.05			
	Range	1.18-1.30			
WHO LIMIT		<b>0.300</b>	<b>0.010</b>	<b>3.00</b>	<b>0.003</b>
WORLD SURFACE ROCK AVERAGE/BACKGROUND VALUE		<b>6.93</b>	<b>3.59</b>	<b>20</b>	<b>129</b>

Mean values <0.01 is Below Detectable Limit (BDL)

#### 4.4 Quantification of Heavy metals

##### 4.4.1 Pollution Load Index

The Contamination Factor (CF) ranges, pollution grades and their corresponding status according to Nyarko *et. al.*, (2004) are given in Table 8. The Contamination Factors (CF's) and Pollution Load Index (PLI's) of the river at the sampling points are shown in Table 9. Recorded CF values for Fe were highest at ADT (0.3510) and lowest at ADB (0.2883). Sampling point ATO had the highest Cr Contamination Factor (CF) value of 0.0065 and sampling point ADF had the lowest value of 0.0058. Sampling point ATO recorded CF value of 0.000041 for Zn and 0.000039 for ADO, ADT, ADB and ADF. The same CF values were recorded for Pb (0.0025) and Cd (0.0007), respectively at all the sampling points. The contamination factor for Fe was the highest among the monitored elements.

Table 8: PLI ranges and their designated pollution grade and intensity.

PIF	GRADE	INTENSITY
<1.2	I	Unpolluted area
1.2–2	II	Light polluted area
2–3	III	Medium polluted area
>3	IV	Heavily polluted area

Source: Nyarko *et. al.*, (2004)

Table 9: Contamination Factors (CF's) and Pollution Load Indices (PLI's) for the Asukawkaw River

Sampling points	Contamination Factors (CF's)					PLI	Grade
	Fe	Pb	Zn	Cd	Cr		
ATO	0.3200	0.00025	0.000041	0.0067	0.0065	<b>0.00242</b>	<b>I</b>
ADO	0.3400	0.00025	0.000039	0.0067	0.0061	<b>0.00240</b>	<b>I</b>
ADT	0.3510	0.00025	0.000039	0.0067	0.0054	<b>0.00240</b>	<b>I</b>
ADB	0.2883	0.00025	0.000039	0.0067	0.0064	<b>0.00240</b>	<b>I</b>
ADF	0.3482	0.00025	0.000039	0.0067	0.0058	<b>0.00240</b>	<b>I</b>

The CF result shows that all the sampling points have low levels (CF 1) of Fe, Pb, Zn, Cd and Cr in the surface water. The overall Pollution Load Indices for the river water sampled were found to be in the order: ATO (PLI = 0.00242) > ADO (PLI = 0.00240) = ADT (PLI=0.00240) = ADB (PLI = 0.00240) = ADF (PLI=0.00240).

#### 4.4.2 Geoaccumulation Index ( $I_{geo}$ )

The results for the individual elemental Geoaccumulation ( $I_{geo}$ ) values for each sampling point are presented in Table 4.11. The water samples were classified using the table of seven classes of Geoaccumulation index values used by Grzebisz *et. al.*, (2002), Lokeshwani and Chandrappa *et. al.*, (2007) and Yaqin *et. al.*, (2008) [Table 10].

Table 10: The seven classes of Geoaccumulation index values

Geoaccumulation index	Pollution Class	Intensity
0	0	Background concentration
0-1	1	Unpolluted
1-2	2	Moderately to unpolluted
2-3	3	Moderately polluted
3-4	4	Moderately to highly polluted
4-5	5	Highly polluted
>5	6	Very highly polluted

\*Source: Singh *et. al.*, (2003)

Table 11: Geo-Accumulation Index ( $I_{geo}$ ) Values for the Asukawkaw River

Sampling Points	Fe	Pb	Zn	Cd	Cr	Al
ATO	0.0363	-0.2548	-0.0395	-19.9240	-0.00459	-0.6391
ADO	0.0555	-0.2548	-0.0391	-19.9240	-0.00520	-0.6391
ADT	0.0619	-0.2548	-0.0395	-19.9240	-0.006484	-0.6391
ADB	0.0092	-0.2548	-0.0395	-19.9240	-0.00471	-0.6391
ADF	0.0598	-0.2548	-0.0395	-19.9240	-0.005696	-0.6391

$I_{geo}$  was the same for all sampling points for Pb (-0.2548), and Al (-0.63910). Zn  $I_{geo}$  (-0.0395) was the same for ATO, ADT, ADB, ADF with ADO recording a value of (-0.0391). The Fe  $I_{geo}$  values varied mostly, ranging from 0.0092 at ADB to 0.0619 at ADT. Cr  $I_{geo}$  also ranged from (-0.00459) at ATO to (-0.006484) at ADT.

Table 12: Results of Geochemical Index Classes at the sample location along the Asukawkaw River.

Sampling	Pollution Classes of Heavy metals
----------	-----------------------------------

Locations	Fe	Pb	Zn	Cd	Cr	Al
ATO	1	0	0	0	0	0
ADO	1	0	0	0	0	0
ADT	1	0	0	0	0	0
ADB	1	0	0	0	0	0
ADF	1	0	0	0	0	0

The  $I_{geo}$  values (Table 12) showed that nearly all the profiles for Pb, Zn, Cd, Cr and Al fell into class 0 with Fe being the only exception (Table 12). The  $I_{geo}$  values for Pb, Zn, Cd and Cr for all the sampling points are  $<0$ , indicating practically unpolluted river with respect to these metals. The  $I_{geo}$  values for Fe for all the sampling points were  $>0$  but  $<1$  indicating unpolluted to background polluted water.

Therefore, all the sampling points were practically background polluted with respect to Pb, Zn, Cd, Cr and Al with  $I_{geo}$  class index of 0. With exception of Fe,  $I_{geo}$  class of 1 (Unpolluted), all the examined water samples in the river had class of 0 and therefore classified as background pollution.

#### 4.4.3 Enrichment Factor (EF)

Table 13: Enrichment Factors (EF's) calculated for the indicated heavy metals along the Asukawkaw River

SAMPLING POINTS	Enrichment Factors				
	Fe	Pb	Zn	Cd	Cr
ATO	1.00	0.000784	0.00013	0.020902	0.020348
ADO	1.00	0.000730	0.00011	0.019458	0.017837
ADT	1.00	0.000712	0.00011	0.018995	0.015274
ADB	1.00	0.000867	0.00013	0.023124	0.022241
ADF	1.00	0.000718	0.00011	0.019147	0.016667

EF less than 3 is depleted to minimal enriched

EF value 3-5 is moderately enriched

EF value 5-10 is significantly enriched.

All the water samples analysed are depleted to minimal enriched with Fe, Pb, Zn, Cd and Cr with Enrichment Factor (EF) which are less than 3 (Table 13).

#### 4.4.3 Contamination degrees of water samples from the river

The contamination degrees of the monitored Asukawkaw river water samples for the five sampling points are presented in Table 14. ATO water sampling point recorded the highest contamination degree value of 11.916 for the elements Fe, Pb, Zn, Cd, and Cr. ADO followed with contamination degree value of 11.465. ADT, ADB and ADF sampling points registered contamination degree values of 10.109, 11.399 and 10.936, respectively. Generally, the contamination degrees of the river water samples were low.

Table 14: Contamination degrees (CD) of streams for the elements Fe, Pb, Zn, Cd, and Cr

