KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI
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DEPARTMENT OF ENVIRONMMENTAL SCIENCE

Physico-Chemical and Biological Quality of Kankama River in the Berekum Municipality

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BY

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DECLARATION

I hereby declare that this work being submitted as Master of Science thesis is the result of my original research and that to the best of my knowledge, it contains no material previously published by another person and has neither in whole nor in part presented for another degree elsewhere and that production of this thesis in part or in full is strictly resolved unless authorized by the author and the parties associated with this work, herewith under a written agreement.

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DEDICATION

This thesis is dedicated to my mother, Dora Akosua Kraa and my siblings, Seth, Boateng, Comfort, Akosua Gina, Amma, Benim and Esther.

It is also dedicated to all my friends, my wife and children

ABSTRACT

The study was carried out in the Berekum Municipality to investigate the physico-chemical and biological quality of Kankama River. Three different sampling sites were located on the main stem of the Kankama River, namely Amangoase, Kookoase and Kyiribaa. Water samples were taken once every month from these sites from December, 2010 to March, 2011. The water samples were analyzed for total coliforms, faecal coliforms, *E. coli*, turbidity, conductivity, total dissolved solids, alkalinity, total hardness, pH, phosphate and nitrate. Amangoase sampling site was characterized with mean pH (6.428), conductivity (503.725 µs/cm), turbidity (31.155 NTU), alkalinity (209.75 mg/L), total hardness (130.6 mg/L), total coliforms (6.239- $\log_{10}$ of geometric mean CFU/100 ml), faecal coliforms (4.024- $\log_{10}$ of geometric mean CFU/100 ml), and *E. coli* (2.45-$\log_{10}$ geometric mean CFU/100 ml). Water samples analysis from Kookoase also showed pH (5.676), conductivity (320.75 µs/cm), turbidity (24.4 NTU), total dissolved solids (241.25 mg/L), Alkalinity (144.25 mg/L), total hardness (86.42 mg/L), total coliforms (5.379 $\log_{10}$ of geometric mean CFU/100 ml), faecal coliforms (3.765 $\log_{10}$ of geometric mean CFU/100 ml) and *E. coli* (1.843 $\log_{10}$ of geometric mean CFU/100 ml). Similarly, a pH of (5.977), conductivity (339 µs/cm), turbidity (11.76 NTU), total dissolved solids (251.55 mg/L), alkalinity (127.75 mg/L), total hardness (80.81 mg/L), total coliforms (4.563 $\log_{10}$ of geometric mean CFU/100 ml), faecal coliforms (3.44 $\log_{10}$ of geometric mean CFU/100 ml) and *E. coli* (1.616 $\log_{10}$ of geometric mean CFU/100 ml) were recorded at the Kyiribaa sampling site. At all the sites, mean indicator bacteria numbers were very high above the WHO guideline values of zero CFU per 100 ml. These high numbers were due to human faeces and cow dung from livestock confinements through storm water runoff from surrounding communities and direct defaecation into the river. Again, turbidity, conductivity and phosphate levels measured were above the WHO guideline values except total dissolved solids, total hardness and Nitrate which were below the guideline values. Though alkalinity have no health based guideline values, however its level was not satisfactory at all the sampling sites. In general, the level of pollution of Kankama River reflected the land use of its catchment- refuse dump, slaughter house, motor mechanics activities, car washing, gardening, livestock activities and human settlement. In order to help curb the growing pollution of the river, it is recommended that the Municipal Assembly with her environmental department should institute measures like tree planting along the banks of the river; and relocation of the existing refuse dump, slaughter house and the car washing bay. Again, the inhabitants around the river catchment area should be educated on the adverse impacts of their activities on the river water quality and the subsequent cross-loop effect on their health.

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With God all things are possible! Amen.

CHAPTER ONE

INTRODUCTION

1.0 Background

Water is needed by all living organisms on this planet. It plays important roles in many natural processes and is essential in countless physical and chemical reactions. This vital resource can loss its value when its quality deteriorates. Water abstraction for domestic use, agricultural production, mining, industrial production, power generation, and forestry practices can lead to deterioration in water quality and quantity that impact not only the aquatic ecosystem (i.e. the assemblage of organisms living and interacting together within an aquatic environment), but also the availability of safe water for human consumption (Geneviève and James, 2006). According to the United Nations/World Water Assessment Program (2003), although 70% of the earth's surface is covered by water, only 2.5% of that water is fresh and only 0.3% of the water is available for human use. Furthermore, pressures on this water resource are growing. Currently, it is estimated that humans appropriate 54% of all available fresh water contained in rivers, lakes and underground aquifers and by 2025 this will increase to 70% (United Nations/World Water Assessment Programme, 2003). This implies fresh water which is considered renewable is becoming finite and therefore the studies and management of freshwater bodies like rivers has become very important in environmental studies. They offer a number of benefits and services to man and the environment. Rivers provide water for domestic uses such as drinking, bathing, washing and gardening. Not only do they provide water for industries but for agricultural production as well. These valuable and useful resources are being polluted and threatened on a global scale by anthropogenic activities.

According to Akaninwor *et al*. (2007), pollution of freshwater bodies such as rivers, streams, lakes and ponds is mostly experienced as a result of industrial discharge, municipal waste disposal and surface runoff. These pollutants may be point source (those that reach water or the environment from a single pipeline or channel, such as sewage discharge) or non-point source (those pollutants coming from diverse sources, entering the environment from multiple venues). Indiscriminate and uncontrolled discharges of waste into rivers impact negatively on human health and river ecosystems. Avnish (2010) added that Pollution of surface and ground water is largely a problem due to rapid urbanization and industrialization. The large scale urban growth due to increase in population or migration of people from rural areas to urban areas has increased domestic effluents while industrial development manifested either due to setting up of new industries or expansion of the existing industrial establishments resulting in generation of copious volume of industrial effluents.

It was found that water-related diseases kill a child every eight seconds, and are responsible for 80% of all illnesses and deaths in the developing world; and in Africa, 5,853 deaths due to cholera were reported to WHO in 1997 (http://www.pollution.com/ve-z/water-pollution=freshwater.html). In the developing world countries, 80% of all diseases are directly related to poor drinking water and unsanitary conditions (Sharma, 1995). Further, diseases like bilharzia, ulcers, tumors, diarrhea, skin rashes and infections to intestines usually emanate from fresh water pollution. The effects of water pollution on the health of aquatic ecosystem cannot be underestimated. Pollution of freshwater bodies lead to the promotion of oxygen-consuming algae (algal bloom) especially the blue green algae, as a result of the inflow of inorganic nutrients and decomposition of organic wastes. This leads to a condition that is termed eutrophication. Water pollution may result in large scale death of

aquatic and terrestrial animals; reduced reproductive rate; increased incidence of diseases, and bioaccumulation of toxins.

Kankama River is one of the rivers that drain the Berekum Municipality and supply drinking water for inhabitants around the riparian areas who cannot access the Ghana Water Company supply grid, and many farmers who farm around the river catchment area. Other communities downstream use the river water for domestic purposes.

The river receives its waste at the source from leachate from domestic waste dump sites, a slaughter house, a kraal, runoff from garages, car washing bays, urban runoffs and nutrients and pesticides runoff from sheet flow over agricultural fields. These are subsequently transported downstream where the water is widely used for domestic purposes. Again, indiscriminate disposal of variety of rubbish and defaecation is a practice at the banks of the river. This has made the quality of the water in the river very doubtful. Hence assessing the water quality will enable a deeper understanding of the extent of pollution and the need to institute mitigation measures to improve on the water quality (the suitability of water to sustain various uses or purposes) of the river.

The Kankama River passes through the Berekum town; therefore the wholeness of its water quality is worse. It is mainly contaminated by human excreta, sewage, food waste, and silt. These can be attributed to the increase in urban population and its attendant socio-economic development and sanitation problems. The rate at which the river is being polluted is very high and therefore if nothing is done to control the situation, the water quality will deteriorate beyond levels that can offer useful services to humankind, plants and animals, and the environment at large.

In Ghana, most of the river water quality monitoring has been conducted in the cities and studies are mainly focused on larger rivers. The smaller rivers which serve as tributaries to the large rivers need to be studied and understood with regard to their water quality and source of pollution in order to find a sustainable solution to water pollution problems in the larger rivers since it is the smaller rivers which confluence at various points to form the larger rivers.

1.1 Justification of the Study

Undeniably, monitoring and analyzing river water quality is essential for ensuring the quality of drinking water and protecting human health, and wildlife. Findings of the study could be used to evaluate and correct water-quality issues such as impacts on fishing and eutrophication. The research findings will provide a significant and credible scientific basis for governmental decision makers, managers, and planners, as well as those in nongovernmental organizations, industry, academia, and the public sector to cost–effectively address a wide range of water-quality issues related to natural and human influences on the quality of water and potential effects on aquatic ecosystems and human health. The research data will hence serve as basis to:

- Sustain life in the aquatic ecosystem through improved stream protection and restoration management.
- Prioritized geographic areas, basins and aquifers in which water resources and aquatic ecosystems are most vulnerable to contamination.
- Give an insight into the impact of human activities on freshwater bodies.

1.2 Problem Statement

Berekum, like other urban centres of the developing world is experiencing rapid and uncontrolled growth typified by poor planning, rapid population growth, inadequate amenities and poor sanitation. The effects of this urban growth on surrounding water bodies cannot be overemphasized.

Kankama is one of the rivers in the Municipality with its headwaters and banks surrounded by refuse dumps, slaughter house, a kraal and a car washing bay. Agricultural activities are also carried out at the riparian areas. These issues coupled with runoff from surrounding communities have generated concern about the ecological integrity of the river as well as its water quality.

The study therefore aims at investigating the physico-chemical and biological quality of Kankama River in the Berekum Municipality.

1.3 Broad objective

The broad objective of the study is to investigate the Physico-chemical and biological quality of Kankama River in the Berekum Municipality

1.4 Specific Objectives

The research is designed to:

- Measure conductivity, turbidity, total hardness, pH, nitrate, phosphate, alkalinity, and total dissolved solids levels in the river.
- Determine total coliforms, faecal coliforms and *E. coli* populations in the river.

CHAPTER TWO

LITERATURE REVIEW

2.0 Water quality

Water quality is a term used to express the suitability of water to sustain various uses or processes (Jamie and Richard, 1996). Water quality can also be seen as the physical, chemical and biological characteristics of water. It is the measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Wikipedia, 2010). Therefore, any particular use will have certain requirement for the physical, chemical or biological characteristics of water. For example, limits on the concentration of chemicals and levels of physical and microbiological characteristics of water for drinking are different from those of water intended to be used for agricultural purposes. Consequently, water quality can be defined by a range of variables which limit water use (Jamie and Richard, 1996).

