KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

EFFECTS OF MUNICIPAL SOLID WASTES ON FOUR MAJOR RIVERS IN GYENEGYENE, BEREKUM MUNICIPAL

SALIFU ALI DAYINDAY

SEPTEMBER, 2011

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A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (ENVIRONMENTAL SCIENCE)

SALIFU ALI DAYINDAY

SEPTEMBER, 2011

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 be presented for another degree elsewhere and that reproduction of this thesis in part or in full is strictly reserved unless authorized by the author and the parties associated with this work, herewith under a written agreement.

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DEDICATION

I wish to dedicate this thesis to my Mother, Ramatu Karim (a.k.a Away), my lovely wife, Amadu Ayinawu and my dear children, Shakur, Raiyan and Ridwan Ibn Ali for being a great source of inspiration through their limitless prayers, support and motivation throughout my thesis work.

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ABSTRACT

The effects of Municipal Solid Wastes on Major Rivers; Suntri, Mmabamena, Kyenebra and Slaughter house Suntri in the Gyenegyene Community, were investigated from August, 2010 to July, 2011. Physico-Chemical parameters; pH, Colour and Turbidity, Mercury, Phosphate and Nitrate and microbial load were investigated using Standard methods.

A total of thirty-two (32) samples were taken and analyzed. pH was below the World Health Organization Guidelines value of 8.50 pH and the Ghana Environmental Protection Agency Guideline value of 9.00. All the sampling sites had temperatures and colour values below the acceptable Guidelines. However, microbial loads in the rivers were high. Phosphate and Nitrate were below the EPA and WHO guidelines values. Lead (Pb) and Mercury concentrations were above the permissible limit of 0.01mg/L for heavy metal contamination of rivers. A cluster analysis performed on the data to establish contamination trends between the rivers showed that Slaughter House Suntri was the most polluted and Mmabamena was the least polluted.

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CHAPTER ONE

1.0 INTRODUCTION

Water pollution is any physical, chemical, or biological change in the quality of water that has a harmful effect on any living organism that drinks or uses or lives in the water. When humans drink polluted water it often has serious effects on their health. Water pollution involves the introduction of anything which adversely and unreasonably impairs the beneficial use of water even though actual health hazard may not be involved (Klein *et al.,* 1962).

Every economic activity makes use of water in some way. Water managers look at direct uses of water – as coolant, cleaning agent, power source, for drinking, irrigation and diluting wastes-and classify them as to whether they are 'consumptive' or 'non consumptive'. There is a sense in which the technical terms "consumptive use" and "non-consumptive use" mislead people into thinking that using water as a sewer for waste, or to turn turbines, or to cool steam that turned turbines, or for any other "non-consumptive use" makes no demands on the environment, for no water is consumed. In fact, although the same amount of water may be returned to the water body that supplied it, some part of the aquatic ecosystem has probably suffered, or will suffer, because of the disruption in supply or a change in the quality of the water.

Water bodies have limited capacity to absorb the impacts of waste discharged into them. Rivers and lakes continue to be used as sinks for disposal of society's wastes. Some pollutants, such as municipal and industrial effluents, are discharged directly into aquatic ecosystems which are referred to as point source pollutants (Hart, 2009). Other path ways for example, urban and agricultural runoff and air deposition- and more diffuse and indirect are considered non-point sources. Contaminants, whether deliberately or accidentally released, can enter water body directly or indirectly. Although this distinction between point and non-point sources makes little difference from an overall ecosystem perspective, it is important from a prevention and management viewpoint. When one considered an aquatic ecosystem as a whole and just water as a resource, very few human activities are truly non consumptive (Keyser, 1997).

Non-point pollution from several waste dumps, some the size of small mountains, dot the landscape around 'Gyenegyene' which may pollute water bodies in various locations throughout the catchment area. Preventive activities are not adequate, so surface and groundwater quality may be degenerating in this area. The major water pollutants are chemical, biological, or physical materials that degrade water quality and present its own set of hazard (Charest, 1991)

Pollutants in water include a wide spectrum of chemicals, pathogens and physical chemistry or sensory changes. Many of the chemical substances are toxic. Pathogens can obviously produce waterborne diseases in either human or animal hosts. Alterations of water's physical chemistry include acidity, conductivity, temperature and eutrophication (Svobodova *et al.,* 1993).

The frequent contamination of surface water in many parts of the world by *Cryptosporidium* and *Giardia* oocysts is well established (Smith *et al.,* 1995). Providing clean drinking water for the growing population of the inhabitants of Gyenegyene is one of the most pressing issues in the Community. Although drinking water may not carry detectable concentration of toxic chemicals, the cumulative effect of long-term, low- dose exposure to drinking water and other pathway cannot be ignored; it is important to reduce concentrations in all exposure pathway.

In the United States, the USEPA is in charge of antipollution efforts. The USEPA sets standards, approves state control plans, and steps in (if necessary) to enforce its own rules. Under the Safe Drinking Water Act (SDWA), passed in 1974 and amended in 1986 and 1996, the EPA sets standards for drinking water. Among other provisions, the SWDA requires that all water drawn from surface water supplies must be filtered to remove *Cryptosporidium* bacteria by the year 2000. The law also requires that individual States map the watersheds from which the drinking water comes and identify sources of pollution within those watersheds. While America's drinking water is among the safest in the world, and has been improving since passage of the SDWA, many water utilities that serve millions of Americans provide tap water that fails to meet the EPA standards (Hart, 2009)

The four rivers; 'Suntri', 'Kyenebra', 'Mmabamena' and 'Slaughter house Suntri' remain the principal sources of domestic water supply which serve most of the inhabitants and their environs. The banks of these rivers have been encroached with various human activities due to population increase along the banks of the rivers. The most significant environmental concern of the study area is the contamination and pollution of the rivers through intense human activities such as runoff from rubbish and human wastes, excreta disposal, and agricultural activities. These activities caused substantial damage to the environment resulting in river pollution and incidence of water-associated diseases like cholera, typhoid and bilharzias in the area.

Regardless of the type or source of a pollutant entering a river or stream, the overall consequences to the environment may be the same, be it the degradation caused by soil erosion that eliminates the habitat of a river organisms, or the discharge of a chemical that interferes with a species' reproductive cycle (Howard, 1980). The use of water by humans can be compromised whether toxic chemical pollutants necessitate the treatment of drinking water, whether nutrients promote the growth of nuisance aquatic weeds that choke waterways, or whether bacteria close beaches.

Around the banks of the rivers under study, degraded localities have been singled out by the researcher as ‘’ Areas of Concerns’’. A combination of human wastes and relentless ecological destruction has left these areas with environmental crises that can only be relieved by expenditures of vast sums of money and decades of remedial attention. Many parts of the rivers are closed at intervals because of fecal and chemical contamination which make it not safe for bathing and other domestic uses. Therefore, a far reaching commitment to reduce the surface water assault on the rivers from waste runoff is very necessary.