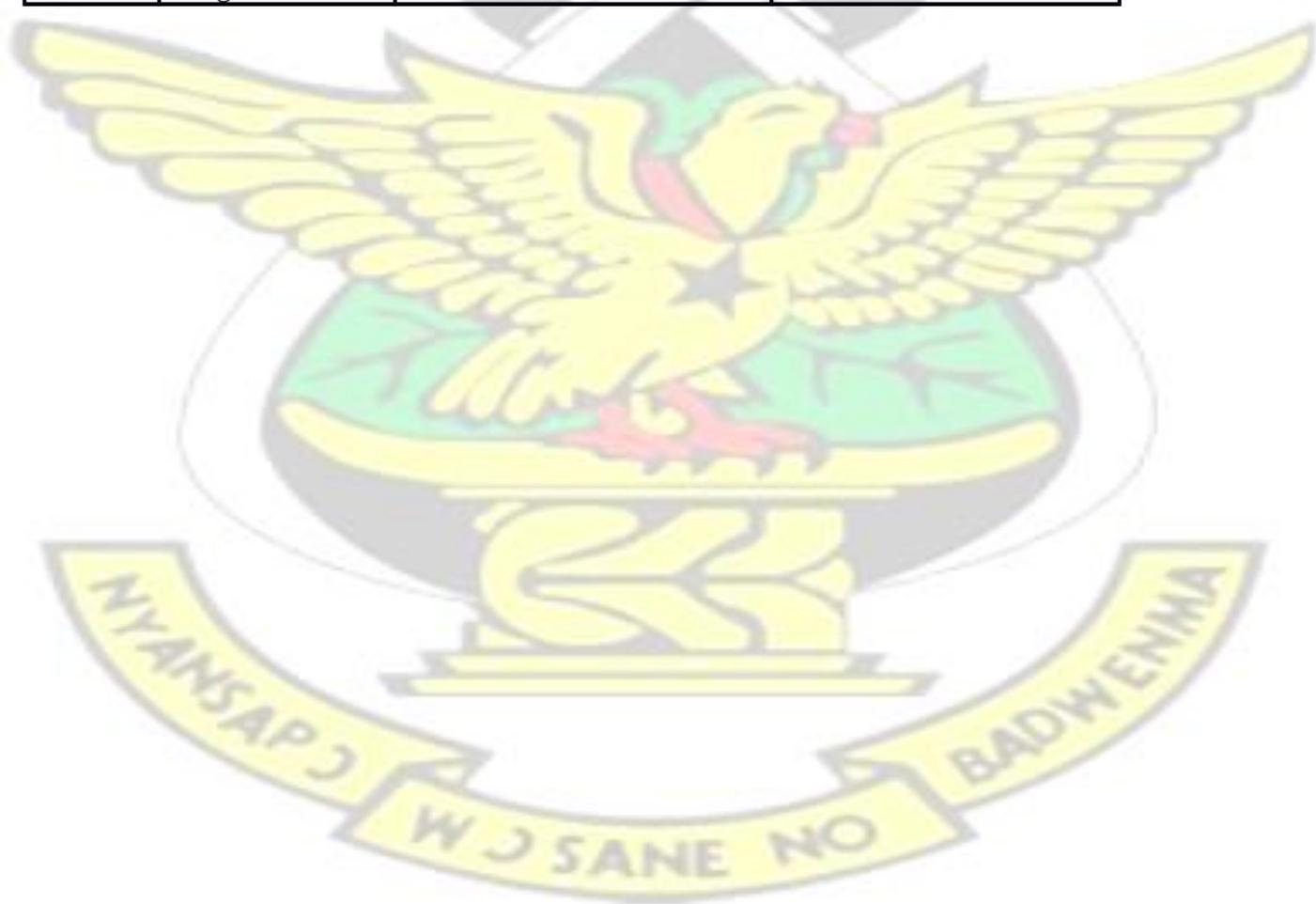
SAMPLING POINTS	CD
ATO	11.916
ADO	11.462
ADT	10.109
ADB	11.399
ADF	10.936

#### 4.5 MICROBIOLOGICAL ANALYSIS

The results obtained for the microbial analysis of sampled water from the Asukawkaw river are shown in Table 15. All the water samples analysed from the river showed the presence of coliform far above the recommended permissible limit of 0.00 FC and TC per 100ml for faecal and total coliform respectively. The highest faecal coliform count was  $425.50 \pm 180.92$  FC/100ml and was recorded at Dodo Tamale whilst the lowest count of  $121.00 \pm 32.47$  FC/100ml was recorded at Dodo Bethel. Total coliform counts ranged from  $497.50 \pm 44.81$  TC/100ml at Dodo Bethel to  $1323.25 \pm 204.15$  TC/100ml at Dodo Fie.

Table 15: Mean loads of microbiological parameters in the Asukawkaw River

Sampling points		FAECAL COLIFORM (FC/100ml)	TOTAL COLIFORM (TC/100ml)
<b>WHO LIMIT</b>		<b>0.00</b>	<b>0.00</b>
ATO	Mean	282.25	734.50
	Std. Deviation	±70.38	±170.88
	Range	200.00-372.00	558.00-930.00
ADO	Mean	317.75	709.50
	Std. Deviation	±34.39	±102.10
	Range	286.00-348.00	558.00-780.00
ADT	Mean	425.50	673.00
	Std. Deviation	±180.92	±32.59
	Range	210.00-591.00	651.00-720.00
ADB	Mean	121.00	497.50
	Std. Deviation	±32.47	±44.81
	Range	80.00-149.00	465.00-560.00
ADF	Mean	252.25	1323.25
	Std. Deviation	±76.82	±204.15
	Range	139.00-310.00	1023.00-1470.00



## CHAPTER FIVE

### DISCUSSION

#### 5.1 ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS

##### 5.1.1 pH

The Asukawkaw river water revealed a neutral (pH range 7.29–7.62). The pH of surface water samples taken from the river was within the (WHO, 2003) stipulated range of 6.5–8.5 for drinking and domestic purposes and potable water is 6.5 to 8.5 and within the “no effect” range of 6.0–9.0 for drinking water use (WRC, 2003). But these values were slightly above the natural background level of 7.0 that is, slightly alkaline. This may be due to the presence of dissolved carbonates and bicarbonates present in the water, which are known to affect pH of almost all surface water (Chapman, 1992), and could also be due to the release of acid-forming substances such as sulphates, phosphates, nitrates, etc. into the water. These substances might have altered the acid-base equilibria and resulted in the reduced acid-neutralizing capacity and, hence, raising the pH. Based on these guidelines, and considering no significant difference ( $p > 0.05$ ) between all samples, the taste perceptions of the water points with the maximum and minimum pH were all deemed satisfactory among the consumers. Though the selection of raw water as a drinking water source is never based on solely pH, these results show should be presumed as having no significant adverse health effects.

##### 5.1.2 Temperature

Water temperatures ranged from 24.03°C to 26.50°C (Table 1). These values are within the temperature ranges experienced in the river. The relatively low sampling temperature could be attributed to the fact that most of the samples were collected in the early hours of the day. There

is no guideline value set by the WHO. Temperature of drinking water is often not a major concern to consumers especially in terms of drinking water quality. The quality of water with respect to temperature is usually left to the individual taste and preference and there are no set guidelines for drinking water temperature.

### 5.1.3 Electrical Conductivity

Electrical conductivity (EC) is the numerical expression of an aqueous solution to carry electrical current and is a useful indicator of the mineralization in a water sample (Jain *et. al.*, 2005), and it also gives an account of all the dissolved ions in solution. Electrical conductivity values varied from 63.10 to 168.98  $\mu\text{S}/\text{cm}$ ; Dodo Fie recorded the highest conductivity of 168.98  $\mu\text{S}/\text{cm}$  and Asukawkaw Upstream the lowest (63.10  $\mu\text{S}/\text{cm}$ ). The acceptable limit of conductivity is 1500  $\mu\text{S}/\text{cm}$  (WHO, 1992). The average value of typical, unpolluted rivers is approximately 350  $\mu\text{S}/\text{cm}$  (Koning & Roos, 1999). Therefore, the parameter values recorded for communities sampled from the river does not give cause for alarm and it makes the water suitable for direct domestic use without posing any potential health risk for consumers. Generally, the conductivity of a river is lowest at the source of its catchments and, as it flows along the course of the river, it leaches ions from the soils and also picks up organic material from biota and its detritus (Ferrar, 1989). When compared with conductivities of the Volta river at Kpong (range 62.0– 77.5  $\mu\text{S}/\text{cm}$ ) reported by Antwi & Ofori-Danson (1993), and the conductivities of Densu river (range 237-402  $\mu\text{S}/\text{cm}$ ) by Karikari and Ansa-Asare, they were found to be higher than Volta river at Kpong and lower than the Densu river but followed the same trend from upstream to downstream. The fluctuations in electrical conductivity correlated positively with the total dissolved solids (TDS). The high conductivity recorded for the third sampling could be because of surface run-off from the

cultivated fields which might have increased the concentration of ions. Health effects in humans for consuming water with high EC may include disturbances of salt and water balance; and adverse effect on certain myocardic patients and individuals with high blood pressure (Fatoki and Awofolu, 2003).

#### **5.1.4 Turbidity**

The observed mean turbidity values obtained for all the river sampling points were well above the safe limit for drinking water (WHO, 2003) although they varied with local circumstances. The levels of turbidity recorded in this study were much higher than those reported for the same river (range 6.10–7.10 NTU) by Larmie *et. al.*, (2009). Soil erosion and runoff from the catchments could be the source of high turbidity in the river. It has been realized that the type and concentration of suspended solids in a water body controls the turbidity of the water (Chapman, 1992). Over-cultivation along sections of the river banks and commercial oil palm agricultural plantation activity upstream of the sampling points leave the soil bare and hence susceptible to erosion during the raining season. Hence, more soil particles, which constitute the major part of suspended matter contributing to the turbidity in most natural waters, were discharged into, or displaced in, the water. The low values recorded for the first sampling, which was the beginning of the rainy season, could have been due to dilution by the rainwater. Turbidity values were, generally, as expected, higher upstream than downstream. This may be due to human/anthropogenic activities upstream in the Togo Highlands. These activities discharge suspended matter into the water and displace the settled matter. The lower values recorded downstream may be attributable to self-remediation action of the river (Larmie *et. al.*, 2009). The excessive turbidity in water causes problems with water purification processes such as flocculation and filtration, which may increase treatment cost

(DWAF, 1998). The consumption of highly turbid water may constitute a health risk as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants, and also stimulate the growth of bacteria during storage (Zvikomborero, 2005). Elevated turbid water is often associated with the possibility of micro-biological contamination as high turbidity makes it difficult to disinfect water properly (DWAF, 1998). Turbidity is mostly affected by a dry spell; the higher turbidity values obtained can be associated with the breaks between the rainfalls during the sampling period.