The composition of surface water is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes as well as weather conditions. Again, human interventions have a significant effect on water quality. Some of these effects are the result of hydrological changes such as the building of dams, drainage of wetlands and diversion of flow.

Although the natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually disrupt the ecosystem and/or restrict water use. The quality of any body of surface or ground water is a function of either or both natural influences and human activities. Without human influences, water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, by the natural leaching of

organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water (Geneviève and James, 2006).

2.1 Factors affecting water quality

2.1.1 Natural factors affecting water quality

According to Jamie and Richard (1996), although degradation of water quality is almost invariably the result of human activities, certain natural phenomena can result in water quality falling below that required for a particular purpose. Natural events such as torrential rain falls and hurricanes lead to erosion and landslides, which in turn increase the content of suspended particles in the affected rivers and lakes (Balek, 1977). Seasonal over turn of water in some lakes bring with water little or no dissolve oxygen to the surface. Further, permanent natural conditions in some areas may make water unfit for drinking or for specific uses, such as irrigation (Peavy *et al.*, 1985). Common examples of this is the salination of surface water through evaporation in arid and semi-arid regions and the high content of salt and iron in groundwater under certain geological conditions.

The nature and concentration of elements and compounds in freshwater systems are subject to change by various types of natural processes i.e. physical, chemical, hydrological and biological (Balek, 1977). The effect on water quality of these processes will depend on a large extent on environmental factors brought about by climatic, geographical and geological conditions. Examples of such environmental factors include aquatic vegetation: the growth,

death and decomposition of aquatic plants and algae will affect the concentration of nitrogenous and phosphorus nutrients, pH, carbonate and dissolved oxygen.

The amount and timing of rainfall are strongly linked to hydrological patterns within drainage basins, so seasonally varying precipitation produces seasonal differences in river discharge and patterns of flooding and thus seasonal differences in the physical and chemical characteristics of the river. River discharge has important effects on water quality, including the dilution of dissolved substances at high flows and the suspension of sediment particles eroded from the river banks or substrate by high flows. Rainfall can also cause erosion within the drainage basin, and elevated surface flows can carry eroded sediment to the river. Flooding can result in the exchange of nutrients between flooded river banks and the river itself (Regional Aquatics Monitoring Programme, 2010).

2.1.2 Human factors that affect water quality

Humans have long used air, land and water resources as sink into which we dispose off the waste we generate from our homes, industries and farms. According to Nsiah-Gyabaah (2010), many cities depend on the surrounding regions or peri-urban areas to act as sinks and disposal sites for domestic and industrial waste. He added further that a project carried out in Kumasi to examine the effects of the growth of the city on the natural resources in 1997, revealed that the main water problems relate to contamination from hospital wastes, degrading of watersheds through bush fires, housing encroachment, bacteriological contamination of rivers, streams and aquifers through inappropriate waste disposal system, urban and rural runoffs leading to soil erosion and siltation of water resources, and increased

water resource pollution caused mainly by domestic wastes, industries, abattoirs and garages.

Edwin (1996) adds that agriculture is the largest user of freshwater on a global basis and a major cause of degradation of surface water and underground water resources. Poor agricultural practices at river catchment area have a profound link to the reduction of its water quality. Poor land preparation techniques in river catchment area hasten erosion by runoff, and subsequently increase sediment load in rivers. Also, if animals' wastes, fertilizers, herbicides, and fungicides are applied to croplands, some residues remain in the soil after plant uptake and may leach into subsurface waters or the residues may move to surface water by dissolving in runoff or adsorb to sediments.

2.2 Water quality indicators

2.2.1 Turbidity as an indicator of water quality

Turbidity is viewed as the "cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air" (Julian, 2009). Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water (American Public Health Association, 1998). In addition, soil erosion, urban runoff, high flow rate, wastewater, and bottom-feeding fish may result in turbidity in rivers. Runoffs from snowmelt and storm events in areas burned by forest fires exhibit higher levels of turbidity (Hopkins, 2001). Increased surface runoff contributes to turbidity, which is an easily measured variable that is often associated with total suspended solids (Packman *et al.*, 1999), and microbial concentrations (Francy and Darner, 1997).

Moreover, turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. It may also indicate the presence of

microbes. The United State Environmental Protection Agency (2010), observed that higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macro invertebrates.

2.2.2 pH as an indicator of water quality

The term pH was originally derived from a French word, "*pouvoirhydrogéne*", which means "hydrogen power" which shows the quantity of hydrogen ions (H^+) in water (Annex 2, no date). In other words, pH is a measurement of the hydrogen ion (H^+) concentration in water, and is commonly used to describe the acid/base balance of water. The pH scale used for measuring the degree of acidity or alkalinity ranges from 1 to14. A pH value of 7.0 is considered neutral, i.e. neither acidic nor basic, while values below 7.0 are considered acidic, and above 7.0 are basic. The pH of most natural waters is between 6.0 and 8.5 (Regional Aquatics Monitoring Programme, 2010). Similarly, the WHO range for pH in water for domestic use is 6.5 to 8.5 (WHO, 2003). An investigation into concentrations of some physico-chemical and bacteriological qualities of water samples from the major streams within the Owabi watershed in Kumasi, Ghana, found that mean pH of the samples varied between 7.08 ± 0.24 and 7.88 ± 0.61 mg/L which were within the range (6.6o-8.5) set by the WHO (Osei *et al.,* 2009). Similarly, the physico-chemical parameters of surface waters measured in the lower volta Basin, Ghana, from 1996-2006 indicated that their pH ranged

between 6.9 and 7.9 (Amoah and Koranteng, 2006). Low pH can also allow toxic compounds to become more available to aquatic plants and animals. Abnormal acid readings in water may be caused by industrial effluent, and livestock contaminated areas.

In addition, it has been stated that human activities have effect on the pH of a water source through sulfur dioxide and nitrogen oxide emissions; industrial operation and vehicles and acid rains (http://www.safewater.org/PDF/resourcesknowthefacts/TDS_AND%20_pH.pdf). The pH of a water resource is not static but keeps changing due to natural and human factors. These can produce conditions that hurt aquatic life. pH can be affected by acid rain, wastewater discharges, agriculture runoff, decomposing organic matter, drainage from mines and the type of rock naturally found in the area. For instance, Stephanie and Naomi (1998) indicated that acid soils and rocks such as basalt, granite and sandstone contribute to lower pH values in water. Similarly, basic rocks such as limestone contribute to high pH values in water.

pH is also noted to be affected by activities of phytoplankton through photosynthesis during the day, and respiration during the night. It can be toxic in itself at certain levels, and also known to influence the toxicity as well of hydrogen sulphide, cyanides, and heavy metals (Klontz, 1993).

From http://www.safewater.org/PDF/resourcesknowthefacts/TDS_AND%20_pH.pdf), when there are a large number of plants growing in a lake or river, they release carbon dioxide when they die and decompose. When the carbon dioxide mixes with the water, weak carbonic acid is formed; this can cause the pH of the water body to decrease.

2.2.3 Bacteria as indicators of water quality

"The discharge of wastes from municipal sewers is one of the most important water quality issues world-wide. It is of particular significance to sources of drinking water. Municipal sewage contains human faeces, and water contaminated with these effluents may contain pathogenic (disease-causing) organisms and, consequently, may be hazardous to human health if used as drinking-water or in food preparation. Faecal contamination of water is routinely detected by microbiological analysis", (Jamie and Richard, 1996). The task of routinely search for specific individual pathogenic organisms is difficult, costly and time consuming. The solution to this problem is the use of indicator bacteria that would be present when potential pathogen containing materials are present.

Indicator organisms are organisms that signal particular conditions: organisms whose presence or absence in an environment indicates conditions such as its oxygen level or the presence of a contaminating substance (Microsoft Encarta, 2009). Various microorganisms are used to test for faecal contamination in waters but indicator bacteria of the coliform group are used to indicate recent faecal contamination and human health risk as well.

"Coliform bacteria include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within twenty-four hours at 357°C" (http://www.manoramaonline.com/advt/palathulli/reportspdf/IISC_KERALA_RESULT01_MPN.pdf.). The presence of these bacteria in water is evidence of faecal contamination from human and warm-blooded animals and, therefore, of the risk that pathogens are present. If indicator bacteria are present in large numbers, the contamination is considered to be recent and/or severe.

The key criteria for ideal bacterial indicators of faecal pollution are that they should be:

- Universally present in large numbers in the faeces of human and other warm-blooded animals.
- Present in sewage effluent.
- Be readily detectable by simple methods and should not grow in natural waters.
- Ideally, of exclusive faecal origin and be present in greater numbers than faecal transmitted pathogens (www.environment-agency.gov.uk).

It has been observed that no single indicator organism fulfils all these criteria, but the member of the coliform group that satisfies most of the criteria for the ideal indicator organism in temperate climates is *E. coli*. The commonly used indicator bacteria in environmental fresh waters and drinking waters are the total coliforms, faecal coliforms and *E. coli* (Abaidoo and Obiri-Danso, 2008).

The term "coliform organisms (total coliforms)" refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties, and able to ferment lactose at 35-37 °C with the production of acid, gas, and aldehyde within 24 to 48 hours (WHO, 1996). According to Kelly (2003), metabolically, total coliforms are defined as a group of closely related bacteria with the ability to ferment lactose, producing both acid and gas when incubated at 35^{o}C for 48 hours. Total Coliforms include genera that originate in faeces :"Fecal Coliforms" (e.g. *Escherichia*) as well as genera not of faecal origin - "non-Faecal Coliforms." (E.g. *Enterobacter*, *Klebsiella*, *Citrobacter*). Thus the presence of total coliforms may or may not necessarily indicate faecal contamination. If total coliforms are found in water then it might be caused by entry of organic matter or soil into the water or prevalence of conditions suitable for the growth of other type of coliforms.

The Washington state department of Health, Division of Environmental Heath (2010), describes faecal coliforms as a sub-group of total coliforms bacteria which can ferment lactose at 44.5^{o}C. Kelly (2003) added further that faecal coliforms are differentiated by their thermo tolerance, i.e. their ability to grow at 44.5^{o}C. They appear in great quantities in the intestines and faeces of people and animals. The presence of faecal coliform in a drinking water sample often indicates recent faecal contamination, which implies there is a greater risk that pathogens are present than if only total coliform bacteria is detected. Faecal coliform group is a more definitive indicator of faecal contamination.

Faecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage. However, their presence may also be the result of plant material, and pulp or paper mill effluent, (Doyle and Erickson, 2006). An investigation by Kumasi *et al*. (2010) to find out the microbial quality of Barekese reservoir and its feeder streams showed high *E. coli*, total and faecal coliform numbers due to human activities of communities living along the feeder streams as well as increasing population of local communities and an admitted lack of toilet facilities. Bordalo and Savva-Bordalo (2007) indicated that the free range system being the preferred method of rearing animals often result in their faeces being washed into surrounding surface waters. The contamination of water with faecal coliform bacteria may result in water borne diseases like dysentery and typhoid fever,

(http://www.manoramaonline.com/advt/palathulli/reportspdf/IISC_KERALA_RESULT01_MPN.pdf). Unfortunately, unlike many developed countries, Ghana has no legislation on permitted microbial numbers in inland water bodies as used extensively for various human activities (Obiri-Danso *et al.*, 2005). Currently, the permitted amount of microbial contamination in liquid effluent discharge to water bodies has been set as TC 400 per 100 ml

and *E. coli* 10 per 100 ml, (GEPA, 1994). The presence of *E. coli* in water always indicates potentially dangerous contamination requiring immediate attention WHO (1996). Though faecal coliforms are not pathogenic, certain strains of *E. coli* are directly pathogenic themselves, particularly, the serotype *E. coli* O: 157-H7. According to the Wikipedia (2010), an indicator organism, *Escherichia coli* provides conclusive evidence of recent faecal pollution and should *not* be present in water meant for human consumption. The presence of *E. coli* in a sample of drinking water may indicate the presence of intestinal pathogens. However, the absence of *E. coli* cannot be taken as an absolute indication that intestinal pathogens are also absent.

2.2.4 Nutrients as indicators of water quality

Nutrients are chemical elements and compounds found in the environment that plants and animals need to survive. Further, Nutrients can be referred to as those chemical elements or compounds that are essential in the system of plants and animals for normal growth and development. Examples of such important nutrients elements include nitrogen, phosphorus, potassium, calcium, carbon, etc. When it comes to water quality investigation, the various forms of nitrogen and phosphorus are the nutrients of interest.

Just as flora and fauna in terrestrial ecosystem require nutrients for growth and survival so do flora and fauna in aquatic ecosystems. However, if these nutrients are present in excess in water, they over stimulate the growth of aquatic plants, leading to water quality problems. These nutrients contaminants may enter water systems through specific points such as industrial discharge, called point sources. It may also enter through diffused sources or nonpoint sources such as nutrient losses from manure and waste products applied over large agricultural fields, sediments from eroded soils, and runoff from residential or agricultural

areas**.** The presence of nutrients, in even small amounts enables submerged aquatic vegetation to grow and serve as food and habitat for aquatic animals including fish. If the nutrient concentrations in surface waters increase, the growth rate of microscopic algae accelerates and algal growth clouds the water bodies, making it difficult for the vegetation to receive sufficient sunlight and maintain adequate oxygen levels for supporting life. As a consequence, the vegetation may die leading to a severe reduction in the available habitat area and food for other aquatic life. Also, the death and decomposition of algae during the normal lifecycle will reduce the dissolved oxygen levels in the water.

Nitrates (NO_3) and phosphates (P) are the primary nutrients that are of concern in most water bodies because of phosphorus association with the growth and decomposition of aquatic plants. However, other nutrients can be of concern, for example, high levels of potassium, calcium, lead, and iron (Rao, 2009). Phosphorus is an essential nutrient for plant growth, but too much phosphorus in streams can cause excessive growth of algae and weeds; for this reason, total phosphorus is often used as an indicator of the potential for algal growth in fresh water ecosystems,

(http://www.envcomm.act.gov.au/soe/soe2004/Ind/surfacewaterquality.htm).

High phosphorus ion content of Osun River was attributed to leachate of agricultural wastes into the river and/ or the use of phosphate additives in detergent formulations, which get leaked into water bodies through waste water generated industrially, domestically or municipally and/or from cloth dyeing and garment industries operating in the study area (Olajire and Imeokpaaria, 2000). According to Geneviève and James (2006), Phosphates can enter aquatic environments from the natural weathering of minerals in the drainage basin, from biological decomposition, and as runoff from human activities in urban and agricultural

areas. Phosphorus is the key element of concern because the natural occurrence of P in surface water bodies is minimal. Therefore, even a minute amount of phosphorus entering a water body can trigger a significant algal bloom (although Nitrogen (N) and Carbon (C) are required for algal growth), lowering light penetration and dissolved oxygen levels; it also causes aesthetic degradation of surface water bodies. In some extreme cases, algal blooms can be harmful to human health (Rao, 2009). A lake with nutrient concentration of below 0.010 mg/L is considered as oligotrophic, while concentrations between 0.010 and 0.020 mg/L are indicative of mesotrophy, and concentrations exceeding 0.020 mg/L are already considered eutrophic (David and Helsel, 1999). Investigation of the physico-chemical parameters of surface waters in the lower volta Basin, Ghana, from 1996-2006 indicated that their nitrates concentrations raged between 0.10 mg/l and 0.5 mg/l (Amoah and Koranteng, 2006).

2.2.5 Water hardness as an indicator of water quality

Water hardness is the measurement of the amount of ions which have lost two electrons (divalent cations) dissolved in tested water. The more divalent cations dissolved in water the "harder" the water (Global water, 2011). Hardness generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}) may also contribute to the hardness of water, but are generally present in much lower concentrations (Sheila, 2007). Generally, the hardness of stream or river water may emanate from natural source and human activities. Again, hardness of water varies with the nature of the geology of the catchment area. According to Exploring the Water Environment (2004), a streams' hardness reflects the geology of the catchment area and sometimes provides a measure of the influence of human activity in a watershed. For instance, acid mine drainage often release iron into a stream,

resulting in extraordinary high hardness readings. The effluent from Wastewater Treatment Plants can add hardness to a stream. The wastewater from our houses contains calcium, magnesium, and other cations from the cleaning agents, food residue, and human waste that we put down our drains (Sheila, 2007). As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution since it is an excellent solvent and readily dissolves minerals (Fairfax County Water Authority, 2011). In fact, the WHO has no health based guideline value for this parameter

(http://www.lenntech.com/applications/drinking/standards/who-s-drinking-water-standards.htm). However, waters with a total hardness in the range of 0 to 60 mg/L are termed soft; from 60 to 120 mg/L moderately hard; from 120 to 180 mg/L hard; and above 180 mg/L very hard (Sheila, 2007). A study of the physico-chemical parameters of surface waters in the lower Volta Basin, Ghana, from 1996-2006 indicated that their hardness ranged between 61 mg/L and 175 mg/L (Amoah and Koranteng, 2006) which by Sheila's (2007) classification is hard.

The importance of water hardness in aquatic life cannot be underestimated. According to William (2011), calcium has an important role in the biological processes of fish. It is necessary for bone formation, blood clotting and other metabolic reactions. Fish can absorb calcium for these needs directly from the water or food. The presence of free (ionic) calcium at relatively high concentrations in culture water helps reduce the loss of other salts (e.g. sodium and potassium) from fish body fluids (i.e. blood). Water hardness therefore is not a safety issue; it is safe for drinking, cooking, and other household use; however, it can cause several problems for consumers including decreased life of household plumbing and water-using appliances, increased difficulty in cleaning and laundering tasks, decreased efficiency

of water heaters, and white/chalky deposits on items such as plumbing, tubs, sinks, and pots and pans (Amber *et. al*, 2009).

2.2.6 Alkalinity as an indicator of water quality

Alkalinity is not a pollutant. It is a total measure of the substances in water that have "acid-neutralizing" ability. Alkalinity indicates a solution's power to react with acid and "buffer" its pH, that is, the power to keep its pH from changing

(http://www.h2ou.com/h2wtrqual.htm.).

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity. An investigation into concentrations of some physico-chemical and bacteriological qualities of water samples from the major streams within the Owabi watershed in Kumasi, Ghana showed mean levels of alkalinity in the samples which varied between 173 ± 24 and 251 ± 57.7 mg/L below the set standard (400mg/L) by the WHO (Osei *et al.*, 2009).

Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity - thus its good buffering capacity. Conversely, granite does not have minerals that contribute to alkalinity. Therefore, areas rich in granite have low alkalinity and poor buffering capacity. Alkalinity in streams is therefore influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (US EPA, 2010).

2.2.7 Total Dissolved Solids and Conductivity as indicators of water quality

"The expression, "total dissolved solids" (TDS), refers to the total amount of all inorganic and organic substances – including minerals, salts, metals, cations or anions that are dispersed within a volume of water. By definition, the solids must be small enough to be filtered through a sieve measuring 2micrometers. TDS concentrations are used to evaluate the quality of freshwater systems" (Wellcare, 2007). The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions (WHO, 2003). TDS is usually concerned with river water quality as it is related to salinity and water hardness, especially its ionic constituents. An investigation into concentrations of some physico-chemical and bacteriological qualities of water samples from the major streams within the Owabi watershed in Kumasi, Ghana showed mean levels of TDS in the samples which varied between 119 ± 57.6 and 572 ±38.9 mg/L (Osei *et al*., 2009) below the set standard -1000 mg/L (WHO, 2003).

The primary Sources for TDS in receiving waters include agricultural run-off, urban run-off, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks (WHO, 2003). The presence of dissolved solids in water may affect its taste; and the palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; Poor, between 900 and 1200 mg/L; and unacceptable, greater than 1200 mg/L (Bruvold and Ongerth, 1969).

The USEPA (2010) sees conductivity as a measure of the ability of water to pass an electrical current. Conductivity in water is affected by presence of organic and inorganic substances dissolved in it. It is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25^{o}C.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. It is used as an indicator of the presence of chlorides, nitrates, sulphates and phosphate anions (negatively charged ions) and sodium, magnesium, calcium, iron and aluminium cations (positively charged ions). If a conductivity level is high, it indicates a potential problem from these materials, (SDCK Watershed Wiki, 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.0 Study Area

Berekum Municipality lies between latitude 7/15/ south and 8.00/ north and longitude 2/25/ and 2/50 west of Sunyani, the regional capital. The Municipality lies in the semi-equatorial climatic zone with abundant sunshine and rainfall which produces a warm and humid weather. The average annual rainfall values for the area range between 1143 mm-1270 mm. The main rainy season occurs between May to August and the minor season in august to September. Patches of roofed savannah are found in the northern parts of the district notably, Domfete and Abi off the Berekum-Sampa road. Basically, the semi-deciduous forest is the dominant vegetation type, occupying about 80 per cent of the entire middle stretch of the land with isolated patches of wooded savanna in the Northern-most and with the eastern corner of the district (Berekum Municipal Assembly, 2006). The location of the Berekum Municipality on the Ghana map is shown below.

Figure 3.0 Map of Ghana showing the location of Berekum Municipality

(Source: http://www.mapsofworld.com/ghana/ghana-political-map.html

3.1 Geology and soil of Kankama Basin

The geology of the study area consists of metamorphic rock, which has undergone several thermodynamic changes in the mineral composition and structure. Upper and Lower Brimin rocks are the most predominant geological formation composed of phyllite, schist, tuff and grey rocks. Soils of the basin are mostly forest ochrosols, well-drained soils in the weathering products of intermediate or moderately acidic rocks. During the dry season there is a gradual increase in the level of nitrate and a more rapid increase as soon as the rain begins (Berekum Municipal Assembly, 2006).