Observations made in the area highlight how rivers and streams have been polluted with municipal solid waste and water bodies previously used by thousands of villagers for drinking water, fishing and irrigation are now unusable. “All the fish are dead,” said a local resident, pointing out toxic sludge floating down the river that flows through her village and was once its main source of drinking water. Local residents claim that new cases of serious water pollution and flooding are still occurring and that alternative sources of water provided by Ghana Water Company such as public standpipes are insufficient, broken or obsolete. Large areas of land in the area previously used for cultivation are believed to have been contaminated through the improper disposal of municipal solid waste.

With this, paying attention in finding out the effects of improper waste disposal practices on quality of the following selected Rivers; thus; Suntri, Kyenebra, Slaughter house Suntri and Mmabamena is very important.

1.1 STATEMENT OF THE PROBLEM

The problem of water quality actually becomes the key issue in water use. In the past, the first settlers of Gyenegyene, found in their environment a vast area of rich soil, dense forests, and abundant fish, game and fresh water. The arrival of more inhabitants set off a pattern of uncontrolled development and assault on the natural environment that has continued largely unabated to this day. The quality of water has been impaired in many parts of 'Gyenegyene'. As a rural community, inhabitants employ a diversity of means to help meet their basic water needs. The recent intensification of dumping of municipal solid waste near surface water bodies in the area due to population pressure has resulted in several undesirable changes in the water environment with adverse effects on Agriculture and health.

The demand for fresh water currently has more than doubled relative to that of immediate past years. This fact notwithstanding the proportion of available but polluted water continuously increases particularly because of changes in the modes of industrial and agricultural production and increasing urbanization (Pestle, 1997).

The Public alarms over surface water quality that domestic pollution from improper municipal solid waste posed acute health problems along nearly every major river in the area called for serious attention to ascertain the real state of affairs. The extent to which the various rivers of the study area are polluted by anthropogenic activities is necessary because the rivers could affect the quality of life of the inhabitants in the area.

In the light of the above expositions, this study seeks to analyze and assess the effect of improper disposal Municipal Solid Waste on the quality of some major rivers in the Gyenegyene community.

1.2 RESEARCH HYPOTHESIS

This study intend to test the hypothesis; thus; four selected sampling sites', Suntri', Kyenebra, Slaughter house Suntri and Mmabamena serving the inhabitants of Gyenegyene have been contaminated due to human activities such as dumping of refuse close to river banks within the community.

1.3 JUSTIFICATION OF THE STUDY

Water is needed in all aspect of life. A general goal is to make certain that adequate supplies of good quality water is made available for current and future generations, while preserving required quantity and quality of water flow to sustain crucial function of ecosystem (UNEP, 2000). It is therefore necessary to conserve water since water is equally indispensable to humans and other animals.

The environment of the rivers continues to decline as some people still use waterways as a storage area for unwanted items, including domestic waste; trade waste; industrial waste; agricultural wastes and special waste. This has resulted in the contamination of river bodies with poorly treated sewage, runoff from agricultural operation and other pollutants.

The degree to which river pollution is determined depends on whether the physical, chemical and bacteriological parameters of the water are considered for analysis. The rivers within the study area receive pollutants mainly from untreated sewerage, domestic and agricultural runoff which contained several pollutants. Although concentrations of some pollutants meet ambient water quality standards, concentrations may still be high enough to cause serious contamination problems in human, fish and other wildlife.

Urgent action is needed by the Municipal Assembly if the process of long-term environmental degradation in the rivers is to be reversed. Therefore, enforcement of environmental regulations that protect the quality of rivers will make it impossible for solid waste in the form of trash, litter, and garbage to often end up in these surface waters.

Furthermore, the quality of water for drinking cannot be assured by chemical analyses alone. The presence of bacteria in water which are normally found in the intestinal tracts of humans and animals signal that disease-causing pathogens may be present. Bacteriological indicators such as faecal coli forms and E. coli can enter streams by direct discharge from mammals and birds, agricultural runoffs, or from open or broken sewers (Karikari and Ansa-Asare, 2006).

1.4. OBJECTIVES OF THE STUDY

1.4.1 GENERAL OBJECTIVE

The purpose of this study was to assess the quality of four major rivers; Suntri', Kyenebra, Slaughter house Suntri and Mmabamena whose banks have been extremely subjected to deposits of refuse dump through human activities.

1.4.2 THE SPECIFIC OBJECTIVES

1. To analyze some physico-chemical parameters of the four rivers in order to determine their quality
2. To determine the concentrations of some heavy metals in the rivers
3. To assess levels of total coliforms in the water samples

CHAPTER TWO

LITERATURE REVIEW

2 .0 SURFACE WATER HYDROLOGY

Oceans contain most of the water on the planet. Only a small proportion, some 2.7%, of Earth's water is fresh, and only a tiny percentage, little more that 0.01% is both fresh and accessible, in lakes, rivers, soil, and atmosphere. Almost all of the 2.7% is locked up in glacier and polar ice or buried deep underground (Pearse *et al.*, 1985).

The water running across the surface of the ground is designated surface water. It picks up many substances such as microorganisms, organic matter and minerals as it flows. Surface water collects in low areas forming lakes and ponds, and is rich in nutrients. It therefore becomes a perfect medium for the growth of all types of microorganisms (McKinney, 1962).

Water is constantly in motion. It evaporates from the surface of land or water or is transpired from plants and moves into the atmosphere as water vapour, which, in turn, condenses and falls back to the surface as precipitation. As water moves through this cycle it transports, in addition to essential nutrients, contaminants harmful to the environment. The hydrological cycle is global in scale. Through interaction with the land and atmosphere, it links widely separated regions, and in the process it spread contamination throughout the environment.

The hydrologic cycle is a constant movement of water above, on, and below the earth's surface. It is a cycle that replenishes ground water supplies. It begins as water vaporizes into the atmosphere from vegetation, soil, lakes, rivers and oceans in a process called evapotranspiration. Streams are created when excess water from rain, snowmelt, or near-surface groundwater accumulates on the ground surface and begins to run downhill. This excess water from rain or snowmelt generally occurs when the water accumulates at a faster rate than the soil and organic matter can absorb the water, plants can use it, or the water can be evaporated into the atmosphere.

Surface runoff eventually reaches a stream or other surface water body where it is again evaporated into the atmosphere. Infiltration, however, moves under the force of gravity through the soil. If soils are dry, water is absorbed by the soil until it is thoroughly wetted. Then excess infiltration begins to move slowly downward to the water table. Once it reaches the water table, it is called ground water. Ground water continues to move downward and laterally through the subsurface. Eventually it discharges through hillside springs or seeps in to it catchment area regardless of its source.