#### **5.1.5 Total Dissolved Solids**

TDS is a common indicator of polluted waters. TDS values ranged from  $32.90 \pm 0.70$  to  $111.88 \pm 54.36$  mg/l. These values were not high compared with WHO guideline value of 1000 mg/l. Water containing more than 500 mg/l of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/l is also allowed (Shrinivasa Rao, 2000). According to McCutcheon *et. al.*, (1983), the palatability of water with TDS level less than 600 mg/l is generally considered to be good whereas water with TDS greater than 1200 mg/l becomes increasingly unpalatable.

#### **5.1.6 Total Suspended Solids**

According to the US Environmental Protection Agency (USEPA, 2000), the higher the mineral content in the water, more total suspended solid will be formed. Thomas & Greene (1993) found that site characteristics contributed to elevated suspended solids concentrations, with activities such as earthmoving and heavy mining activities which increase the dust and particulate matter in the atmosphere. The analyses done on the samples proved that the amount of the total suspended

solids in the sampled water was mainly due to the discharge of industrial and domestic waste (Palanivel and Rajaguru, 1999) coming from agricultural soil erosion, forestry or construction, runoff, industrial effluents and excess phytoplankton growth (US EPA, 1997) in the catchment areas of the river and from the commercial oil palm plantation upstream of the river.

### **5.1.7 Total Alkalinity**

The permissible limit of alkalinity in water sample is 200 mg/l (WHO, 2003). Alkalinity values ranged from a minimum of  $12.68 \pm 1.37$  mg/l at Asukawkaw upstream (ATO) to the highest value of  $16.05 \pm 2.42$  mg/l at Dodo Fie for the river. Total alkalinity in the water samples, were within the WHO permissible level. The reason for the low amount of the alkalinity in the water could be due to the fact that, many waters are deficient in natural alkalinity. In the absence of sufficient carbonic acid, the bicarbonate ion in the water dissociates to form additional carbon dioxide (Baird, 2000).

## **5.2 ANALYSIS OF NUTRIENTS PARAMETERS**

The recorded values of sulphates ( $\text{SO}_4^{2-}$ ), phosphate ( $\text{P-PO}_4^{3-}$ ), nitrate ( $\text{NO}_3^-$ ) and nitrite ( $\text{NO}_2^-$ ) showed significant level of variation. This observation is due largely to dilution factor as the river volume increased tremendously with rainfall episodes.

### **5.2.1 Sulphate ( $\text{SO}_4^{2-}$ )**

The sulphate concentrations varied between  $6.33 \pm 1.30$  to  $51.39 \pm 32.08$  mg/l and found within the prescribed WHO limit of 250 mg/l and the GWCL limit of 400 mg/l. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Manivaskam, 2005).

Discharge of industrial wastes and domestic sewage tends to also increase its concentration. The observed variations along the river course between all sampling points were statistically significant at the 5% level. Sulphates, when added to water, tend to accumulate to progressively increasing concentration (WRC, 2003). This could account for the high levels recorded for the fourth sampling regime. The much lower sulphate values recorded for the third sampling and ADO could be because sulphate easily precipitates and settles to the bottom sediment of the river as reported by Mathuthu *et. al.*, (1997). Also, under anaerobic conditions, bacteria use sulphate as an oxygen source (Peirce *et. al.*, 1998). Water with sulphate levels above 500 mg/l can have a laxative effect until an adjustment to the water is made. All the sulphate values fell within the “no effect” range of 0-200 mg/l for drinking water use (WRC, 2003). This implies that no adverse health and aesthetic effects were expected.

### 5.2.2 Phosphate (P-PO<sub>4</sub><sup>3-</sup>)

Phosphate P-PO<sub>4</sub><sup>3-</sup> may occur in surface water as a result of domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste water. The P-PO<sub>4</sub><sup>3-</sup> content in the study area was found in the range of 0.36±0.16 and 0.71±0.36 mg/l, which were above the WHO (2003) limit of 0.5 mg/l. This was probably due to rainfall flushing P-PO<sub>4</sub><sup>3-</sup> rich pollutants or agricultural fertilizer (N-P-K fertilizer) into the water bodies (Cornish *et. al.*, 1999), from the large oil palm plantation lying within the river. The concentrations of all the nutrients showed significant positive correlation with the exception of P-PO<sub>4</sub><sup>3-</sup>, which showed weak relationship. This is because the major proportion of phosphorous transported to the aquatic environment from cultivated land is usually in particulate form through erosion (Sharpley *et. al.*, 1987; Ansah-Asare and Karikari, 2003). P-PO<sub>4</sub><sup>3-</sup> like any other nutrient is harmless in lower concentrations but becomes harmful

only in higher doses. Higher doses of  $P-PO_4^{3-}$  are known to interfere with digestion in both humans and animals.

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### 5.2.3 Nitrate ( $NO_3^-$ )/Nitrite ( $NO_2^-$ )

Surface water can be contaminated by sewage and other wastes rich in nitrates. The nitrate content in the study area varied in the range  $0.096 \pm 0.10$  mg/l to  $0.129 \pm 0.12$  mg/l and the nitrite varied between  $0.053 \pm 0.05$  mg/l to  $0.099 \pm 0.07$  mg/l and both were found within the prescribed permissible limit of 3.0 mg/l (WHO, 2003) and GWC limit of 50.0 mg/l. There were significant positive correlations between the nitrates and phosphates and between the nitrates themselves are indicative of a common source of pollution in the rivers (Akoto *et. al.*, 2008) probably from runoff or seepage from hugely fertilized commercial agricultural plantation lands upstream of the Ghana portion of the Asukawkaw river. According to Adedokum *et. al.*, (2008), significant nitrate contamination of surface water is found in areas of high population pressure and agricultural development. Also, many nitrogenous fertilizers are converted into mobile nitrates by natural processes which contaminate nearby water bodies more profusely (Freeze and Cherry 1979, Walter *et. al.*, 1975).

Nitrogen like any other nutrient is harmless in lower concentrations but become harmful only in higher interconvertible organic nitrogen. Exposure to high levels of nitrates for a long time could lead to methaemoglobinaemia (WHO, 2006) in infants (Adebowale et al 2008).

### 5.2.4 Nutrient Loads

From Table 6, the Asukawkaw river has a general trend of  $NO_3^-$  load increasing from upstream to downstream. The mean nitrate load for Asukawkaw river is estimated to be **0.1112** kg day<sup>-1</sup>,

reflecting the impact of agricultural activities in the river. The nitrate loads at ADO (0.135 kg day<sup>-1</sup>), and ADB (0.112 kg day<sup>-1</sup>) were slightly high as a result of domestic and agricultural activities in that part of the river. Generally, when compared with the loads of Birim river reported by Ansa-Asare & Asante (2000), loads of Densu river reported by Ansa-Asare and Karikari (2003) and Asukawkaw (2.17 kg day<sup>-1</sup>), recorded by Ansa-Asare and Akraasi (2005) Asukawkaw mean loads were relatively lower. This implied that there were less domestic and agricultural activities in the Asukawkaw catchment area and also probably due to good environmental management practices by the sole oil palm plantation upstream.

Ortho-phosphorus (PO<sub>4</sub>-P) also had a general trend of increasing load from upstream to downstream. The Asukawkaw river had PO<sub>4</sub>-P loads from mainly domestic, agricultural, and commercial activities. The high load of 0.619/ kg day<sup>-1</sup> at Asukawkaw downstream is mainly due to palm-oil production and 0.753 kg day<sup>-1</sup> at Dodo Bethel is due to cocoa production. The PO<sub>4</sub>-P load of Dodo Tamale (0.462 kg day<sup>-1</sup>) and Dodo Fie (0.378 kg day<sup>-1</sup>) were mainly due to domestic and commercial activities.

The mean daily sulphate (SO<sub>4</sub><sup>2-</sup>) load in Asukawkaw river is estimated to be 23.6574 kg day<sup>-1</sup>, a reflection of domestic and commercial activities. The high level of sulphate recorded at Dodo Tamale (53.947 kg day<sup>-1</sup>) was as a result of the impact of palm oil production on the river waters downstream. The sulphate values varied considerably from station to station with discharge, reflecting the influence of the rains. The sulphate load of 25.425 kg day<sup>-1</sup> at Dodo Fie was also due to the dredging and bridge construction activities being carried out in that area.