3.2 Description of sampling area.

The Kankama River lies within the Berekum Municipality stretching to Sunyani. The river takes its source from the foot of mountain Kankama within the Berekum Township. The Kankama River lies in a semi deciduous forest type of vegetation.

Human population around the source is growing; and the major activities around the river include garages, car washing, meat processing, palm kernel extraction, cattle rearing, farming, and petty trading. During dry seasons, inhabitants around the river fetch the water for domestic activities like bathing, washing, cooking, gardening, etc. People who farm around the banks of the river use it for watering their crops. Farmers downstream farther away from the major sources of pollution drink it while on the farm

3.3 Description of study sites

The study was carried out along the main Kankama River which has its source at the foot of a mountain Kankama in the Berekum Township. The source is almost completely inhabited by Human beings; leaving a narrow belt of vegetation at the banks. Sampling was done at three sites along the river; namely, Amangoase (A), Cocoase (B), and Kyiribaa (C) (Fig. 3.3). Sampling site A is surrounded by refuse dumps, slaughter house, a kraal, garages and dense human settlement which are the major sources of contaminants or pollutants that enter the river at that site. Sampling site B was located 200 m downstream from site A. Pollution activities here are not serious except some few patches of farmlands and building construction works. Similar conditions exist at sampling site C.

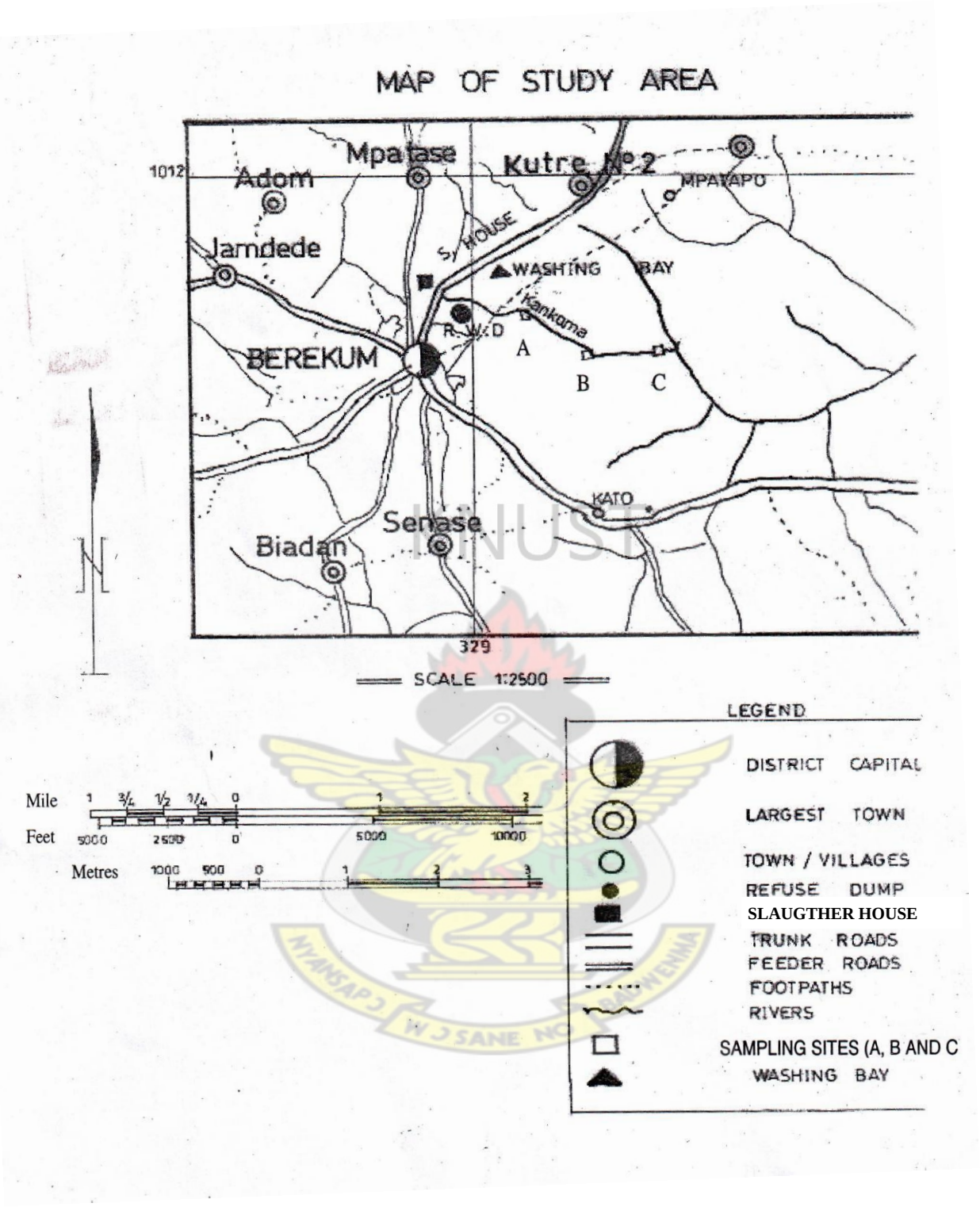

Figure 3.3 Map of study area showing sampling sites and the various land use of the catchment area (source: Berekum Municipal Assembly).

3.4 Treatment of sampling containers

Transparent plastic bottles, beakers, test-tubes, pipettes, syringes, used for the determination of the physico-chemical and biological parameters were washed with a brush using detergent OMO® (washing powder) solution under running water and thoroughly rinsed with warmed tap water to make sure that all the detergent is removed. The plastic bottles were made to dry by using air from a blower. The glass containers (beakers, test-tubes, pipettes and syringes) were sterilized in an autoclave at 121^{o}C for 15 minutes. The sterile bottles were caped and stored in a clean environment.

3.5 Sample collection

Monthly sampling was made at each sampling site over a period of four month starting from December, 2010 to March, 2011. The samples were collected using 1000 ml transparent plastic bottles. At each sampling point, a plastic bottle was filled with the river water by immersing it into the water at a depth of 5cm from the surface of the water. This was repeated anytime samples were to be taken over the study period. The caps of the plastic bottles were removed by making sure they were not contaminated. Also the bottles were filled by positioning their mouth in the direction of the water current. The filled bottles were properly labelled with the site number, date, and time immediately after collecting the water from the site.

Samples were packed into an ice chest with ice blocks on them to maintain the sample temperature at 4^{o}C to 10^{o}C. Sample bottles were not filled completely, at least 2.5 cm air space was allowed for mixing the sample prior to analysis. They were transported to the

microbiological laboratory at the Kwame Nkrumah University of Science and Technology within 24 hours after collection.

3.6 Preparation of MacConkey broth

An aluminium foil was placed on the scale and 40g of MacConkey powder was weighed. The 40g MacConkey powder was poured into a 1000 ml beaker and distilled water added to the mark. Thirty (30) column test-tubes racks were filled with test-tubes.

A 500 ml syringe was used to withdraw the prepared MacConkey broth into a beaker and 5ml of the broth were poured into each test-tube. The test-tubes were firmly corked using a clean cotton wool. In addition 10 ml of distilled water were also poured into different test-tubes and corked to serve as dilutes.

The corked test-tubes containing 5 ml of MacConkey broth were removed from the racks and arranged vertically in the autoclave basket. The test-tubes containing the 5 ml of MacConkey broth were sterilized in the autoclave at 121^{o}C for 30 minutes.

3.7 Determination of micro-organisms

Total coliforms, faecal coliforms and *E. coli* were isolated and enumerated using the three-tube Most Probable Number (MPN) method.

3.7.1 Total coliforms

5 m1 of the prepared media was measured and transferred into test tubes; and Durham tubes were inverted into them and corked. The test tubes with the media and inverted Durham tubes were sterilized in the autoclave for 15 minutes at 121^{o}C. Sample water dilutions of 10^{-1} - 10^{-8} were prepared with sterilized distilled water for each sampling site. Sample dilutions for each sampling site were defined from a trial sampling run.

A 1ml aliquot of each dilution was inoculated in triplicates in 5 ml of the sterilized MacConkey broth with the aid of a sterile pipette. These were incubated at 37^{o}C for 24 hours.

The incubated samples were observed after the 24 hours incubation period for total coliforms growth. Samples that were total coliform positive showed cloudiness and production of gas (CO_2) which was collected in the Durham tubes, and the colony forming unit per 100 ml (CFU/100 ml) was estimated using the MPN tables.

3.7.2 Faecal coliforms

Faecal coliforms were isolated and enumerated using the same procedure for total coliforms, but samples were incubated at 44.5^{o}C for 24 hours. Samples which showed cloudiness and production of gas above the media in the inverted Durham tubes were counted as faecal coliforms positive, and the colony forming unit per 100 ml (CFU/100 ml) were estimated using the MPN tables.

3.7.3 *E. coli*

Positive test tubes for faecal coliforms were collected and sample dilution of 10^1-10^8 were prepared serially. 1 ml of each of the diluted samples was transferred into a 5 ml of peptone water in triplicates. These were incubated at 44^{o}C for 48 hours. After the 48 hours, a few drops of Kovac's solution were added. Reddish ring formed around the tips of the meniscus of the media (peptone water) confirmed the presence of *E. coli*; and green ring confirmed the absence of *E. coli.*

3.8 Determination of pH

The pH of the water samples were measured in the field using a portable pH meter. The pH electrode was cleaned with distilled water and then calibrated in order to give a precise measurement using pH4, pH7 and pH10 standard buffer solutions before used to measure the water samples.

After calibration of the pH electrode, 50 ml of the water sample was poured into a small beaker. The pH electrode was immersed into the water sample and the pH reading was shown on the LCD of the meter. The pH was recorded after the reading stabilized. The procedure was repeated for all the three sampling sites namely Amangoase, Kookoase, and Kyiribaa.

After measuring the pH of water samples from each sampling site, the pH electrode was rinsed in distilled water. The pH electrode was calibrated anytime new samples were brought for analysis.

3.9 Determination of Total hardness

A 100 ml of the water sample was measured into a conical flask using a measuring cylinder. 1 ml of ammonia buffer solution was pipetted into the conical flask.

Eriochromschwarz T (powder particles) was added gradually and shaken until colour changed to violet. This was further titrated against EDTA and the colour changed to sea blue. The volume of EDTA that was added to attain the end point was recorded and multiplied by ten (10) as the total hardness of the water measured.

3.10 Determination of Conductivity and Total Dissolve Solids (TDS)

The Conductivity meter electrode was cleaned with a tap water and rinsed with distilled water or deionized water and gently blotted dried with a paper towel. Sodium chloride standard solution was put into a beaker and conductivity meter electrode put into it and calibrated to 1000 us/cm ± 10 us/cm. The calibration button was pressed and adjusted until it met the conductivity of the standard solution. 100 ml of sample water was poured into a beaker and the conductivity electrode / probe immersed into it. The probe was moved up and down, and it was slightly hit on the beaker to free bubbles from the electrode area.