Surface water hydrology is a field that encompasses all dynamics of flow in surface water systems (estuaries, overland flow, rivers, canals streams, lakes, ponds, wetland, marshes, arroyos, oceans, etc). It provides a balanced system that serves plant and animal life and the environment as it provides a multitude of uses including commercial, fisheries, drinking and municipal water supply, industrial water supply, power generation and other aesthetic recreational uses such as tourism, agricultural irrigation and canalization and increasingly for waste disposal. All these uses are obviously in direct conflict with each other. They have the ability to cause considerable problems unless there is management of the water resources to maintain their quality and quantity. Good quality surface water is therefore essential in maintaining and ensuring the multiple use of it (Karikari and Bosque-Hamilton, 2004)

2.1 SURFACE WATER QUALITY

The quality of water varies naturally with season and geographic location, and this natural variation affects it suitability for human use and its response to disturbances. The legal definition of what constitute "good water" varies according to its intended use, whether for drinking, swimming in, or as a healthy home for aquatic life and is expressed in terms of its chemical, physical and biological characteristic.

A number of factors influence water chemistry. Gibbs (1970) proposed that rock weather, atmospheric precipitation, evaporation and crystallization control the chemistry of surface water. Therefore, influence of geology on chemical water quality is widely recognized. Also, the influence of soils on water quality is very complex and can be ascribe to the processes controlling the exchange of chemical between the soil and water (Hesterberg, 1998).

Agriculture's impact on water quality depends on the type of agricultural activity employed. Soil erosion and sedimentation, nutrients, pesticides, and irrigation are the major agricultural concerns to nonpoint source pollution

There are a number of other potential threats to water quality resulting from chemical and physical inputs and other human causes. Heavy metals (e.g., mercury), pesticides, polycyclic aromatic hydrocarbons, and other chemicals are common sources of concern. Additionally, characteristics of the water such as temperature and pH can become problematic as a result of human activity within the watershed.

Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, and use of water bodies as a heat. The quality of surface water is regularly altering on a daily basis due to seasonal and climatic variation. Therefore, lack of clean drinking water and sanitation systems is a severe public health concern in Ghana, contributing to major diseases in the country. Consequently, households without access to clean water are forced to use less reliable and hygienic sources, and often pay more. Therefore, without adequate and healthy water for drinking, cooking, fishing, and farming, the human race would perish. Contaminants that may be in untreated water include microorganisms such as viruses and bacteria; inorganic contaminants such as salt and metals; organic chemical contaminants from industrial processes and petroleum use; pesticides and herbicides contaminants.

Good quality water is necessary for recreational interests such as swimming, boating, and water skiing. Therefore, discharging harmful materials such as organic wastes, sediments, minerals, nutrients, thermal pollutants, toxic chemicals, and other hazardous substances into water bodies constitute a great threat to the survival of water-depended organisms.

Organic wastes are produced by animals and humans, and include such things as fecal matter, crop debris, yard clippings, food wastes, and rubber, plastic, wood, and disposable diapers. Such wastes require oxygen to decompose. When they are dumped into river and lakes and begin to break down, they can deprive aquatic life of the oxygen it needs to survive. Sediments may be deposited into lakes and streams through soil erosion caused by the clearing, excavating, grading, transporting, and filling of land. Minerals, such as lead, mercury, iron, copper, chromium, platinum, nickel, zinc, and tin, can be discharged into streams and lakes as a result of various human activities. Excessive levels of sediments and minerals in water can inhibit the penetration of sunlight, which reduces the production of photosynthetic organisms.

2.2 WATER QUANTITY-QUALITY INTERACTIONS

Sustaining a reasonable quality of life requires about 80 L of water daily (Myers, 1984). Natural variation in flow levels affects quality of water in complex ways. A river's capacity to dissolve or absorb pollutants, salts, and other solids is reduced under low-flow conditions. The quality of its water declines because there is less of it to dilute the contaminant that it does pick up, and because a higher proportion of the flow volume comes from groundwater, which generally contains more minerals. During periods of heavy rain or snowmelt, runoff carries dissolved and suspended material into rivers. Thus, high-flow conditions, as well, can result in a reduction in water quality.

2.3 MAIN POLLUTANTS RELATED TO RIVERS

A vast number of contaminants enter fresh water because of human activity. Many of these substances are capable of causing harm to the environment or human life and therefore, critical pollutants in rivers are capable of producing adverse, often irreversible effects in a wide range of mammalian and aquatic species. Because of their ability to bioconcentrate and to bioaccumulate up the food chain, the recognized threat to human health and aquatic ecosystem is significantly enhanced.

The concern is further exacerbated because of lack of unenforced regulatory controls and reductions in ecosystem concentrations for many water bodies.

Assessment of water quality by its chemistry includes measurements of many elements and molecules dissolved or suspended in the water. Several of these metals are essential to the human body. The metals are mainly utilized in enzymes to make them function properly. But we only need the metals in small quantities (WHO 1996). Some of them we need as trace elements and some are non-essential for us. Calcium, sodium and magnesium are essential metals and cobalt, molybdenum, selenium, chromium, nickel, vanadium and silicon are added as trace metals. Major pollutants related to river and other water sources can be classified as chemical, physical and biological assessments

2.4. CHEMICAL ASSESSMENT OF MAJOR POLLUTANTS RELATED TO RIVER

Metals exist naturally in the bedrock and are released through weathering. In water, metals exist in different forms, both solved and suspended, depending on a number of different parameters. The solubility, transportation and toxicity differ between different metal species.

Many metals can be stored in living tissue and remain there for a long time and can acts as a pollutant or becomes harmful to human health depending on the metal and the environment it is acting in. Both humans and plants exhibit a big variation concerning both the need of essential metals and the sensitivity to non-essentials metals and to high levels of essential metals and trace metals. Some metals are harmful mostly to plants, for example zinc, nickel and chromium, and some mostly to animals, for example cadmium and molybdenum.

Chemical measurements can be used to directly detect pollutants such as lead or mercury as well, used to detect imbalances within the ecosystem. Such imbalances may indicate the presence of certain pollutants. For examples, elevated acidity levels may indicate the presence of acid mine drainage (Akabzaal *et al.*, 2007). Commonly measured chemical parameters include pH, alkalinity, hardness, nitrates, nitrites and ammonia, total phosphates, dissolved oxygen and biochemical oxygen demand (APHA, 1998).

2.4.1 pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Acidity increases as the pH gets lower. A pH of 7.0 is neutral.