Mean  $\text{NO}_3^-$  and  $\text{PO}_4^-$  loads varied considerably from station to station (Table 6).  $\text{PO}_4^-$  load exported from agricultural and forested catchments was three times more than that of  $\text{NO}_3^-$  load. However,  $\text{NO}_3^-$  is known to be more soluble and can be exported more frequently through runoffs than  $\text{PO}_4^-$ . The predominance of  $\text{PO}_4^-$  in runoff from watersheds in the Asukawkaw River may be due to watershed characteristics such as gentle slopes, which result in longer leaching times and a high proportion of organic soils. This is because  $\text{PO}_4^-$  predominates in run-off from Asukawkaw river, typical erosion control measures such as grassed filter strips may not be sufficient to reduce dissolved P inputs to aquatic systems (Sharpley *et. al.*, 1981). This conforms with results of similar studies conducted by (Ansah-Asare and Akraasi, 2005) in the Asukawkaw river.

### **5.3 HEAVY METAL PARAMETER ANALYSIS**

Metal contamination in the Asukawkaw River has been assessed for Fe, Pb Zn, Cd, and Al. With the exception of Iron and Chromium, all the other heavy metals analysed were below detection limit (BDL) in all the samples collected. These elements may have also entered the waterways through wet and dry deposition from air or through rain. The high levels of these elements in the river water could also be due to the inherent mineralogy of the rocks of the study area.

#### **5.3.1 Iron**

Iron is naturally present throughout the environment and is generally perceived as safe, as often taste will deter users from drinking water rich in these compounds (Schäfer *et. al.*, 2008). The mean concentrations of Fe in the water ranged from  $1.04 \pm 0.02$  mg/l to  $1.26 \pm 0.03$  mg/l. All the

water points exceeded the background level and the WHO limit of 0.3 mg/l probably as a result of weathering from rocks in the river. Despite not having a health-based guideline for Fe, a value of 0.3 mg/l is mentioned in the WHO drinking water guidelines as a safe concentration, with the comment that taste will often be affected below this level. The values, however, fell within the 0.1–10 mg/l range for which slight adverse health effects can be expected in children and sensitive individuals (WRC, 2003). The concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminium and the occurrence of several heavy metals, notably manganese (WRC, 2003). Hence, the high values recorded during the sampling period can be attributed to the high turbidity and pH levels recorded. This implies that iron and turbidity were from similar pollution source. The soils of the Asukawkaw river are made up of the Salom-Mate/Banda-Chaiso complex (Obeng, 2003). *Banda series* are characterised by the presence of ironpan at shallow depth from the ground surface. *Chaiso series* are moderately shallow, concretionary clay loams derived from the remnants of the ironpan surface (Obeng, 2003). This could primarily be the source of Fe in surface waters in the Asukawkaw River. It has also been demonstrated by Langanegger (1987) and Pelig-Ba (1989) that corrosive materials contribute significantly to the amount of Fe in waters.

### 5.3.2 Chromium

The net uniform increase in total Cr at all sampling points over the recommended WHO limit of 0.05 mg/l was due to a net increase in Cr (particulate), suggesting that bottom sediments may have been resuspended or that some particulate Cr (Cranston, 1980) might have been deposited during rainfall episodes.

### 5.3.3 Quantification of river water pollution

#### 5.3.3.1 Pollution Load Index (PLI)

The Contamination Factor (CF) assessment of the quality of water has shown that the Asukawkaw river is mainly unpolluted with Fe, Pb, Cd, Zn, and Cr (Table 7). This can be attributed to few industrial activities going on in the Asukawkaw River. This is not surprising since this river course is located far away from the probable anthropogenic pollution sources due to industrial chemicals and also buffers are created along the river course where agricultural chemicals could be a source of pollution. The general Pollution Loads (PLI's) of the river are less than 1.2, indicating the unpolluted nature of the river with respect to the five tested heavy metals. The unpolluted nature of this river might be due to the water river not being close to a main pollution source and the less use of industrial chemicals in the rivers catchment area. The river is covered by a thick canopy of vegetation reducing the possibility of direct settling of particulate matter and other chemicals in the river which could also contribute to its pollution. The overall Pollution Load Index of this river as far as the five examined elements were concerned was less than 1.2. This is regarded on the pollution scale as an unpollution of the water quality. The PLI of Fe was the highest for all sampling points compared with the other heavy metals. This is likely to be a result of the soils of the Asukawkaw river which are made up of the Salom-Mate/Banda-Chaiso complex (Obeng, 2003), which might be the cause of the elevated levels of Fe of this river. The overall Pollution Load Index of this river is 0.01202, slightly higher than PLI value for each sampling point of the river. The results show that all the sampled areas of the river were unaffected by the commercial activities in the study area probably because milling and production of FFB's into CPU's had not commenced and that wood processing factories were located far away from the river catchment areas.

### 5.3.3.2 Geoaccumulation Index ( $I_{geo}$ )

The Geoaccumulation Index ( $I_{geo}$ ) calculations of the water samples have indicated the pollution levels for the examined elements. The  $I_{geo}$  values for Fe for ATO, ADO, ADT and ADB, ADF showed that the river has background concentration for iron (Tables 8 and 9). ATO had background concentration for Pb, Zn, Cd and Cr as suggested by the  $I_{geo}$  values. The  $I_{geo}$  values for all the elements for ADT, ADB and ADF show background concentration status of the water body with Pb, Zn, Cd and Cr. The Fe  $I_{geo}$  values varied mostly, ranging from 0.0092 to 0.619. Also, apart from Fe, which has an  $I_{geo}$  class of 1 for all the sampled points, all other sampling points recorded an  $I_{geo}$  class of 0 for Pb, Zn, Cd and Cr. Except for Fe, which is influenced by the lithology of the area, the  $I_{geo}$  values of all other metals suggest negligible pollution since there is no industrial activity in the Asukawkaw river.

### 5.3.3.3 Enrichment Factor (EF)

The Enrichment Factor (EF) computation for the elements (Table 11) has revealed that the sampled points of the Asukawkaw River were depleted to minimal enriched with Pb, Zn, Cd, and Cr. The depleted to minimal enrichment of the elements in the river may be due to the less industrial activities in the river and natural sources could be the source of the relatively small levels of enrichment of the river.

### 5.3.4 Contamination degrees (CD)

The contamination degrees values obtained showed that the Asukawkaw river's sampled points were less polluted with Pb, Zn, Cd, Cr, and Fe (Table 14). This is not surprising since there is no

major industrial activity taking place in the study area. The soil samples have relatively low levels of these metals and that run-off due to soil erosion may contain low levels of these elements into the river, except for the Fe levels.

#### **5.4 MICROBIAL WATER QUALITY ANALYSIS**

Monitoring data from sections of the river indicated that the microbial water quality of the Asukawkaw river is poor (Larmie *et. al.*, 2009). The mean total coliforms ranged between  $497.50 \pm 44.81$  TC/100ml and  $1323.25 \pm 204.15$  TC/100ml while the faecal coliforms ranged between  $121.00 \pm 32.47$  FC/100ml and  $425.50 \pm 180.92$  FC/100ml, indicating that the water is grossly polluted with Total and Faecal Coliform and the entire river as sampled is unacceptable for domestic use without treatment. For agricultural purposes there is a possibility of contamination from vegetables and other crops eaten in their raw state. For water to be considered as no risk to human health, the faecal coliforms counts/100 ml should be zero (WHO, 2002). These results have indicated faecal pollution of the water sources, and imply that these water sources pose a serious health risk to consumers. Anthropological and animal activities in the vicinity of water collection sites (Plate 4) as well as settlements lacking proper sanitation facilities, contributed to the poor water quality of the different water sources, especially at Dodo Tamale. The report of Amoah *et. al.*, (2004) has shown that there are potential pathogenic and opportunistic bacteria in the riverine water in the Volta. These microorganisms may presumably play a role in incidence of diarrhoea and enteropathogenic diseases. For instance the District Health Directorate of Kadjebi District lying south of the river listed diarrhoea and typhoid among the top ten OPD diseases recorded from 2006 – 2009 (EPA, 2010). As faecal coliform levels increase beyond 20 FC/100 ml, the amount of water ingested required to cause infections decreases (WRC, 2003).

Similar contaminations from direct human and animal excreta were observed by Abdul-Razak, *et. al.*, (2009) in the Oti river of Ghana.

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## CHAPTER SIX

### CONCLUSION AND RECOMMENDATIONS

#### 6.1 CONCLUSION

The study has provided useful baseline information on the water quality of the Asukawkaw River for the management of the ecosystem as well as the ecosystem of the Asukakaw river, to support sustainable water resource management. It is concluded that the Asukawkaw river water is not suitable for direct human consumption at all the sampled locations, in view of the high counts of both faecal coliforms (minimum of 121.00 FC/100ml and maximum of 425.50 FC/100ml) and total coliforms (minimum of 497.50 TC/100ml and maximum of 1323.25 TC/100ml).