Total Dissolved Solids (TDS) was measured by selecting the TDS key and values displayed were recorded.

The conductivity of the water sample was read on the LCD screen of the meter. The probe was rinsed in deionized water after final reading was taken. This was repeated for all the water samples at the various sampling sites.

3.11 Determination of Nitrate

The Wagtech photometer was used to measure nitrate in samples. Nitratest Tube was filled with sample to the 20 ml mark, and one level spoon full of Nitratest powder and one Nitrate tablet was added. The Tube was caped and shaken for one minute. The tubes were allowed to stand for about one minute and were gently inverted three times or four times to help flocculation. Again, the tube was allowed to stand for two minutes or longer to allow content to completely settle. The screwed caps were removed and the top of the tube was cleaned with a tissue. The clear solution was carefully decanted into a round test tube, topping it up to the 10 ml mark. A crushed Nitrates tablet was added and mixed to dissolve. The solution was allowed to stand for 10 minutes to develop full colour. The dial of the photometer was dialed to select wavelength of 570 nm and the reading was taken.

3.12 Determination of phosphate

10 ml of the water sample was measured into a test tube. One phosphate HR tablet was crushed and dissolved in the sample. It was then allowed to stand for 10minutes for full colour development. A wavelength of 490 nm was selected on the spectrophotometer and the reading was recorded.

3.13 Determination of Alkalinity

A 50 ml of the water sample was pipetted into a clean 250 ml Erlenmeyer flask; and three drops of phenolphthalein indicator was added until sample turned pink. This was titrated with standardized solution of 0.1N H_2SO_4 until the pink colour just disappeared; and the burette volume was recorded. Next, five drops of methyl orange indicator was added to the titration

flask (i.e. sample in which phenolphthalein alkalinity was determined). Titration was continued with standardized 0.1N H_2SO_4 until the colour changed from bluish green to light pink; and the final volume was recorded.

3.14 Data Analysis

The data collected from the field were analyzed using SPSS to calculate the mean values, standard errors and p-values, and Microsoft Excel to draw the bar graph

CHAPTER FOUR

RESULTS

4.0 Levels of physico-chemical parameters at the sampling sites

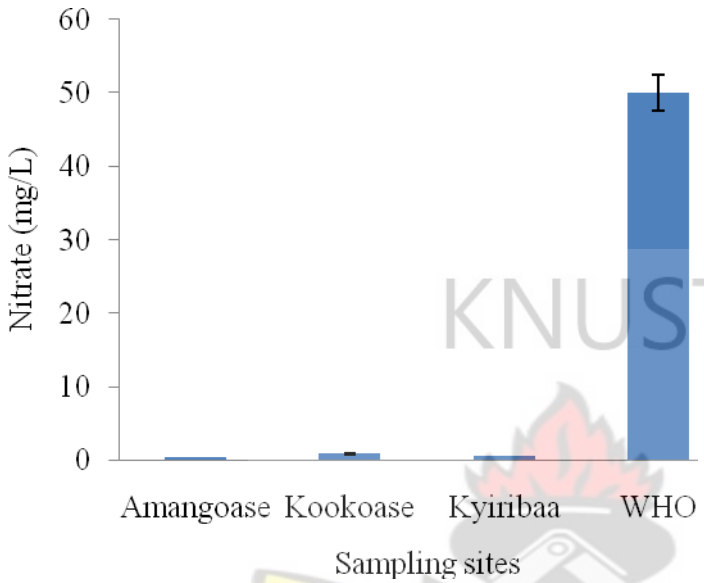

Figure 4.0a: Nitrate levels at all the sampling sites

The mean Nitrate concentrations at all the sampling sites are indicated in figure 4.0a above as 0.435 mg/L, 0.823 mg/L, and 0.575 mg/L at Amangoase, Kookoase and Kyiribaa respectively. Kookoase recorded the highest nitrate level of 0.823 mg/L; followed by Kyiribaa of 0.575 mg/L. Amangoase recorded the lowest nitrate level of 0.435 mg/L. From the figure above it is apparent that the concentrations of nitrate at the three sampling site were far below the WHO (1993) guideline value of 50 mg/L, and therefore not polluted with nitrate. The variation of nitrate among the three sampling sites was not significant ($p=0.27$) at 95% level of confidence.

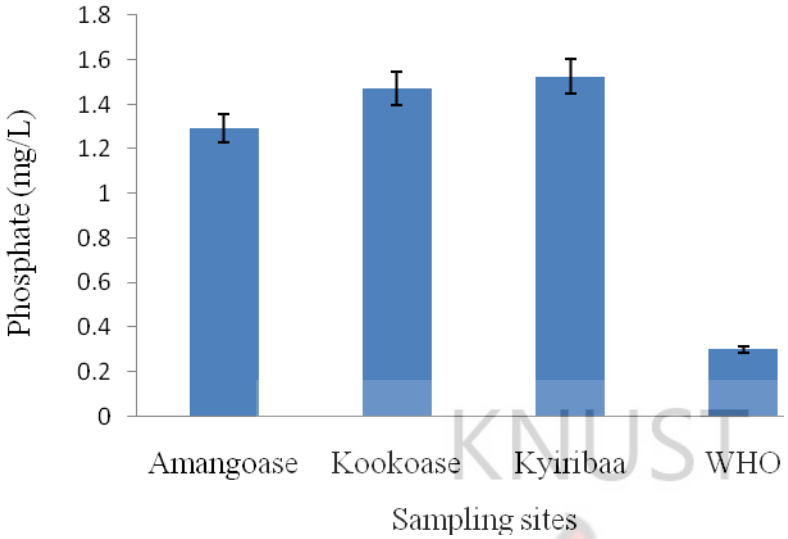

Figure 4.0b: Phosphate levels at the sampling sites

The phosphate levels at the three sampling sites are presented in Figure 4.0b above. Amangoase recorded the lowest mean phosphate level of 1.293 mg/l; followed by Kookoase with phosphate level of 1.472 mg/L. The highest mean phosphate level of 1.525 mg/L was recorded at Kyiribaa. Phosphate levels therefore increased gradually from Amangoase to Kyiribaa. Generally, all the phosphate levels recorded at all the sampling sites were above the WHO guideline value of 0.3 mg/L; and hence the river has phosphate pollution problem. The variation of phosphate among the three sampling sites was not statistically significant ($p=0.824$) at 95% level of confidence.

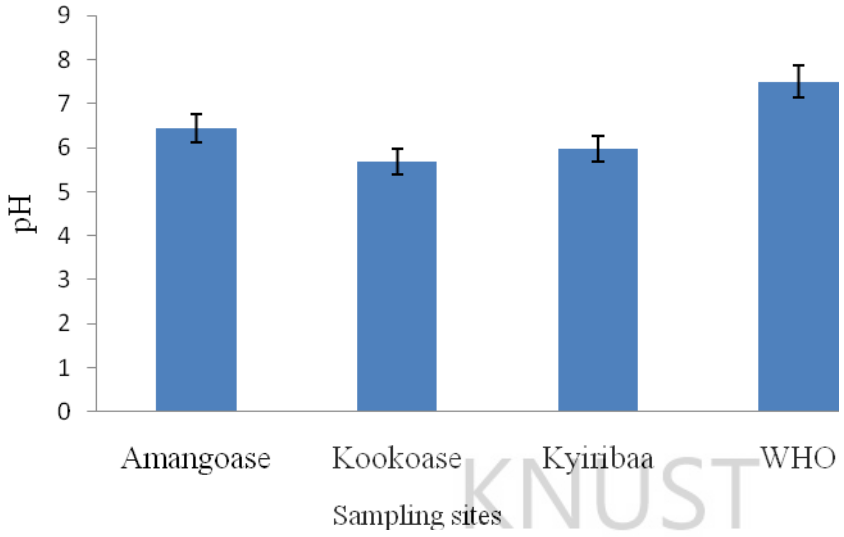

Figure 4.0c pH levels at the sampling sites

The mean pH values at Amangoase, Kookoase and Kyiribaa are 6.428, 5.676 and 5.977 respectively are shown at Fig 4.0c. Amangoase recorded the highest pH level. It was followed by Kyiribaa. The lowest pH level was recorded at Kookoase. The pH levels recorded at all the sampling sites were below the WHO guideline range of 6.5-8.5. Thus the river has water quality problem with respect to pH. The variation of pH among the three sampling sites was not significant (p=0.954) at 95% level of confidence.

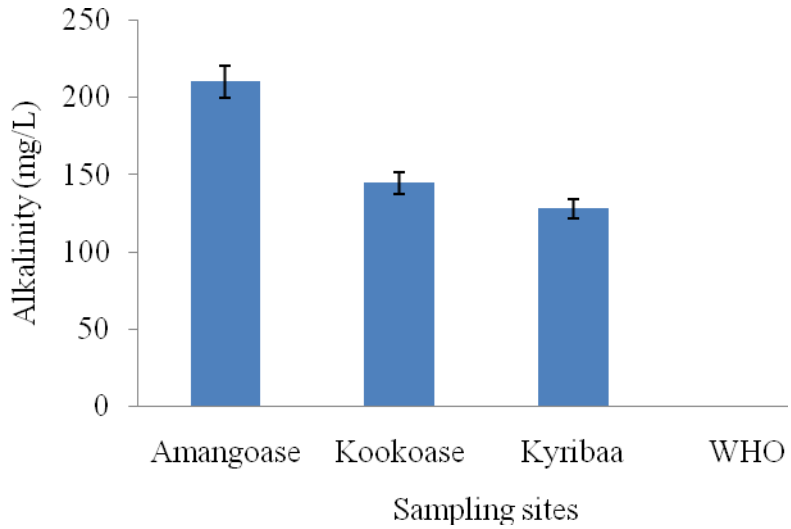

Figure 4.0d: Alkalinity levels at the sampling sites

Mean Alkalinity levels at the various sampling sites are indicated on fig 4.0d above as 209.75 mg/L, 144.25 mg/L and 127.75 mg/L at Amangoase, Kookoase and Kyiribaa respectively. Amangoase recorded the highest alkalinity level; followed by Kookoase. Alkalinity decreased from upstream at Amangoase to downstream at Kyiribaa. The lowest alkalinity level was recorded at Kyiribaa. The variation of Alkalinity among the three sampling sites was statistically significant (p=0.014) at 95% level of confidence.