Aquatic organisms differ as to the range of pH in which they flourish. pH can be measured electronically or visually. Water that is a good buffer contains compounds, such as bicarbonates, carbonates, and hydroxides, which combine with H^+ ions from the water thereby raising the pH of the water. Without this buffering capacity, any acid added to a river would immediately change its pH. The pH of a buffered solution would change when the buffering capacity of the solution is overloaded. Aquatic organisms need the pH of their water body to be within a certain range for optimal growth and survival. Although each organism has an ideal pH, most aquatic organisms prefer pH of 6.5 – 8.0. Outside of this range, organisms become physiologically stressed. Reproduction can be impacted by out-of-range pH, and organisms may even die if the pH gets too far from their optimal range. In addition to directly affecting the physiology of aquatic organisms, additional aspects of lake dynamics are influenced by pH. Low pH can cause the release of toxic elements and compounds from sediments into the water where they may be taken up by aquatic animals or plants. Changes in pH also influence the availability of plant nutrients, such as phosphate, ammonia, iron and trace metals, in the water. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0.

The pH of water does not fall evenly as acid contamination proceeds. The natural buffering materials in water slow the decline of pH to around 6.0. This gradual decline is followed by a rapid pH drop as the bicarbonate buffering capacity is used up. At a pH of 5.5, only very weak buffering materials remain and pH drops further with additional acid. Sensitive species and immature animals are affected first. As food species disappear, even larger, resistant animals are affected.

2.4.2 ALKALINITY

Alkalinity is the buffering capacity of a water body. It measures the ability of water bodies to neutralize acids and bases thereby maintaining a fairly stable pH.

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. Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic. This capacity is commonly known as "buffering capacity."

The buffering capacity of water or its resistance to pH change, is critical in the proper metabolism of most forms of life, maintenance of aquatic life forms, understanding the geochemical nature of water, and how best to deal with problems associated with both drinking water and waste water. Alkalinity of surface and ground waters is directly related to the underlying sediment and bedrock.

Alkalinity is also an important factor in maintaining aquarium and swimming pools. Therefore, alkalinity plays an essential role in all aspects of aquatic chemistry. Alkalinity also refers to the capability of water to neutralize acid. This is really an expression of buffering capacity. A buffer is a solution to which an acid can be added without changing the concentration of available H^+ ions appreciably. It essentially absorbs the excess H+ ions and protects the water body from fluctuations in pH. Alkalinity of natural water is determined by the soil and bedrock through which it passes. The main sources for natural alkalinity are rocks which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates also may contribute to alkalinity. Limestone is rich in carbonates, so waters flowing through limestone regions or bedrock containing carbonates generally have high alkalinity - hence good buffering capacity. Conversely, areas rich in granites and some conglomerates and sandstones may have low alkalinity and therefore poor buffering capacity.

The presence of calcium carbonate or other compounds such as magnesium carbonate contribute carbonate ions to the buffering system. Alkalinity is often related to hardness because the main source of alkalinity is usually from carbonate rocks (limestone) which are mostly $CaCO_3$. If $CaCO_3$ actually accounts for most of the alkalinity, hardness in $CaCO_3$ is equal to alkalinity. Since hard water contains metal carbonates (mostly $CaCO_3$) it is high in alkalinity. Conversely, unless carbonate is associated with sodium or potassium which don't contribute to hardness, soft water usually has low alkalinity and little buffering capacity. So, generally, soft water is much more susceptible to fluctuations in pH from acid rains or acid contamination. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Alkalinity is a measure of how much acid can be added to a liquid without causing a large change in pH. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life.

For protection of aquatic life the buffering capacity should be at least 20 mg/L. If alkalinity is naturally low, (less than 20 mg/L) there can be no greater than a 25% reduction in alkalinity. Alkalinity values of 20 – 200mg/L indicate freshwater ecosystems (Chapman, 1992).

2.4.3 IMPORTANCE OF ALKALINITY

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes and makes water less vulnerable to acid rain. Limestone is rich in carbonates, so waters flowing through limestone regions generally are high in alkalinity, hence 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.

Aquatic organisms benefit from a stable pH value in their optimal range. To maintain a fairly constant pH in a water body, a higher alkalinity is preferable. High alkalinity means that the water body has the ability to neutralize acidic pollution from rainfall or basic inputs from wastewater. A well buffered lake also means that daily fluctuations of Carbon (IV) Oxide result in only minor changes in pH throughout the course of a day.

Alkalinity comes from rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (detergents and soap based products are alkaline). If an area's geology contains large quantities of calcium carbonate ($CaCO_3$, limestone), water bodies tend to be more alkaline. Granite bedrock is deficient in alkaline materials to buffer acidic inputs. Additions of lime as a soil amendment to decrease acidity in home lawns can runoff into surface waters and increase alkalinity.

2.4.4 LEAD

Lead is a contaminant of major concern because of the harm it does to many human tissues and organs especially the nervous system, the kidneys, and the cardiovascular system and particularly in children. It adverse effects have been observed in some population groups with blood lead levels as low as 10 μg/dL, and some scientists suggest that any level, no matter how small, may be harmful. Lead can cause serious damage to the nervous, circulatory, urinary, gastro-intestinal, and reproductive systems (Anderson and Harmon, 1985)

Lead is the most common of the heavy elements, accounting for 13 mg/kg of the earth's crust. More than 80% of the daily intake of lead is derived from the ingestion of food, dirt, and dust. That means that an average of 5 μg/l lead intake from water forms a relatively small proportion of the total daily intake for children and adults, but a significant one for bottle-fed infants. Lead is possible human carcinogen and it is also a cumulative poison so that any increase in the body burden of lead should be avoided. A provisional tolerable daily intake is set to 3.5 μg of lead per kg of body weight for infants lead to a calculated guideline value of 0.01 mg/l. As infants are considered to be the most sensitive subgroup of the population, this guideline value will also be protective for other age groups (WHO, 1996).

2.4.5 MERCURY

One tablespoon of mercury in a body of water covering a football field to a depth of 4.6m is enough to make fish in that water unsafe to eat (Howard, 1980). Mercury contamination of aquatic ecosystem can occur either directly through discharge to the system or indirectly by flooding mercury-containing soils and by air emissions from metal smelters. Approximately, 80% of mercury that enters the global ecosystem comes from natural sources (Charest, 1991).

Mercury is an example of non-essential metals which when in uncontaminated drinking water is thought to be in the form of Hg^{2+}. It is only the carbon-mercury bond in organic mercury compounds that are chemically stable. The solubility of mercury compounds in water varies. Mercury (II) chloride is readily soluble, mercury chloride much less soluble, mercury sulphide has a very low solubility and elemental mercury vapor is insoluble. Some anaerobic bacteria are capable of mercury methylation. Methyl mercury can then easily enter the food chain as a consequence of rapid diffusion and tight binding to proteins. Environmental levels of methyl mercury depend on the balance between bacterial methylation and demethylation. Naturally occurring levels of mercury in groundwater and surface water are less than 0.5µg/l. The WHO guideline value for total mercury is 0.001 mg/l. Mercury attacks the central nervous system, causing loss of sensation, tunnel vision, lack of coordination, and impairment of speech, hearing and gait. Exposure to methyl mercury during the fetal stage may lead to delayed motor and intellectual development later in life (Charest, 1991)