All heavy metals studied except iron and chromium have concentrations below detection limit (BDL) in all sampled areas. Levels of iron exceeded the WHO guideline value of 0.30 mg/l. Mean levels of Cr measured in this study were far in excess of the average of the WHO guideline value of 0.05 mg/l for Cr in drinking water. Hence, except for Fe and Cr the heavy metals concentrations do not pose any health hazard to consumers.

Generally, the levels of phosphate, heavy elements (e.g. iron and chromium) were gradually increasing indicating gradual organic contamination, nutrient enrichment and gradual deterioration of the water quality in the Asukawkaw River. The Asukawkaw river had  $\text{PO}_4^-$  loads coming from mainly domestic and agricultural activities.

Some of the pollutants such as chromium are non-degradable, can bioaccumulate in the tissues of aquatic organisms and enter the food chain with dangerous consequences for the ecosystem and humans as final consumers in the food chain.

## 6.2 RECOMMENDATIONS

Based on the outcome of the study, the following are recommended:

1. Farmers should be assisted in fertilizer and agro-chemicals application by agricultural extension officers of the Ministry of Food and Agriculture and EPA to avoid the incidence of high nutrient loads in surface waters.
2. The bi-annual water quality analysis being carried out upstream and downstream of the oil palm concession zone should be extended to include the communities living down the concession. This will ensure that incidences of downstream actual residual contamination are noticed earlier for remedial action to be taken.
3. The District Assembly and commercial plantations in the river and other stakeholders should provide sanitary facilities in the area to control river pollution. Appropriate water treatments or safe potable water sources should be provided in the area to improve the welfare of the riparian dwellers.
4. In future developments, organic compounds (pesticides, PAH's and PCBs) should be integrated into the contamination evaluation which can be correlated with other parameters. Biological testing and ecological analysis of existing benthic community structure (crabs, molluscs, and mudskippers) related to sediment contamination should be undertaken for final decision making in the case of river Asukawkaw.

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## APPENDICES

### Appendix 1a-Raw data for the Physico-chemical and nutrient level parameters in Asukawkaw river

#### RAW SAMPLING DATA.

TABLE OF PHYSICO-CHEMICAL PARAMETERS AND NUTRIENTS												
PHYSICO-CHEMICAL PARAMETERS							NUTRIENT PARAMETERS					
SAMPLE CODES	pH	TEM	E.C.	TURBIDIT	TDS	TSS	ALKALINITY	SULPHAT E	PHOSPHATE	NITRATE	NITRITE	
UNITS	pH	°C	µS/cm	NTU	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	
WHO LIMIT	6.50-8.50	-	-	5.00	1000.0	-	-	250.00	0.5	3.00	3.00	
ATO01	7.47	23.6	60.8	18.6	33.0	9.00	14.2	4.60	0.151	<0.001	0.008	
ADO01	7.47	24.2	59.4	15.2	32.7	7.00	16.6	4.90	0.769	<0.001	0.008	
ADT01	7.50	25.3	60.4	13.1	33.2	5.00	16.0	3.60	0.228	<0.001	0.012	
ADB01	7.47	25.7	63.3	13.8	35.6	8.00	19.6	2.60	0.175	<0.001	0.013	
ADF01	7.50	26.9	64.8	16.0	34.8	6.00	19.6	2.60	0.175	<0.001	0.013	
ATO02	7.53	24.9	58.7	22.5	32.3	13.00	13.4	11.00	0.491	0.023	0.030	
ADO02	7.61	24.4	67.1	16.2	36.9	8.00	14.0	5.55	0.447	0.058	0.071	
ADT02	7.58	24.9	222.0	17.6	122.0	10.00	14.8	66.50	0.481	0.026	0.027	
ADB02	7.53	25.4	214.0	12.2	101.0	6.00	15.0	25.50	0.848	0.039	0.020	
ADF02	7.68	26.6	183.0	12.1	118.0	4.50	15.6	29.50	0.368	0.027	0.030	
ATO03	7.50	23.9	69.1	24.31	33.70	17.00	11.2	8.10	0.563	0.162	0.050	
ADO03	7.49	24.5	69.2	21.78	35.40	13.00	12.8	7.43	0.538	0.197	0.093	
ADT03	7.10	24.8	169.5	22.37	135.60	16.00	12.6	72.30	0.462	0.165	0.049	
ADB03	6.51	25.1	184.8	20.10	129.20	11.00	13.8	31.70	0.893	0.178	0.042	
ADF03	6.73	26.3	266.1	21.64	137.10	8.00	14.4	32.60	0.472	0.166	0.052	
ATO04	7.02	23.7	63.80	26.67	32.9	16.90	11.9	9.80	0.594	0.210	0.123	
ADO04	7.92	24.2	110.00	26.32	35.6	13.10	13.1	7.43	0.617	0.260	0.171	
ADT04	7.70	24.3	114.90	24.43	156.7	15.00	13.7	63.14	0.573	0.190	0.132	
ADB04	7.63	24.8	160.50	21.96	133.2	12.00	14.2	29.63	0.932	0.210	0.158	
ADF04	7.69	26.2	162.01	22.42	141.6	9.00	14.6	30.41	0.486	0.200	0.165	

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**Appendix 1b-Heavy metal concentrations detected in the Asukawkaw river.**

TABLE OF HEAVY METAL PARAMETERS						
SAMPLE CODES	HEAVY METAL PARAMETERS					
	Total Fe	Pb	Zn	Cd	Cr	Al
<b>WHO LIMIT</b>	<b>0.3</b>	<b>0.0100</b>	<b>3.0000</b>	<b>0.30</b>	<b>0.05</b>	<b>1.11</b>
	<0.005	0.006	<0.002	0.249	<0.010	
ATO02	1.16	<0.005	<0.005	<0.002	0.754	<0.010
ATO03	1.14	<0.005	<0.005	<0.002	0.759	<0.010
ATO04	1.17	<0.005	<0.005	<0.002	0.756	<0.010
ADO01	1.26	<0.005	<0.005	<0.002	0.700	<0.010
ADO02	1.20	<0.005	<0.005	<0.002	0.533	<0.010
ADO03	1.22	<0.005	<0.005	<0.002	0.617	<0.010
ADO04	1.24	<0.005	<0.005	<0.002	0.521	<0.010
ADT01	1.29	<0.005	<0.005	<0.002	0.144	<0.010
ADT02	1.23	<0.005	<0.005	<0.002	0.641	<0.010
ADT03	1.27	<0.005	<0.005	<0.002	0.632	<0.010
ADT04	1.25	<0.005	<0.005	<0.002	0.663	<0.010
ADB01	1.06	<0.005	<0.005	<0.002	0.276	<0.010
ADB02	1.01	<0.005	<0.005	<0.002	0.733	<0.010
ADB03	1.02	<0.005	<0.005	<0.002	0.739	<0.010
ADB04	1.05	<0.005	<0.005	<0.002	0.741	<0.010
ADF01	1.18	<0.005	<0.005	<0.002	0.658	<0.010
ADF02	1.30	<0.005	<0.005	<0.002	0.499	<0.010
ADF03	1.24	<0.005	<0.005	<0.002	0.553	<0.010

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ADF04      1.28   <0.005 <0.005 <0.002 0.542   <0.010 **Appendix 1c -Total Coliform and Faecal Coliform counts sampled from the indicated locations along the Asukawkaw River**



**TABLE OF MICROBIOLOGICAL PARAMETER**

<b>MICROBIOLOGICAL PARAMETERS</b>		
SAMPLE ID	FAECAL COLIFORM (FC/100 ml)	TOTAL COLIFORM (TC/100ml)
<b>WHO LIMIT</b>	<b>0.00</b>	<b>400</b>
ATO01	372	558
ATO02	200	930
ATO03	281	630
ATO04	276	820
ADO01	286	744
ADO02	290	558
ADO03	348	756
ADO04	347	780
ADT01	558	651
ADT02	210	651
ADT03	343	670
ADT04	591	720
STD		
MEAN		
ADB01	80	465
ADB02	110	465
ADB03	145	500
ADB04	149	560
ADF01	279	1023
ADF02	139	1372
ADF03	281	1470
ADF04	310	1428