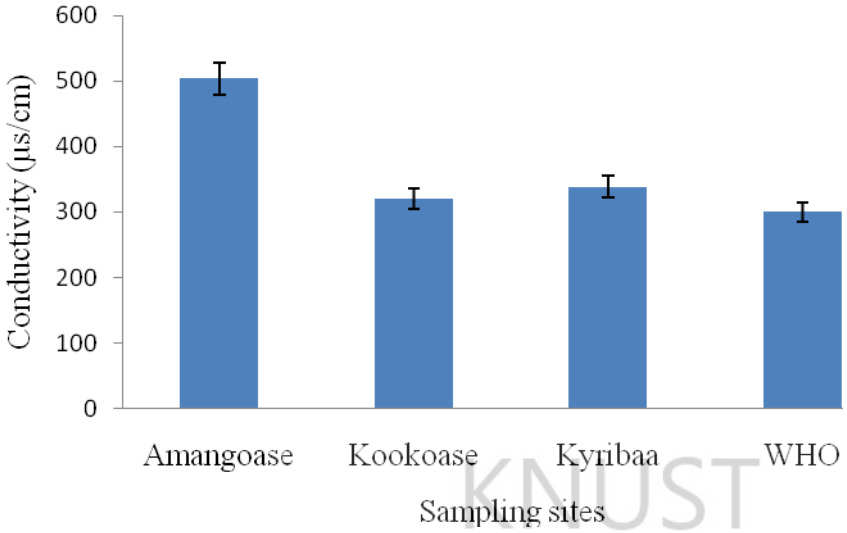

Figure 4.0e: Conductivity levels at the sampling sites

Mean Conductivity levels at the three sampling sites namely Amangoase, Kookoase and Kyiribaa are shown in Figure 4.0e. Amangoase recorded the highest conductivity level of 503.5 µs/cm; followed by Kyiribaa of 339 µs/cm. The lowest conductivity level of 320.75 µs/cm was recorded at Kookoase. The conductivity levels recorded at the three sampling sites were below the WHO (1993) guideline value of 2500 µs/cm. The variation of conductivity among the three sampling sites was statistically significant (p=0.000) at 95% level of confidence.

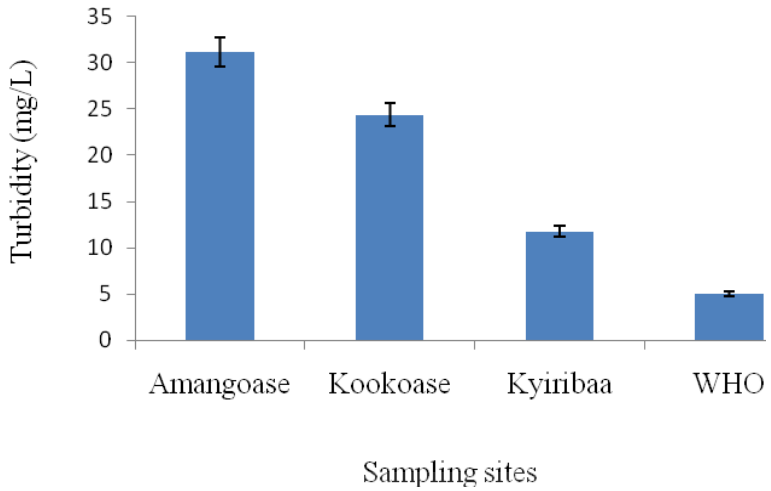

Figure 4.0f: Turbidity levels at the sampling sites

Mean Turbidity levels at the various sampling sites are indicated on fig 4.0f above. From this figure, it can be observed that the mean turbidity levels at Amangoase, Kookoase and Kyiribaa are 31.155 NTU, 24.4 NTU and 11.76 NTU respectively; with Amangoase recording the highest turbidity level of 31.155 NTU; followed by Kookoase of 24.4 NTU. The lowest turbidity level of 11.76 NTU was recorded at Kookoase. All the turbidity levels recorded at all the sampling sites were above the WHO (1993) guideline value of 5 NTU. The turbidity levels followed a pattern-decreasing from upstream to downstream. The variation of turbidity among the three sampling sites was statistically significant (p=0.000) at 95% level of confidence.

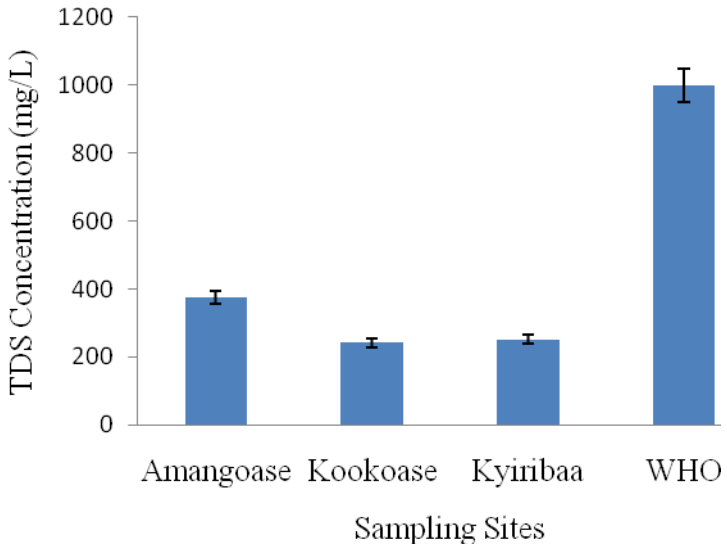

Figure 4.0g: TDS levels at the sampling sites

Mean Total Dissolved Solids (TDS) levels at the sampling sites are indicated in fig 4.0g above. From this figure it can be observed that the mean TDS levels at Amangoase, Kookoase and Kyiribaa are 373.725 mg/L, 241.25 mg/L and 251.55 mg/L respectively. Amangoase recorded the highest TDS level of 373.725 mg/L; followed by Kyiribaa of 251.55 mg/L. The lowest TDS level of 241.25 mg/L was recorded at Kookoase. Generally, all the TDS levels recorded at all the sampling sites were below the WHO (2003) guideline value of 1000 mg/L. The variation of TDS among the three sampling sites was statistically significant (p=0.000) at 95% level of confidence.

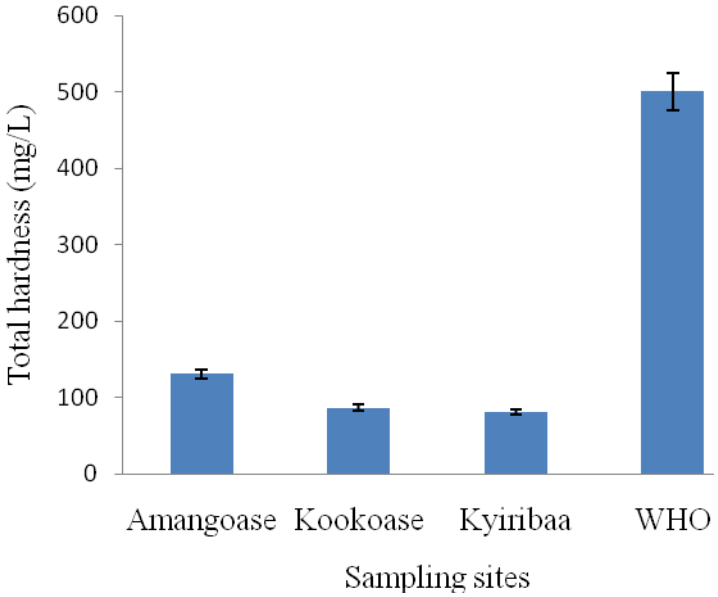

Figure 4.0h: Total hardness at the sampling sites

Mean total hardness of the water at the sampling sites are indicated on fig 4.0h above. From this figure, the mean total hardness level at Amangoase, Kookoase and Kyiribaa are 130.6 mg/L, 86.42 mg/L and 80.81 mg/L respectively. Amangoase recorded the highest total hardness; followed by Kookoase. The lowest total hardness was recorded at Kyiribaa. Total hardness levels at the three sampling sites were below the WHO (1993) guideline limit. The variation of Total hardness among the three sampling sites was statistically significant ($p=0.000$) at 95% level of confidence.

4.1 Populations of total coliforms, faecal coliforms and *E. coli* at the sampling sites

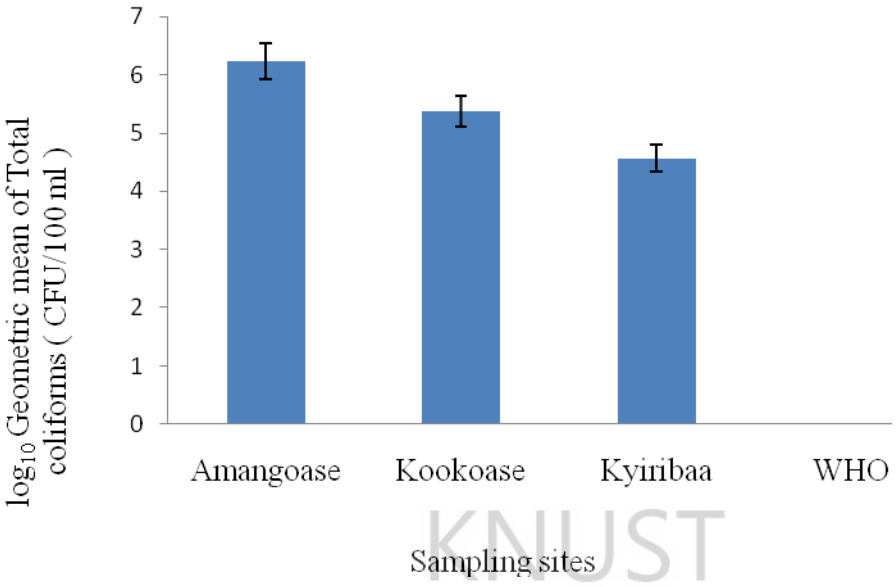

Figure 4.1a: Total coliforms count at the sampling sites

The mean total coliforms numbers/populations at the three sampling sites, namely Amangoase, Kookoase and Kyiribaa are shown in Figure 4.1a. Amangoase recorded the highest mean Total coliforms population of 6.239 CFU per 100 ml (log_{10} Geometric mean) with a range of 4.92 to 9.71 CFU/100 ml (log_{10} Geometric mean). The next highest mean of 5.379 CFU/100 ml (log_{10} Geometric mean) was at Kooakoase with a range between 4.62 to 7.37 CFU/100 ml (log_{10} Geometric mean) over the study period. The lowest mean of 3.4462 CFU/100 ml (log_{10} Geometric mean) was obtained at Kyiribaa with range of 3.71 to 5.96 CFU/100 ml (log_{10} Geometric mean). The mean Total coliforms populations at all the sampling sites were far above the WHO (2003) guideline value of 0 CFU/100 ml.