2.4.6 NITRATE

Municipal and industrial effluents and runoffs from agricultural area are major contributors of nitrogen to the aquatic system. A minimum concentration of nutrients, especially nitrogen, is necessary for plant production in aquatic ecosystem. An oversupply however, leads to an algal bloom, characterized by massive "greening" of water column. In an advanced stage, eutrophication –as this process of uncontrolled plant growth is called-can destroy the biological community of lakes and rivers, ruin the recreational value of a water body, and increase the cost of drinking water treatment. Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. They are usually not found in drinking water supplies at concentrations above 1 or 2mg/l. The nitrate ion (NO_3^-) is the stable form and it can be reduced by microbial action to a nitrite ion (NO_2^-) which is a relatively unstable oxidation state for the ion. It is the nitrite ion that constitutes the toxicity to humans. It is involved in the oxidation of normal hemoglobin to methaemoglobin, which is unable to transport oxygen to the tissues of blood stream (Anoxia). Therefore the health guideline for nitrate-nitrogen is set to 10 mg/l. This value should not be expressed in terms of nitrate-nitrogen but as nitrate itself which is the chemical entity of health concern, and the guideline value for nitrate alone is therefore 50 mg/l (WHO 1996).

The USEPA maximum contaminant level (MCL) for nitrate is 1.0 mg/l. The WHO maximum permissible level for nitrate is 3 mg/l (WHO, 2004).

Nitrogen is a critical nutrient for plants and animals, and terrestrial ecosystems and headwater streams have a considerable ability to capture nitrogen or to reduce it to N_2 gas through the process of denitrification. When loads of nitrogen from fertilizer, septic tanks, and atmospheric deposition exceed the capacity of terrestrial systems (including croplands), the excess may enter surface waters, where it may have "cascading" harmful effects. In humans, infants who drink water containing nitrate in excess could develop blue-baby syndrome (methemoglobinemia) (Spalding and Exener, 1993). Nitrogen and phosphorus loads tend to be substantially higher during years of high precipitation, because of increased erosion and transport of the nutrients to stream channels (Smith *et al.,* 1995) as it moves downstream to coastal ecosystems. Other sources of excess nitrogen include direct discharges from storm water or treated wastewater. This indicator specifically focuses on nitrate, which is one of the most available forms of nitrogen in bodies of water.

2.4.7 PHOSPHORUS

A minimum concentration of nutrient, especially phosphorus is necessary for plant production in aquatic ecosystem. An oversupply, however, leads to an algal bloom, characterized by massive "greening" of the water column. In an advantage stage, eutrophication- as this process of uncontrolled plant growth is called- can destroy the biological community of rivers, lakes and streams, ruin the recreational value of a water body, and increase the cost of drinking water treatment.

Phosphorus enters the environment from anthropogenic sources and may exceed the needs and capacity of the terrestrial ecosystem. As a result, excess phosphorus may enter rivers and streams. Because phosphorus is often the limiting nutrient in these bodies of water, an excess may contribute to unsightly algal blooms, which cause taste and odor problems and deplete oxygen needed by fish and other aquatic species. In some cases, excess phosphorus can combine with excess nitrogen to exacerbate algal blooms (i.e., in situations where algal growth is co-limited by both nutrients), although excess nitrogen usually has a larger effect downstream in coastal waters. The most common sources of phosphorus in rivers are fertilizer and wastewater, including storm water and treated wastewater discharged directly into the river. In most watersheds, the atmosphere is not an important source or sinks for phosphorus. Non-point source pollution (NSP), especially resulting from agricultural activities, has been identified as a significant source of water quality pollution (USEPA, 1997). Nitrogen (N) and phosphorus (P) from excessive N and P fertilizer use can be discharged into the receiving water when rainfall events and irrigation practices occur, which can induce the eutrophication phenomenon in receiving water and losses of biodiversity in the aquatic ecosystem.

2.5 PHYSICAL ASSESSMENT OF MAJOR POLLUTANTS RELATED TO RIVERS

Physical pollutants to lakes, rivers and streams include materials such as particles of soil that are eroded from the landscape or washed from other areas by flowing water. Once in a lake or stream, some particles settle out of the water to become bottom sediments. Chemical pollutants adsorbed (bound) to the particles are also incorporated into the sediments, where they may be permanently buried, or be carried by the water currents to other locations. Changes in any of the indicator pollutants may indicate the presence of particular effluents. Turbidity and color can impact the suitability of water bodies for recreational activities.

2.5.1 TEMPERATURE

Temperature is a measure of how heat or cold the content of a body is. Water temperature is measured using a waterproof thermometer and measurements are generally recorded in degrees Celsius or degree Fahrenheit (^{o}F).Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities, and determines which fish species can survive. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. Temperature influences both the chemical and biological characteristics of surface water. It affects the dissolved oxygen level in the water, rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms, and the sensitivity of organisms to pollution, parasites and diseases (APHA, 1992).

Physical pollutant such as heat may be discharged from an industrial source, or runoff from hot surfaces in warm weather. The over clearing of shade trees along the shoreline of a lake or stream may also permit sunlight to warm waters above the normal temperature range. Water temperature affects the ability of water to hold oxygen, the rate of photosynthesis by aquatic plants and the metabolic rates of aquatic organisms. Causes of temperature change include weather, removal of shading stream bank vegetation, impoundments, discharge of cooling water, urban storm water, and groundwater inflows to the stream.

2.5.2. VARIABLES THAT AFFECT TEMPERATURE OF RIVERS

(a) The color of the water. Most heat warming surface waters comes from the sun, so waterways with dark-colored water, or those with dark muddy bottoms, absorb heat best.

(b) The depth of the water. Deep waters usually are colder than shallow waters simply because they require more time to warm up.

(c) The amount of shade received from shoreline vegetation. Trees overhanging a lake shore or river bank shade the water from sunlight. Some narrow creeks and streams are almost completely covered with overhanging vegetation during certain times of the year. The shade prevents water temperatures from rising too fast on bright sunny days.

(d) The latitude of the waterway. Lakes and rivers in cold climates are naturally colder than those in warm climates.

(e) The time of year. The temperature of waterways varies with the seasons.

(f) The temperature of the water supplying the waterways. Some lakes and rivers are fed by cold mountain streams or underground springs. Others are supplied by rain and/or surface run-off. The temperature of the water flowing into a lake, river or stream helps determine its temperature.

(g) The volume of the water. The more water there is, the longer it takes to heat up or cool down.

(h) The temperature of effluents dumped into the water. When people dump heated effluents into waterways, the effluents raise the temperature of the water

2.5.3 TURBIDITY

The American Public Health Association (APHA) defines turbidity as "the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample." Turbidity is a measure of water clarity and is independent of colour.

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. It is a gross measurement of water quality.