## Appendix 2-Descriptive Statistical Analysis Report for analysed samples

		pH (units)	Temperature (°C)	Electrical conductivity	Turbidity (NTU)	TDS (mg/l)	TSS (mg/l)
ATO	Mean	7.3800	24.0250	63.1000	23.0200	32.9000	13.7500
	Std. Deviation	.24125	.59652	4.51442	3.40555	.69761	3.59398
	Std. Error of Mean	.12062	.29826	2.25721	1.70278	.34881	1.79699
	Range	.51	1.30	10.40	8.07	1.70	8.00
	Skewness	-1.938	1.749	.862	-.603	-.424	-.889
	Variance	.058	.356	20.380	11.598	.487	12.917
ADO	Mean	7.6225	24.3250	76.4250	19.8750	35.1500	10.2500
	Std. Deviation	.20775	.15000	22.77636	5.18100	1.76352	3.20156
	Std. Error of Mean	.10387	.07500	11.38818	2.59050	.88176	1.60078
	Range	.45	.30	50.60	11.12	4.20	6.00
	Skewness	1.521	.370	1.790	.589	-1.123	-.084
	Variance	.043	.023	518.762	26.843	3.110	10.250
ADT	Mean	7.4700	24.8250	141.7000	19.3750	111.8750	11.5000
	Std. Deviation	.26000	.41130	69.63921	5.06785	54.35816	5.06623
	Std. Error of Mean	.13000	.20565	34.81961	2.53392	27.17908	2.53311
	Range	.60	1.00	161.60	11.33	123.50	11.00
	Skewness	-1.408	-.356	-.034	-.495	-1.588	-.738
	Variance	.068	.169	4849.620	25.683	2954.809	25.667
ADB	Mean	7.2850	25.2500	155.6500	17.0150	99.7500	9.2500
	Std. Deviation	.52086	.38730	65.33628	4.74309	45.10355	2.75379
	Std. Error of Mean	.26043	.19365	32.66814	2.37154	22.55177	1.37689
	Range	1.12	.90	150.70	9.76	97.60	6.00
	Skewness	-1.903	.000	-1.348	.034	-1.461	-.323
	Variance	.271	.150	4268.830	22.497	2034.330	7.583
ADF	Mean	7.4000	26.5000	168.9775	18.0400	107.8750	6.8750
	Std. Deviation	.45512	.31623	82.72627	4.88500	49.77934	2.01556
	Std. Error of Mean	.22756	.15811	41.36314	2.44250	24.88967	1.00778
	Range	.96	.70	201.30	10.32	106.80	4.50
	Skewness	-1.792	.632	-.250	-.500	-1.761	-.248
	Variance	.207	.100	6843.636	23.863	2477.982	4.062
Total	Mean	7.4315	24.9850	121.1705	19.4650	77.5100	10.3250
	Std. Deviation	.33985	.95657	67.50605	4.67266	50.23118	3.88070
	Std. Error of Mean	.07599	.21390	15.09481	1.04484	11.23203	.86775
	Range	1.41	3.30	207.40	14.57	124.70	12.50
	Skewness	-1.557	.541	.699	-.192	.345	.238
	Variance	.115	.915	4557.067	21.834	2523.171	15.060

**Appendix 3: Statistical Analysis of the indicated Nutrient parameters in the Asukawkaw River**

Sampling points		Sulphate (mg/l)	Phosphate (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)
ATO	Mean	8.3750	.449750	.099000	.052750
	Std. Deviation	2.78373	.2037864	.1027456	.0498757
	Std. Error of Mean	1.39187	.1018932	.0513728	.0249378
	Range	6.40	.4430	.2090	.1150
	Skewness	-1.015	-1.744	.146	1.318
ADO	Mean	6.3275	.592750	.129000	.085750
	Std. Deviation	1.30042	.1364951	.1200139	.0672873
	Std. Error of Mean	.65021	.0682476	.0600069	.0336437
	Range	2.53	.3220	.2590	.1630
	Skewness	-.212	.584	.041	.321
ADT	Mean	51.3850	.436000	.095500	.055000
	Std. Deviation	32.08056	.1468945	.0957793	.0535350
	Std. Error of Mean	16.04028	.0734473	.0478896	.0267675
	Range	68.70	.3450	.1890	.1200
	Skewness	-1.916	-1.329	.000	1.542
ADB	Mean	22.3575	.712000	.107000	.058250
	Std. Deviation	13.42145	.3596415	.1024858	.0676381
	Std. Error of Mean	6.71072	.1798207	.0512429	.0338191
	Range	29.10	.7570	.2090	.1450
	Skewness	-1.787	-1.946	-.034	1.809
ADF	Mean	24.2175	.364250	.098500	.064500
	Std. Deviation	13.30211	.1641673	.0991245	.0690628
	Std. Error of Mean	6.65106	.0820837	.0495623	.0345314
	Range	28.24	.3550	.1990	.1540
	Skewness	-1.942	-1.452	.042	1.657
Total	Mean	22.5325	.510950	.105800	.063250
	Std. Deviation	22.21965	.2323877	.0935750	.0564390
	Std. Error of Mean	4.96847	.0519635	.0209240	.0126201
	Range	69.70	.8010	.2590	.1630
	Skewness	1.215	.105	.098	.898
	Variance	493.713	.054	.009	.003

**Appendix 4: Statistical analysis of Heavy metals detected in the Asukawkaw River**

Sampling points		Fe	Pb	Zn	Cd	Cr	Al
ATO	Mean	1.145000	.005000	.005250	.002000	.629500	.010000
	Std. Deviation	.0264575	.0000000	.0005000	.0000000	.2536750	.0000000
	Std. Error of Mean	.0132288	.0000000	.0002500	.0000000	.1268375	.0000000
	Range	.0600	.0000	.0010	.0000	.0010	.0010
	Skewness	.5100	.0000	-.864	2.000	-.2000	
ADO	Mean	1.230000	.005000	.005000	.002000	.592750	.010000
	Std. Deviation	.0258199	.0000000	.0000000	.0000000	.0832842	.0000000

	Std. Error of Mean	.0129099	.0000000	.0000000	.0000000	.0416421	.0000000	Range	.0600	.0000	.0000
		.0000	.1790	.0000							
	Skewness	.000	.	.	.	.768	.				
	Variance	.001	.000	.000	.000	.007	.000				
ADT	Mean	1.260000	.005000	.005000	.002000	.520000	.010000				
	Std. Deviation	.0258199	.0000000	.0000000	.0000000	.2510046	.0000000				
	Std. Error of Mean	.0129099	.0000000	.0000000	.0000000	.1255023	.0000000	Range	.0600	.0000	.0000
		.0000	.5190	.0000							
	Skewness	.000	.	.	.	-1.984	.				
	Variance	.001	.000	.000	.000	.063	.000				
ADB	Mean	1.035000	.005000	.005000	.002000	.622250	.010000				
	Std. Deviation	.0238048	.0000000	.0000000	.0000000	.2308584	.0000000				
	Std. Error of Mean	.0119024	.0000000	.0000000	.0000000	.1154292	.0000000	Range	.0500	.0000	.0000
		.0000	.4650	.0000							
	Skewness	.000	.	.	.	-1.999	.				
	Variance	.001	.000	.000	.000	.053	.000				
ADF	Mean	1.250000	.005000	.005000	.002000	.563000	.010000				
	Std. Deviation	.0529150	.0000000	.0000000	.0000000	.0674833	.0000000				
	Std. Error of Mean	.0264575	.0000000	.0000000	.0000000	.0337417	.0000000	Range	.1200	.0000	.0000
		.0000	.1590	.0000							
	Skewness	-.864	.	.	.	1.269	.				
	Variance	.003	.000	.000	.000	.005	.000				
Total	Mean	1.184000	.005000	.005050	.002000	.585500	.010000				
	Std. Deviation	.0917892	.0000000	.0002236	.0000000	.1790270	.0000000				
	Std. Error of Mean	.0205247	.0000000	.0000500	.0000000	.0400317	.0000000	Range	.2900	.0000	.0010
		.0000	.6150	.0000							
	Skewness	-.681	.4.472	-.1.292							
	Variance	.008	.000	.000	.000	.032	.000				