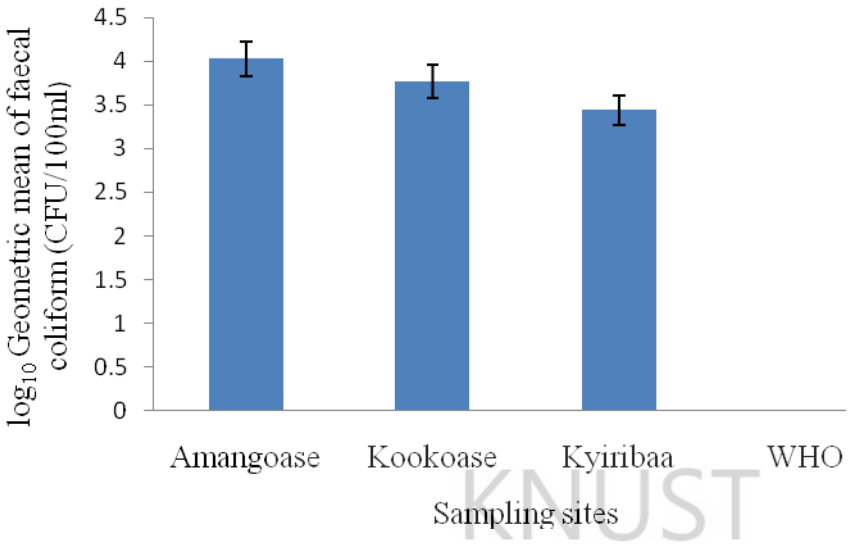

Figure 4.1b Faecal coliforms count at the sampling sites

The mean faecal coliforms numbers at the three sampling sites namely, Amangoase, Kookoase and Kyiribaa are presented in figure 4.1b. Amangoase sampling site recorded the highest mean number of faecal coliforms of 4.024 CFU per 100 ml (log_{10} Geometric mean) with a range of 3.37 to 5.37 CFU (log_{10} Geometric mean). The next highest mean of 3.77 was at Kookoase with a range between 2.96 to 4.96 CFU per 100 ml (log_{10} Geometric mean) over the study period. The lowest mean of 3.4462 CFU/100 ml (log_{10} Geometric mean) was obtained at Kyiribaa with range of 2.62 to 4.37 CFU per 100 ml (log_{10} Geometric mean). The mean faecal coliforms populations at all the sampling sites were above the WHO (2003) guideline value of 0 CFU/100 ml.

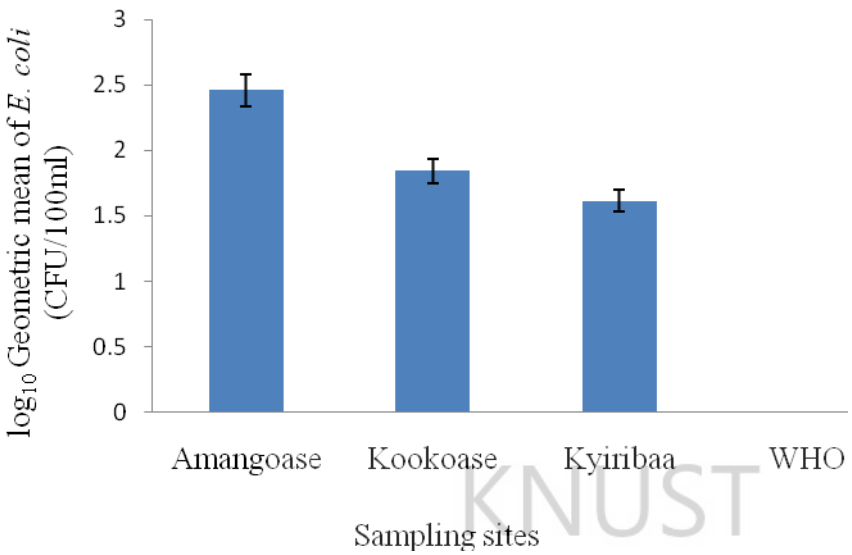

Figure 4.1c: *E. coli* count at all the sampling sites

The mean *E. coli* count at all the sampling sites is shown in Figure 4.1c. Amangoase sampling site recorded the highest mean *E. coli* population of 2.84590 CFU per 100 ml (log_{10} Geometric mean) with a range of 1.89 3.62 CFU/100 ml (log_{10} Geometric mean). The next highest mean of 1.8433 CFU/100 ml (log_{10} Geometric mean) was at Kookoase with a range between 1.52 to 2.62 CFU/100 ml (log_{10} Geometric mean) over the study period. The lowest mean of 1.616362 CFU/100 ml (log_{10} Geometric mean) was obtained at Kyiribaa with range of 1.11 to 2.37 CFU/100 ml (log_{10} Geometric mean). The mean *E. coli* populations at all the sampling sites far exceeded the WHO (2003) guideline value of 0 CFU/100ml. The variation of Total coliforms (p=0.395), faecal coliforms (p=0.625) and *E. coli* (p=0.206) among the three sampling sites was not statistically significant at 95% level of confidence.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.0 Levels of indicator bacteria

The results show that Kankama River is highly polluted with indicator bacteria (total coliforms, faecal coliforms, and *E. coli*). The presence of these bacteria, more especially the faecal coliforms and the *E. coli* in the water is evidence of faecal contamination from human and warm-blooded animals and, therefore, of the risk that pathogens are present; and if indicator bacteria are present in large numbers, the contamination is considered to be recent and/or severe (www.environment-agency.gov.uk).

The high numbers of indicator organisms at the Amangoase sampling site may be due to the unacceptable sanitary practices by some people living at the catchment area. For instance, it is not uncommon to see people defecating around the river banks, and directing wastewaters from residential facilities into the river course. This practice is due to lack of public toilets or toilets in the individual residences and lack of scientifically constructed waste dumpling site for communities around the river. This situation is worsened by a gang of marijuana smokers who gather at a so- called 'wee base' along the bank to smoke and relax. While at this base they defaecate, and urinate direct into the river, and dump various kind of wastes they generate into it. This is in line with a study conducted by Young and Thackson (1999), to establish the source of the unexpectedly high bacterial concentrations of rivers and streams near Nashiville, Tennessee. It showed that total coliforms and faecal streptococci concentrations directly relates to the housing density, population, development, imperviousness of roads and streets, animals density; and surface runoff from densely populated, and sewered areas.

Another important contributory factor to this high increase in indicator bacteria is that, the river acts as a sink for most of the runoffs from Amangoase, zongo, Ahenebronoso and Berenyekwa communities as well as the slurry from the slaughter house that supply the municipality with meat. The slaughter house is located about 30 m away from the headwater/ source. The dung of animals waiting in a kraal to be slaughtered is washed into the river when it rains. This agrees with the findings of Doyle and Erickson (2006), that faecal coliforms bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage. Their presence may also be the result of plant material, and pulp or paper mill effluent. More so, faeces of pets like dogs and other domestic animal are washed into the river. According to Lim and Oliver (1982) dog faeces were identified as the single greatest source contributing feacal streptococci to Balttimore catchment.

In addition, Weiskeh *et al.* (1996) reported that faecal coliforms concentrations in storm water runoff from impervious surfaces were related to the surrounding land use. The highest faecal coliforms yields, from a high – density residential areas were significantly higher than those associated with nearby moderate-density residential, commercial and low-density residential areas.

5.1 Physico-chemical parameters.

The turbidity levels at all the sampling sites were above the WHO drinking water guideline value of 5 NTU (Figure 4.0f). This means the water is highly polluted in relation to turbidity. According to American Public Health Association (1998), turbidity in water is caused by suspended matter such as clay, silt and organic mater as well as by plankton and other microscopic organisms.

Again, turbidity in the river could emanate from runoffs from residential areas. These runoffs carry silt, clay and organic matter into the water. The high turbidity level at Amangoase could also be due to building construction works and the existence of an un-bitumen road near the river at Amangoase sampling site.

The relatively low levels of turbidity at Kookoase and Kyiribaa even though above the WHO (1993) drinking water guideline of 5 NTU could be due to the presence of appreciable vegetation cover at these sites. Again, small-scale agricultural undertakings at the Kookoase and Kyiribaa sites may input sediments and nutrients into the water which could stimulate algae growth, and thus increase turbidity. These may account for the observed turbidity at the sites.

The differences in turbidity observed between the sampling sites may be due to the variation of density of vegetation cover and human population at the various sites. Grazing by cattle, sheep and goats have almost removed the vegetation cover thereby exposing the top soil to erosion, hence scouring soil particles into the water. The river supplies animals in the area with drinking water and through their drinking process they destabilize the banks and the soil slide into the water making it turbid. The activities of car washing, garages, palm kernel oil extraction at the area feed the river with grease, oils and silt. Elevated turbid water is often associated with the possibility of microbiological contaminations as high turbidity makes it difficult to disinfect water properly (D.W.A.F, 1998).

The conductivity measured over the study period at all the sampling sites exceeded the WHO (1993) guide line value for drinking water. Meaning the river has a lot of metal ions dissolved in it. The high conductivity of the water could come from many undefined (non-point) sources. Runoffs from surrounding communities could carry a lot of dissolved ions washed from garages, market areas, roads, laundries, car washing bays into the river, more especially at the Amangoase sampling site. Phosphates, nitrates and chloride are some of the possible ions inputs in the river (SDCK Watershed Wiki, 2010). A heap of refuse dump near the river which continuously drains its leachate into the river may well contribute to the elevated levels of conductivity. The high conductivity at the Amangoase sampling site may also be due the farming activities and the accompanying fertilizers, pesticides and herbicides application. The low conductivity levels at Kookoase and Kyiribaa sampling sites even though they were all slightly above the WHO guideline value could be due to the less human activities at this area.

Amangoase had the highest total dissolved solids (TDS) level followed by Kookoase; and Kyiribaa, the lowest. In all the three cases, TDS levels were below the WHO guideline value and therefore the TDS levels were satisfactory. The low TDS levels may be due to the season of the study, since during the dry season there were no rainfalls with consequent runoffs. However, the highest TDS level at Amangoase site may be because the vegetation cover at the catchment area had been removed for the purposes of buildings, roads and playgrounds. Other important contributory factors included the car washing activities and the slurry from the slaughter house coupled with wastewaters from residences that were directed into the river; and a few agricultural activities that were going on in the area. This is in consonance with the assertion by WHO (2003), that the primary Sources for TDS in receiving waters include agricultural run-off, urban run-off, industrial wastewater, sewage, and natural sources

such as leaves, silt, plankton, and rocks. According to Bruvold and Ongerth (1969), palatability of drinking water has been related to its TDS. It is rated as excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; Poor, between 900 and 1200 mg/L; and unacceptable, greater than 1200 mg/L. Based on this, the palatability of water at Amangoase could be rated as good and that of Kookoase and Kyiribaa as excellent.

Nutrients are needed for survival and growth of aquatic plants. However, if they are present in excess in water, they over stimulate the growth of aquatic plants leading to water quality problems. High concentration of NO_3^- is a potential health risk, particularly in pregnant women and infants under 6 years of age (Kempster *et al.*, 1997).