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 (APHA, 1998). Turbidity is closely related to total suspended solids (TSS), but also includes plankton and other organisms. Visibility or clarity of water decreases as the turbidity increases in a given water body. The reduction in clarity is due to scattering of sunlight by suspended particles in the solution. In effect, the particles act as tiny mirrors that redirect incoming sunlight in other directions, thus reducing light penetration.

Substances that reduce water clarity can originate from natural, developing, and developed areas within a watershed; however, turbidity originating from anthropogenic activities can be of a much higher magnitude, especially since waterfront areas tend to be highly developed. Among these activities, construction and agricultural production tend to disturb land surfaces, potentially contributing soil particles as well as nutrients to aquatic systems.

Dredging of water bodies re-suspends fine particulates, increasing turbidity. Occasionally sewage treatment plants may contribute organic materials and nutrients to water bodies during sewage by-pass periods or when infrastructure fails. In all cases, sand, silt, clay, and organic particles may be dislodged from land surfaces by rainfall and carried by overland flow. The risk of contributing turbidity to aquatic systems is highest when land surfaces are bare and rainfall events occur. Turbidity may also result from the formation of algal blooms. Algal blooms form in response to nutrient import into the aquatic system and from nutrients released during the decomposition of aquatic plants and other organisms. In many aquatic systems, water clarity is determined by the abundance of suspended algae. Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for microbial growth. It also may indicate the presence of microbes.

It is therefore important that inhabitants using surface water or ground water under the direct influence of surface water to disinfect their water, and filter their water or meet criteria for avoiding filtration so that at no time can turbidity go above 5 Nephelometric turbidity units (NTUs). Systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month (APHA, 1998.)

2.5.4. FACTORS AFFECTING TURBIDITY

(i) **High Flow Rates:** The flow rate of a water body is a primary factor influencing turbidity concentrations. Fast running water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles from the land and carry it to surface water. A change in flow rate also can affect turbidity; if the speed or direction of the water current increases, particulate matter from bottom sediments may re-suspended

(ii) **Soil Erosion:** Soil erosion is caused by disturbance of a land surface. The eroded soil particles can be carried by storm water to surface water. This will increase the turbidity of the water body.

(iii) **Urban Runoff:** During storm events, soil particles and debris from streets and industrial, commercial, and residential areas can be washed into streams. Because of the large amount of pavement in urban areas, natural settling areas have been removed, and sediment is carried through storm drains to creeks and rivers.

(iv) **Wastewater and Septic System Effluent:** The effluent from Wastewater Treatment Plants (WWTPs) can add suspended solids and organic material to a stream. The wastewater from our houses contains food residue, human waste, and other solid material that we put down our drains. Most of the solids and organic material are removed from the water at the WWTP before being discharged to the stream, but treatment can't eliminate everything.

(v) **Decaying Plants and Animals:** As plants and animals present in a water body die and decay, suspended organic particles are released and can contribute to turbidity.

(vi) **Bottom-Feeding Fish:** Bottom-feeding fish (such as carp) can stir up sediments as they remove vegetation. These sediments can contribute to turbidity.

(vii) **Algal Blooms:** Algal blooms can contribute to turbidity. Algal production is enhanced when nutrients are released from bottom sediments during seasonal turnovers and changes in water current.

2.5.5 SURFACE WATER COLOUR

Natural colour reflects the presence of complex organic molecules derived from natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds, and industrial wastes. Metallic ions such as iron and manganese typically impart a reddish-brown color to water. Tannins and dissolved organic carbon, a by-product of the degradation of plants and other organisms, usually impart a brown to black color to water. A yellow tint to the water indicates that the humid acids are present. Dark brown stains are created by manganese. Excess copper can create blue stains. True colour of water is the colour due to natural minerals such as ferric hydroxide and dissolved organic substances such as humus or folic acids. Some living plants such as Parrot feather (Myriophyllumaquaticum) also release colored organic compounds into the water column.

Objections to high colour are usually on aesthetic grounds rather than on the basis of a health hazard. Consumers are reluctant to drink water, however safe, which has a yellowish-brown colour not unlike that of urine, and because of this revulsion, any marked colour is very undesirable. So strong may be the objection to colour in water that occasional cases have been noted of people turning from coloured but otherwise safe waters to alternative supplies without coloration, and of a much lower bacteriological quality.

Nonetheless, it must be noted that the presence of colour on a persistent basis in water which is then disinfected by chlorination is highly undesirable. This is because of the readiness with which the colour-causing substances reacted with the added chlorine giving rise to the presence of trihalomethanes which has a potential hazard to public health.

Additionally, the color value of a water sample can also be very dependent on the pH of the sample. It usually increases as the pH of the water increases. Colour measured in water containing suspended matter is defined as apparent colour (APHA, 1992). Natural waters range from 5mg/L PtCo in very clear waters to 1200 mg/L PtCo in dark peaty waters (Keyser, 1997).The presence of any turbidity in water sample can cause the apparent color to be significantly higher than the true color. Therefore removing turbidity by centrifugation or by filtration will give the approximate true color of water.

2.6 BIOLOGICAL ASSESSMENT OF MAJOR POLLUTANTS OF RIVERS

Indicator bacteria are certain species of bacteria used by health authorities to detect contaminated water. Indicator bacteria are not themselves dangerous to health but are used to indicate the presence of a health risk. When testing drinking water for contamination, a variety and often low concentrations of pathogens makes them difficult to test for individually. Health authorities therefore use the presence of other more abundant and more easily detected fecal bacteria as indicators of the presence of fecal contamination. The most popularized known indicator bacteria are faecal Coliform, Salmonella and Escherichia coli. It is generally assumed that, the higher the number of Coliform organisms found in a 100ml sample, the higher the risk for waterborne disease.

While the measurement of faecal Streptococci has been recommended as a source of valuable supplementary information on surface water quality, particularly in combination with data from faecal Coliform assays, it should be remembered that a limitation on the use of faecal Streptococci is their shorter survival time in the aquatic environment.

2.6.1 TOTAL COLIFORMS

The organisms in the total Coliform group are called indicator organisms. That is, if present, they indicate that there is a possibility, but not a certainty, that disease organisms may also be present in the water. When absent, there is a very low probability of disease organisms being present in the water. The ability of the total Coliform test to reliably predict the bacterial safety of water relative to the hundreds of possible diseases that might be present is critical since it is impossible, in a practical sense, to check separately for every disease organism directly on a monthly or a quarterly basis. The presence of only total coliform generally does not imply an imminent health risk but does require an analysis of all water system facilities and their operation to determine how these organisms entered the water system.

Total coliforms bacteria and fecal coliforms are two types of fecal indicator bacteria. Total coliforms bacteria, is a particular group of waterborne microbiological contaminants and is the most common indicator organism applied to drinking water. Escherichia Coli is a specific species (subgroup) within the coliform family. They originate only in the intestines of animals and humans. They have a relatively short life span compared to more general total coliforms. Their presence indicates a strong likelihood that human or animal wastes are entering the water system, and have a much higher likelihood of causing illness.