Mean values 0.01 is Below Detectable Limit (BDL)<



**Appendix 5: Statistical analysis of the microbiological parameters in the Asukawkaw River**

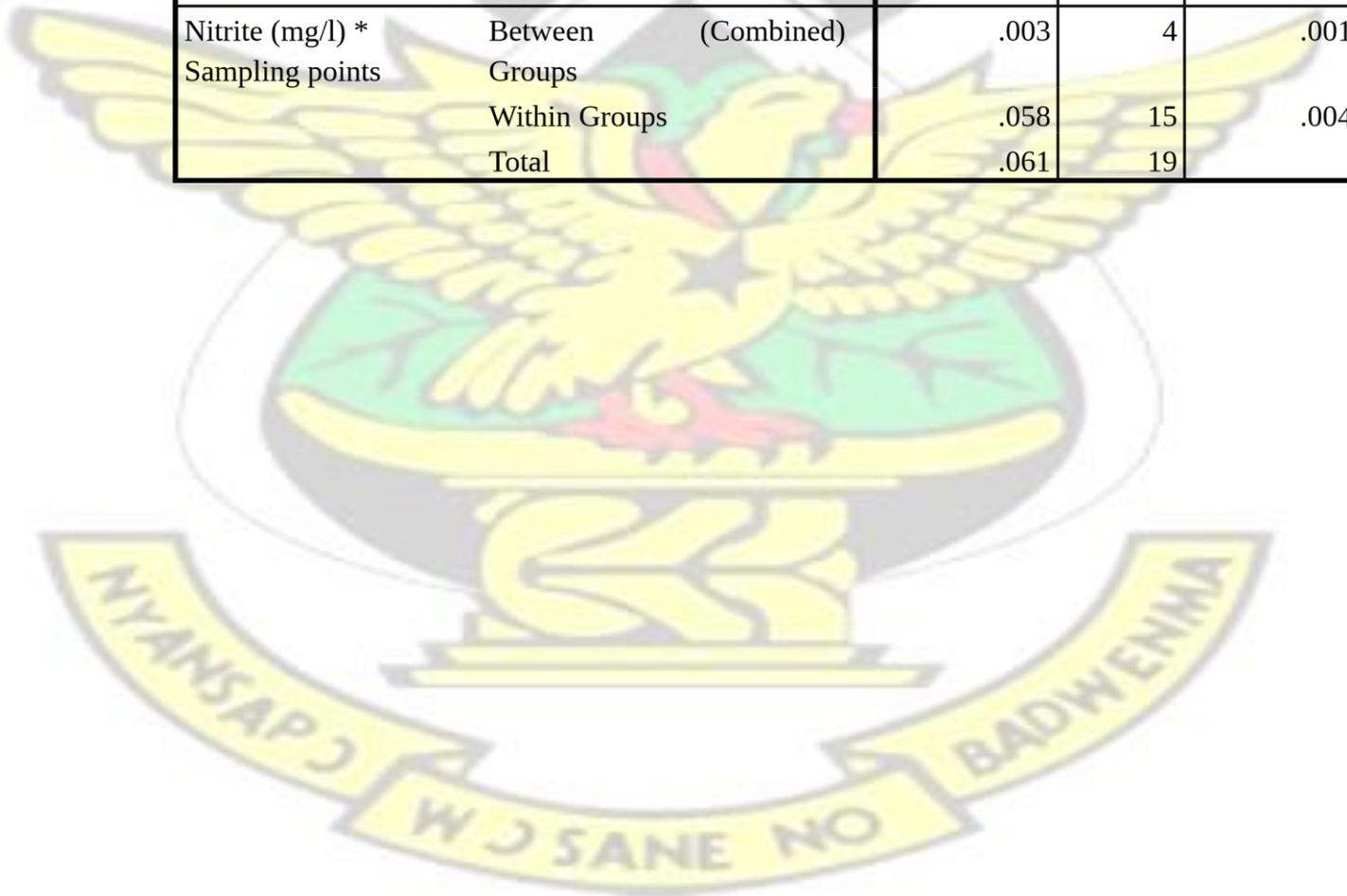
Sampling points	FAECAL COLIFORM (FC/100ml)	TOTAL COLIFORM (TC/100ml)
ATO	Mean	282.250000
	Std. Deviation	70.3816974
	Std. Error of Mean	35.1908487
	Range	172.0000
	Skewness	.318
	Variance	4953.583
ADO	Mean	317.750000
	Std. Deviation	34.3935556
	Std. Error of Mean	17.1967778
	Range	62.0000
	Skewness	-.011
	Variance	1182.917
ADT	Mean	425.500000
	Std. Deviation	180.9171081
	Std. Error of Mean	90.4585540
	Range	381.0000
	Skewness	-.418
	Variance	32731.000
ADB	Mean	121.000000
	Std. Deviation	32.4653662
	Std. Error of Mean	16.2326831
	Range	69.0000
	Skewness	-.672
	Variance	1054.000
ADF	Mean	252.250000
	Std. Deviation	76.8174242
	Std. Error of Mean	38.4087121
	Range	171.0000
	Skewness	-1.790
	Variance	5900.917
Total	Mean	279.750000
	Std. Deviation	132.2023469
	Std. Error of Mean	29.5613434
	Range	511.0000
	Skewness	.815
	Variance	17477.461

**Appendix 6a: ANOVA Tables**

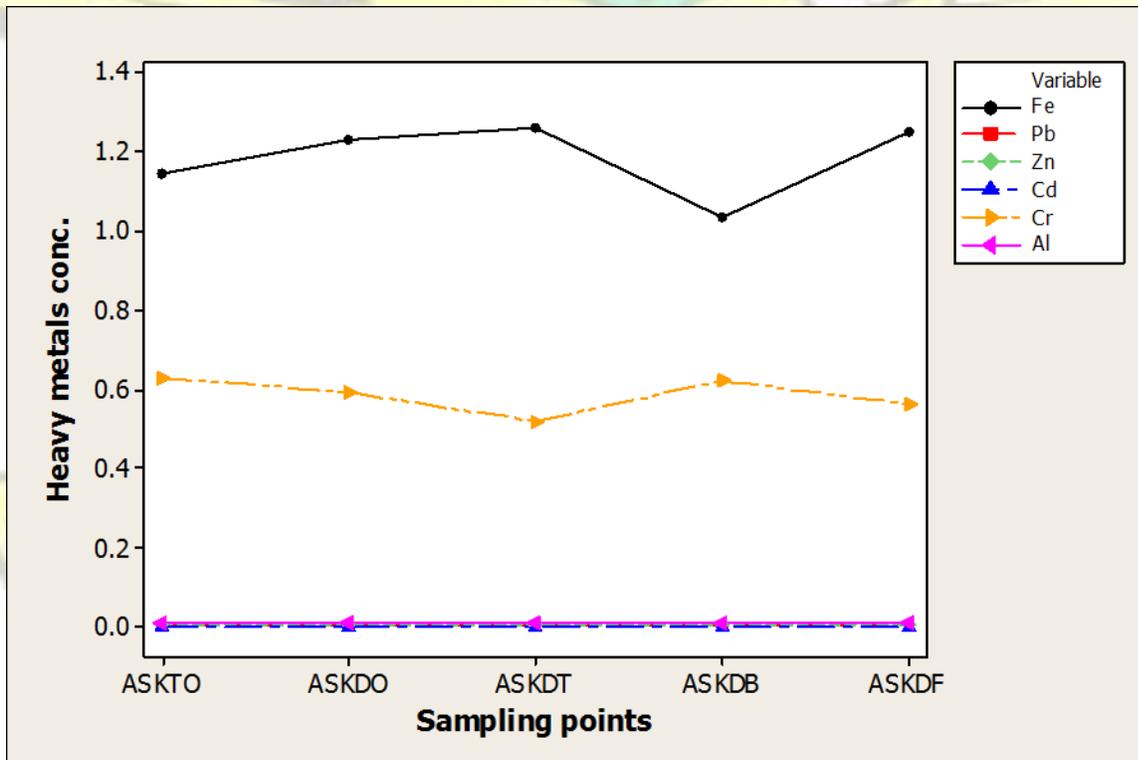
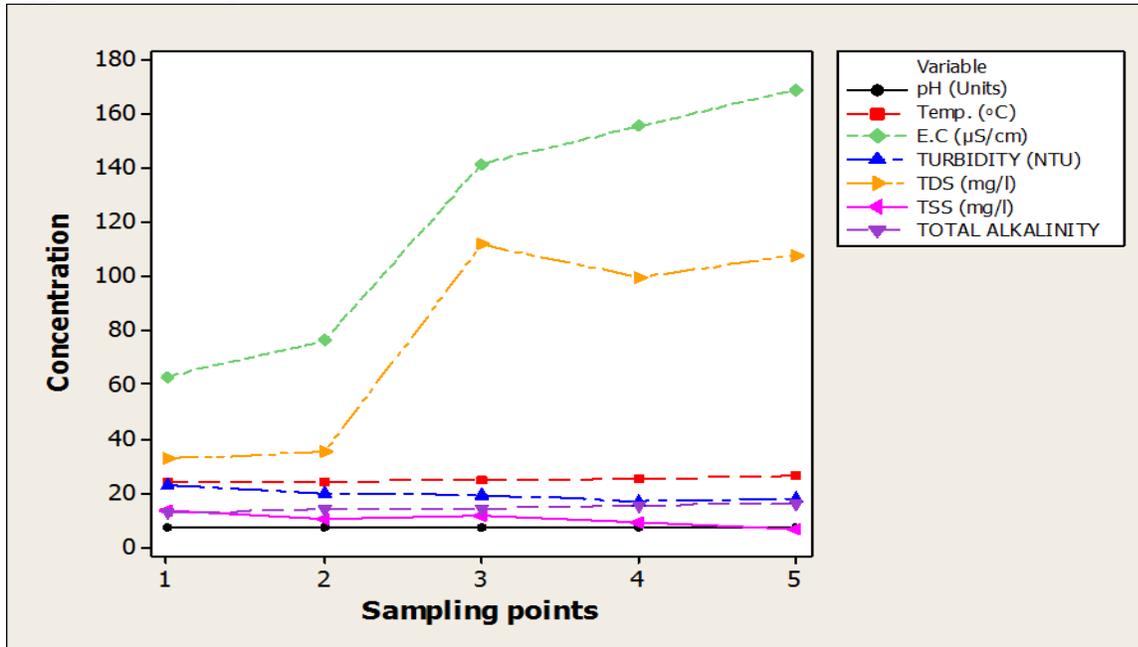
		Sum of Squares	Df	Mean Square	F
Water pH (units) * Sampling points	Between Groups (Combined)	.252	4	.063	.487
	Within Groups	1.942	15	.129	
	Total	2.194	19		
Temperature (°C) * Sampling points	Between Groups (Combined)	14.993	4	3.748	23.500
	Within Groups	2.392	15	.159	
	Total	17.386	19		
Electrical conductivity * Sampling points	Between Groups (Combined)	37080.593	4	9270.148	2.809
	Within Groups	49503.686	15	3300.246	
	Total	86584.279	19		
Turbidity (NTU) * Sampling points	Between Groups (Combined)	83.389	4	20.847	.943
	Within Groups	331.451	15	22.097	
	Total	414.841	19		
TDS (mg/l) * Sampling points	Between Groups (Combined)	25528.103	4	6382.026	4.271
	Within Groups	22412.155	15	1494.144	
	Total	47940.258	19		
TSS (mg/l) * Sampling points	Between Groups (Combined)	104.700	4	26.175	2.164
	Within Groups	181.438	15	12.096	
	Total	286.138	19		
Total Alkaline * Sampling points	Between Groups (Combined)	28.927	4	7.232	1.804
	Within Groups	60.143	15	4.010	
	Total	89.070	19		