The mean Nitrate values at all the sampling sites were below the drinking water Nitrate guideline value set by WHO (1993), hence the river was not nitrate polluted. The levels of nitrate recorded at the study area could be as a result of certain natural processes like decomposition of vegetation and activities of nitrogen fixing bacteria and precipitation. The time of the study could be a factor for the nitrate levels recorded because during dry seasons concentration of nutrients were likely to rise since the volume of water in the stream decreased.

Most importantly, the major causes of high nitrate concentration could be due to the human activities that go on around the catchment of the study area. The location of a slaughter house, a kraal and a refuse dump very close to the river and coupled with runoffs from residential areas and agricultural fields input nitrate into the river. This is in line with the findings of Donald (2012), that elevated levels of nitrate is often noted in streams and rivers draining watersheds with high levels of corn production, nitrogen fertilizer application as well as runoffs from uncontained livestock operations.

Again, from figure 4.0b above, the phosphate level was generally high above the WHO guideline value. The use of detergents in car washing and the use of fertilizers in farming at the banks could be the possible source of high phosphate concentration in the river. The geological characteristics could also influence the recorded phosphate levels.

According to Brain (2011) studies of total phosphate and phosphorus in surface waters, it was established that during natural process of weathering, rocks gradually release phosphorus as phosphate ions which are soluble in water and gradually mineralize phosphate compounds breakdown. Further, a study in Cape Cod, Massachusetts showed that phosphorus can also migrate with ground water flow, and since ground water discharges into surface water such as stream banks, there is a concern about phosphorus concentration in ground water that affects the quality of surface water.

(http://www:ga.com.za/ewater.usgs.gov/edu/urbanpho.htm).

The total hardness for the three sampling sites as indicated in figure 4.0h above is below the WHO guideline value. According to Sheila (2007) when total hardness in water is too low, the water is referred as fresh, soft water. Waters with a total hardness in the range of 0 to 60 mg/L are termed soft; from 60 to 120 mg/L moderately hard; from 120 to 180 mg/L hard; and above 180 mg/L very hard. Therefore the water was hard at Amangoase with a mean hardness of 130.60 mg/L whilst Kookoase and Kyiribaa waters were moderate with mean hardness of 86.42 mg/L and 80.81 mg/L respectively. The low total hardness may be due to the composition of the minerals present in the earth in which the aquifer containing the water is located, or underlying bedrock of the river. According to Exploring the Water Environment (2004), a stream's hardness reflects the geology of the catchments area and sometimes provides a measure of the influence of human activity in watershed.

Alkalinity levels at all the three sampling sites, Amangoase, Kookoase and Kyiribaa, were all below the WHO guideline limits (Fig 4.0d). The high alkalinity level at the Amangoase though below the set guideline value could be due to its nearness to a refuse damp, slaughter house and livestock confinement which drains ions like carbonates, bicarbonates into the water. The alkalinity may also be influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (US EPA, 2010). The relatively low alkalinity values means that the water may have a low capacity to neutralize or "buffer" incoming acids and, therefore could be susceptible to acidic pollution since alkalinity is a measure of all the substances in water that can resist a change in pH when acid is added to the water. This reflects the very low pH values recorded in this study.

From the figure 4.0c above the mean pH readings at the sampling sites are 6.542, 5.676, and 5.977 at Amangoase, Kookoase and Kyiribaa respectively. The mean value at Amangoase fell within the WHO range for pH in water for domestic use of 6.5-8.5 (WHO, 2003). Kookoase and Kyiribaa recorded mean values below the WHO guideline values. The observed pH values at sampling point could be attributed to the refuse damps, slaughter house and agricultural activities in the catchment area. Stephanie and Naomi (1998) indicated that acid soils and rocks such as basalt, granite and sandstone contribute to lower pH values in water. Therefore the low pH values of the Kankuma River may be due to the nature of its geology. This low pH means that the river has a very weak buffering capacity because of the geological composition.

Comparing the various levels pH recorded at the Kankama River to those recorded by Osei *et al.* (2009) from the major streams of Owabi watershed in Kumasi, it can be said that Kankama River had very low mean pH values at the three sampling sites. Therefore based on the guideline limits the waters at the Kookoase and Kyiribaa sampling sites were acidic or

acid polluted. According to RAMP (2010) a pH value of 7.0 is considered neutral, while values below 7.0 are considered acidic, and above 7.0 are basic. The pH of most natural waters is between 6.0 and 8.5. By implication, the pH of the river is acidic and could have a detrimental effect on some aquatic lives and also affect its suitability for domestic use.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Conclusion

The results indicated that most of the physico-chemical parameters of river Kankama were above the WHO limits for drinking water and, therefore water fetched from the Kankama River may be unsuitable for domestic purposes. In addition, the bacteriological quality of the water as suggested by the total coli forms, faecal coliforms and *E. coli* counts, far exceeded the standard (0 CFU/100 ml) for potable water. On the whole, the water quality with respect to physic-chemical and bacteriological quality was unacceptable and has the potential to pose serious health risk to consumers without pretreatment. This poor water quality may be due to specific land use activities in the catchment area like refuse dumping, slaughter house operations and car washing. Other contributory factors to the observed poor water quality were direct human defecation along the river banks and runoffs from the municipality.

The Amangoase sampling site recorded the highest levels of both physico-chemical and bacteriological qualities; followed by Kookoase and Kyiribaa sampling sites.

6.1 Recommendations

The observed poor quality of the river water can pose ecological and human health problems. It is therefore recommend that:

1. The inhabitants around the river catchment area should be educated on the adverse impacts of their activities on the river water quality and subsequent effect on their health.

2. The Municipal Assembly should put measures in place to ensure that there is no further encroachment on the river bank by individuals for the purpose of building and vegetables cultivation.

3. Tree planting around the river banks should be encouraged.

4. The refuse dump near the river as a matter of urgency should be relocated as well as the slaughter house.

5. The car washing activities that go on in the river should be stopped.

6. The notorious ‘wee base’ at the Amangoase site should be collapsed since it is the major source of fresh human faeces in the river.

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APPENDICES

Physico-chemical Parameters

APPENDIX 1: Field research results in Dec. 2010

Report of analysis

Parameter	Sampling sites		
	A	B	C
Nitrate	0.57	0.79	0.14
Phosphate	18	18	21
PH	8.42	8.24	7.68
Conductivity	524	377	360
Turbidity	33.54	27.00	13.32
TDS	390.2	280.8	268.1
Alkalinity	210	200	163
Total hardness	130.4	93.16	81.28

APPENDIX 2: Field research results in Jan, 2011

Report of analysis

Parameter	Sampling sites		
	A	B	C
Nitrate	0.79	0.44	0.66
Phosphate	21	16	15
PH	8.12	6.94	8.06
Conductivity	437	274	315
Turbidity	25.16	21.64	11.23
TDS	325.4	204.0	234.5
Alkalinity	168	108	135
Total hardness	116.16	68.76	87.28

APPENDIX 3: Field research results in Feb, 2011

Report of analysis

Parameter	Sampling sites		
	A	B	C
Nitrate	0.19	1.06	0.70
Phosphate	3.7	14.4	12.8.01
PH	8.30	7.52	7.68
Conductivity	522	316	345
Turbidity	30.62	23.42	9.45
TDS	388.6	235.2	256.8
Alkalinity	228	130	103
Total hardness	134.64	90.76	76.28

APPENDIX 4: Field research results in March, 2011

Report of analysis

Parameter	Sampling sites		
	A	B	C
Nitrate	0.19	1.0	0.8
Phosphate	9.00	14.7	13.0
PH	8.45	7.42	7.40
Conductivity	531	316	336
Turbidity	35.3	25.54	13.04
TDS	390.7	24.50	246.8
Alkalinity	233	139.0	110.0
Total hardness	141.2	93.0	78.40

APPENDIX 5: Report of bacteriological analysis

Sample	Total Coliforms/100 ml		Feacal coliforms/100 ml		*E. coli* /100 ml	
7/12/10						
A	93 x d08	9.0×10^8	2.4×10^5	2.3×10^5	4.3×10^3	4.0×10^3
B	2.4×10^7	2.3×10^7	9.3×10^4	9.0×10^4	4.3×10^2	4.0×10^2
C	9.3×10^5	9.0×10^5	2.4×10^4	2.3×10^4	2.4×10^2	2.3×10^2
17/01/2011						
A	2.4×10^5	2.3×10^5	2.4×10^3	2.3×10^3	2.4×10^2	2.3×10^2
B	2.1×10^4	9.0×10^4	9.3×10^2	9.0×10^2	4.3×10^1	4.0×10^1
C	4.3×10^4	4.0×10^4	4.3×10^2	4.0×10^2	2.3×10^1	2.3×10^1
7/02/2011						
A	9.3×10^4	9.0×10^4	4.3×10^3	4.0×10^3	9.3×10^1	9.0×10^1
B	4.3×10^4	4.0×10^4	1.5×10^3	4.0×10^3	4.3×10^1	4.0×10^1
C	9.3×10^3	9.0×10^3	4.3×10^3	4.0×10^2	4.3×10^1	4.0×10^1
7/03/2011						
A	7.5×10^4	9.0×10^4	3.9×10^3	7.0×10^3	6.4×10^1	9.0×10^1
B	9.3×10^4	2.8×10^4	7.0×10^3	3.0×10^3	4.3×10^1	2.3×10^1
C	3.9×10^3	6.4×10^3	4.3×10^3	7.0×10^2	1.5×10^1	1.1×10^1

Table 4.0: Means, standard errors, and p-values of the parameters for the various sampling sites

Parameters	Sampling sites			P-value
	Amangoase	Kookoase	Kyiribaa	
Nitrate	0.435 (0.148)	0.823 (0.140)	0.575 (0.148)	0.217
Phosphate	1.293 (0.399)	1.472 (0.159)	1.525 (0.202)	0.824
pH	6.428 (1.863)	5.676 (1.622)	5.977 (1.742)	0.954
Conductivity	503.50 (22.25)	320.75 (21.20)	339 (9.41)	0.000*
Turbidity	31.155 (2.219)	24.40 (1.177)	11.76 (0.898)	0.000*
TDS	373.725 (16.115)	241.25 (15.818)	251.55 (7.157)	0.000*
Alkalinity	209.75 (14.767)	144.25 (19.69)	127.75 (13.61)	0.014*
Total hardness	130.60 (5.30)	86.42 (5.91)	80.81 (2.39)	0.000*
Total Coliforms	6.239 (1.161)	5.379 (0.665)	4.563 (0.504)	0.395
Faecal Coliforms	4.024 (0.455)	3.765 (0.427)	3.439 (0.359)	0.625
E. Coli	2.459 (0.407)	1.843 (0.259)	1.616 (0.272)	0.206

*. Significant at the 0.05 level (2-tailed) NB: Standard errors in brackets