Most coliforms bacteria are not harmful to ingest (human intestines contain coliforms that aid in digestion). EPA-Ghana requires testing for coliforms because they can indicate the potential presence of more harmful microorganisms. If water detects coliforms, vigorous follow-up sampling and testing is immediately conducted to ensure no harmful microorganisms are present.

E-Coli is one type of pathogenic fecal coliforms bacteria, and the most common facultative, disease-causing bacteria in the feces of warm-blooded animals. Fecal bacteria are single-celled microorganisms, virtually always associated with fecal contamination of water, but not always harmful. Fecal indicator bacteria are used in determining (indicating) the microbial quality of water. Several bacteria can be classified as coliform, and are commonly found in soil, on the surface of leaves, in decaying matter, and can grow in water distribution mains. These types of coliform bacteria aren't fecal contamination related, and do not necessarily indicate unsafe water. The pathogenic fecal coliform bacteria, E-Coli, are naturally occurring in the intestines and feces of most warm-blooded animals, including humans, and when found in water is a direct result of fecal contamination. Almost all surface waters contain some bacteria, while groundwater's are generally free of bacteria unless under the direct influence of surface water. Surface and groundwater contamination can occur as a result of surface runoff through urban areas, woodlands, pastures, or feedlots; on-site septic tank/sewage disposal system

In addition, feces may contain pathogenic viruses, protozoa and parasites which if ingested would cause disease. For instance, faecal coliforms can enter stream by direct discharge from mammals and birds, from agricultural runoff, and domestic waste disposal. The health risks associated with ingested faecal coliforms include generation of illness through exposure of recreational swimmers and boaters to pathogens and consumption of raw food that have accumulated pathogen. They can result in health problems ranging from common diarrhoea and ear infection to deadly disease such as hepatitis, cholera and typhoid fever. Therefore, it is suggested that one does not have total body contact with water containing levels of faecal Coliform greater than 200 colonies per 100ml of water (WHO, 2004)

2.7. THE GYENEGYENE RIVERS AND THEIR CONNECTING CHANNELS

When it comes to rivers, lakes and ponds, small is often beautiful. Generally, small water bodies are ecologically valuable than larger ones. They provide ideal waterfowl breeding and fish spawning habitat and are usually not affected by human recreational activities, being too small for boating and cottages and too remote for access (Charest, 1991). In Gyenegyene, however, small means threatened since the four rivers share some notable characteristics that influence the quality of water. Smaller water bodies are particularly susceptible to acidification because of their relative small volume, shallowness and geological setting. The relatively small proportion of land within the drainage basin leads to quick delivery, through tributary flow, of any contaminants introduced in upland land.

CHAPTERTHREE

MATERIALS AND METHODS

3.0 STUDY AREA

The four rivers; ‘Suntri’, ‘Mmabamena’,’ Kyenebra’ and ‘Slaughter house Suntri’ are all within the Gyenegyene Township in the Berekum Municipality in the Brong Ahafo region of Ghana.

The Municipality shares boundaries with Wenchi Municipal and Jaman District to the Northeast and Northwest respectively, Dormaa Municipal to the South and Sunyani Municipality to the East. The Municipal’s close proximity to Cote d’ Ivoire is another remarkable feature which promotes economic and commercial activities between the Municipality and Cote d’ Ivoire. Berekum Municipal came into existence as a semiautonomous spatial unit by virtue of the decentralization policy adopted by the Government in 1988. Geographically; the Municipality can be located in the Western part of Ghana in the Brong-Ahafo Region. It lies between latitude 7’15’ South and 8.00’ North and longitudes 2’25’ East and 2’50’ West (Ghana Statistical Service, 2000).

The study was conducted in the Gyenegyene Community where Surface run-off carries contaminants from surrounding communities’ downstream serving as potential sources of faecal contamination to the water body.

Figure 1.0 Map of Ghana with shaded triangle showing the study area

3.2 SAMPLING SITES

The four river sites from which the samples were taken for the study are all situated within the Gyenegyene community.