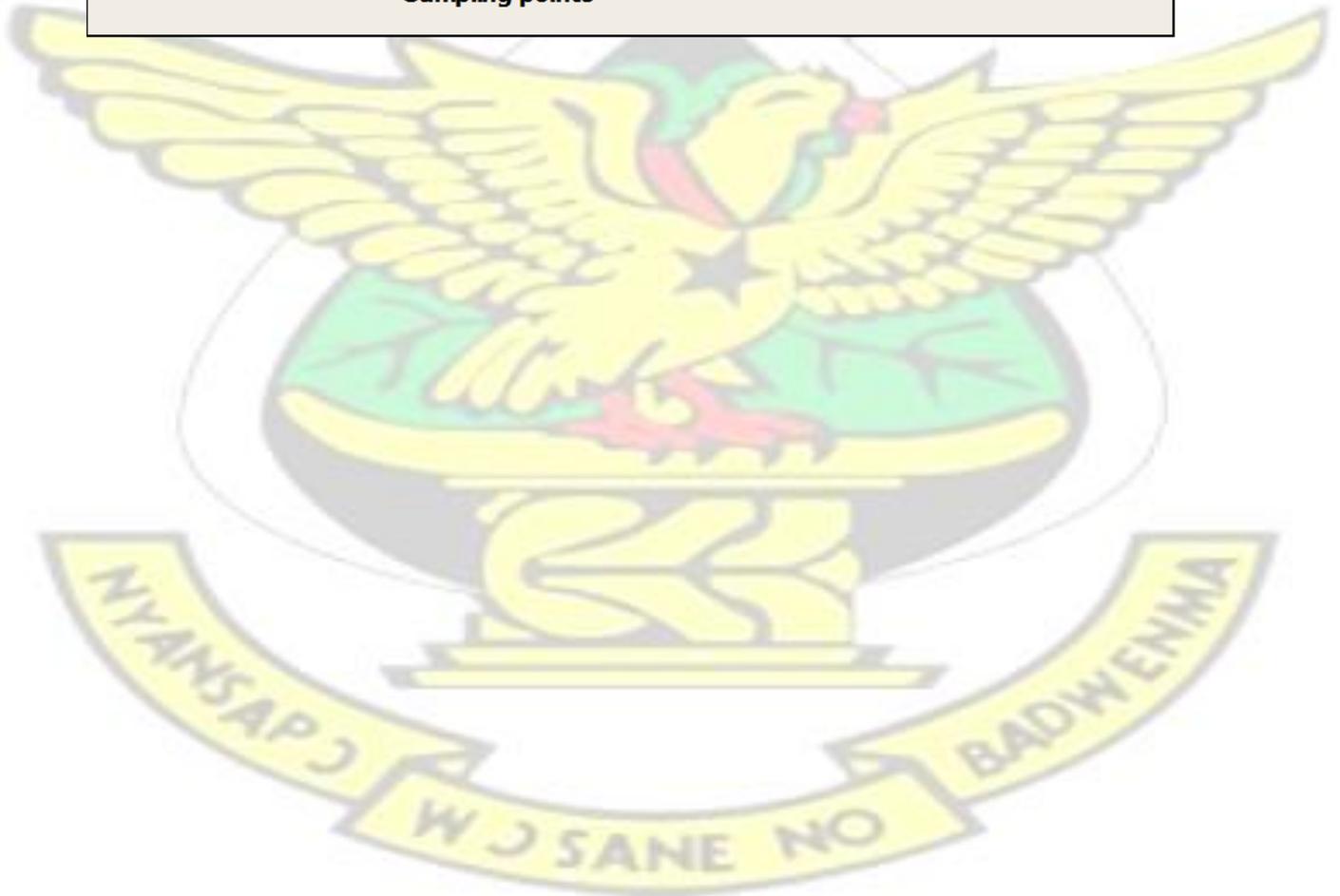
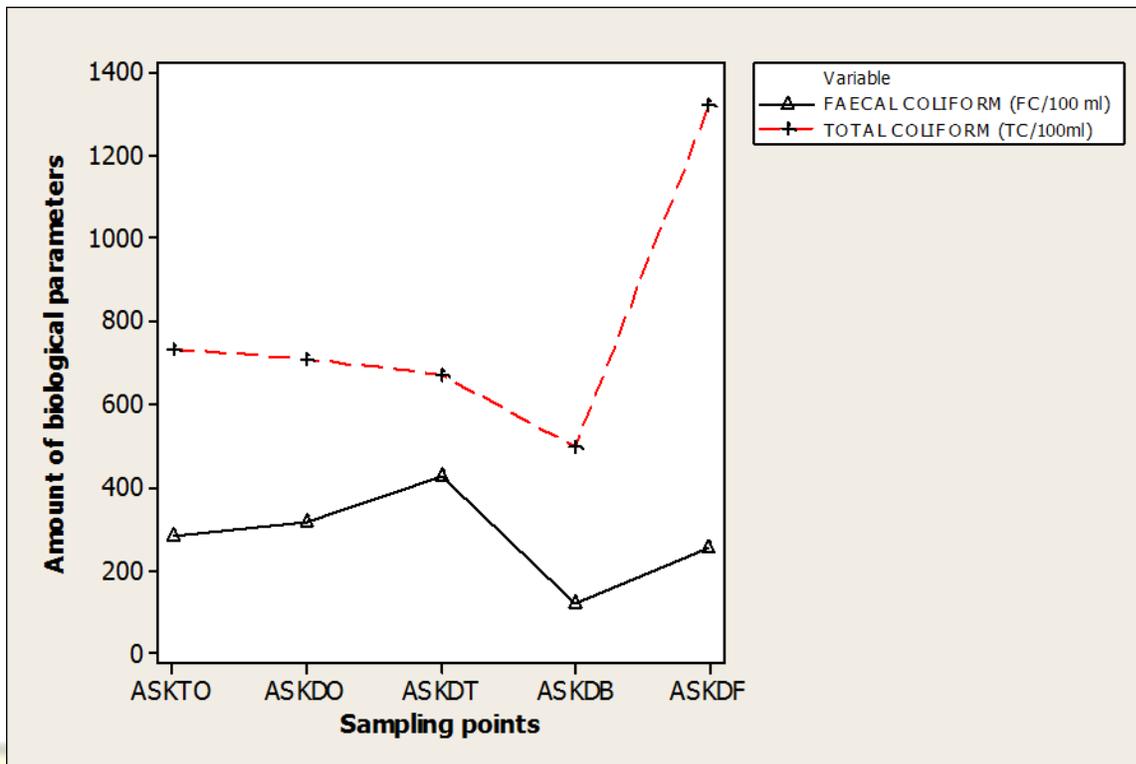
**Appendix 6b** : ANOVA Table for Nutrient parameters

			Sum of Squares	Df	Mean Square	F
Sulphate (mg/l) * Sampling points	Between Groups	(Combined)	5193.494	4	1298.373	4.6
	Within Groups		4187.052	15	279.137	
	Total		9380.545	19		
Phosphate (mg/l) * Sampling points	Between Groups	(Combined)	.312	4	.078	1.6
	Within Groups		.714	15	.048	
	Total		1.026	19		
Nitrate (mg/l) * Sampling points	Between Groups	(Combined)	.003	4	.001	.0
	Within Groups		.163	15	.011	
	Total		.166	19		
Nitrite (mg/l) * Sampling points	Between Groups	(Combined)	.003	4	.001	.1
	Within Groups		.058	15	.004	
	Total		.061	19		



## Appendix 7-Graphs





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