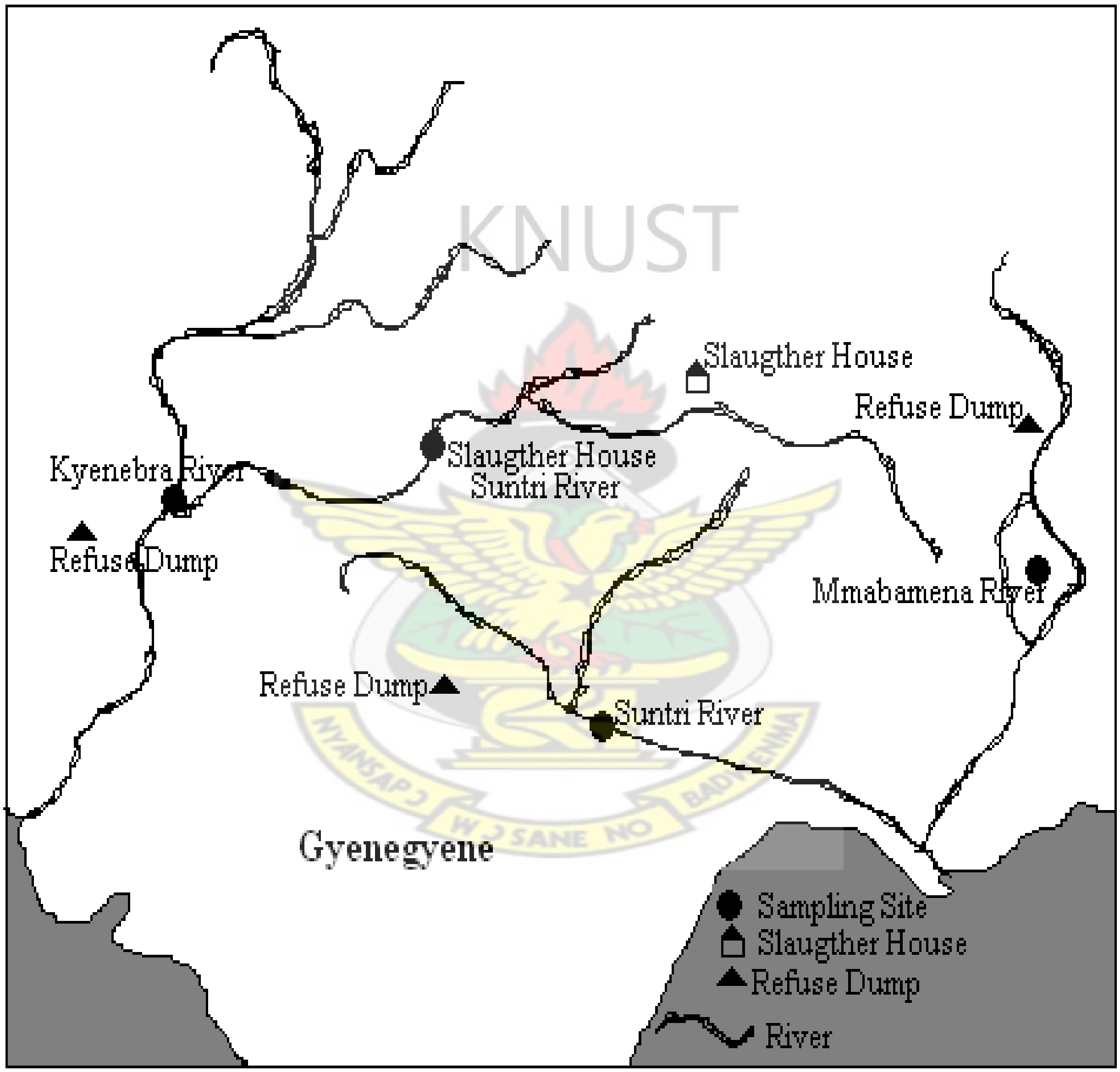

Figure.3.0: Diagram showing rivers and the sampling sites (shaded Circles)

3.2.1 THE SLAUGHTER HOUSE SUNTRI SAMPLING SITE

This river has a slaughter house situated closed to it. A lot of activities such as burning of lorry tyres and dumping of animal wastes around the banks of this river continue to threaten the survival of this river. Injection of liquid waste into this river has long been a common method of waste disposal that may directly affect the river quality.

Plate 3.1 The Slaughter House Suntri sampling site

3.2.2 THE SUNTRI RIVER SAMPLING SITE

This river has a huge refuse dump situated closed to it. A lot of activities such as burning of lorry tyres and dumping of solid and liquid wastes around the banks of this river continue to threaten the survival of this river. Dumping of waste into this river has long been a widespread method of waste disposal that may directly affect the river quality. Farming activities also takes place around this river.

Plate 3.2 The Suntri River Sampling site

3.2.3 THE KYENEBRA SAMPLING SITE

Three distinct human activities occur around this river. A huge refuse dump can be identified close to it. Dumping of solid and liquid wastes around the banks of this river persist to threaten the survival of this river. Farming activities also takes place around this river.

Plate 3.3 the Kyenebra River Sampling Site

3.2.4 THE MMAABAMENA RIVER SAMPLING SITE

A huge refuse dump can be identified closed to it. Dumping of solid and liquid wastes around the banks of this river continue to threaten the survival of this river and human health as it serves as the principal source for domestic use. Fertilizers and other nutrients used to promote plant growth on farms and in gardens may find their way into this water body. Deforestation activity also takes place around this river.

Plate 3.4 Mmabamena River Sampling Site

TABLE 3.1 SAMPLING SITES AND GLOBAL POSITION SYSTEMS READINGS

Sampling Site (Rivers)	Sampling Site code	GPS Reading
Suntri	S	N:07.96949
		W:002.75636
Kyenebra	K	N:07.833693
		W:002.76271
Mmabamena	M	N:07.84922
		W:002.77529
Slaughter house Suntri	SS	N:07.84766
		W:002.77529

3.1.2 SAMPLE PREPARATION

Hundred milliliters of water sample was measured and put into a digestion flask. 10ml of diluted acid mixture of $HClO_4$ and HNO_3 in the ratio 4:9 respectively was added to the water sample. Digestion of water sample was carried out until a clear solution was observed. The clear sample was made to cool and make up to volume in a 50ml volumetric flask with distilled water. Pipetted aliquots of standard sample and blanks were put into test tubes. Finally, analysis for the required parameters using the appropriate method was adopted (Motsara and Roy, 2008).

3.1.3 TREATMENT OF SAMPLING CONTAINERS

All glassware used for laboratory analysis were thoroughly washed by drenching them in regia solution and later washed with tap water followed by risen with distilled water. On the other hand, plastic containers were neatly washed with detergents and tap water. The washed plastic containers were kept in a concentrated Trioxo Nitrate (v) acid (HNO_3) for 24 hours and finally rinsed with distilled water and later made to dry in desiccators before being used for collection of samples from the various sites

3.1.4 SAMPLING FREQUENCY

Monthly water samples were collected from the selected sites of the rivers serving the community from November 2010 to February 2011. Replica samples were taken from each river at every sampling period. A total of eight (8) samples were taken at each time, and altogether, a total of thirty-two (32) samples were taken for analysis in this study area between the morning hours of 07.00 GMT and 10.00 GMT.

3.1.5 SAMPLE COLLECTION

All samples for microbiological analysis were collected in 500ml sterile bottles, capped immediately and transported to the laboratory for analyses.

pH and Turbidity analysis were performed at the Quality Assurance Laboratory of the Ghana Water Company Limited, Sunyani. Water samples for analysis of other Physico-chemical parameters were collected in separate bottles, and placed in a Cool Box and transported to the laboratory for analysis at the Soil Science Section of the Department of Crop and Soil Science, KNUST, Kumasi.

3.1.6. pH DETERMINATION

The pH meter was calibrated by immersing the electrode into three buffer solutions of pH, 4.0, 7.0 and 10.0. pH meter was adjusted to match the standard buffers. The water samples were shaken vigorously in 250 ml of beaker and the electrode rinsed with distilled water and lowered into the sample in the 100ml beaker. The Suntex model SP-701 pH Meter was used. The pH meter was allowed to stabilize and the pH of the sample read.

3.1.7 TEMPERATURE DETERMINATION

Temperatures of the water samples were determined on site. An aliquot of 100mL of sample was measured into 500 mL beaker and the pH meter probe immersed in the water sample. The reading on the pH meter was then recorded after 2 minutes. The Suntex model SP-701 pH Meter was used.

3.1.8 DETERMINATION OF TURBIDITY

A total of twelve (12) tubes were rinsed clean with deionised water (turbidity free). A 10ml of the deionized water was filled to the test tube line of 10ml. The tubes were inserted into a chamber with closed lid where "Scan Blank was selected. Second clean tubes were rinsed with sample water filled to the 10ml line with sample. A cap tube wipe off excess water and fingerprints were carried out. Re-suspended particulate matters were shaken to achieve uniform mixture. The second tubes containing the samples were inserted into the chamber with closed lid and "Scan Sample" was selected and the value was recorded. For most accurate results, the samples were at 25+/-4ºC. The range was 0-400 NTU

3.1.9 DETERMINATION OF LEAD (Pb)

A 50 ml of the water sample containing the suspected lead was measured and put into a conical flask. 2.0g of potassium sodium tartrate was added to the sample. A Spatulaful of Eriochrome Black T was added. 2ml of ammonium solution was also added. However, pH≠10-10.5, the quantity of ammonium solution was increased. The sampled mixture was heated to about 40ºC and titrated quickly with 0.1M Triplex solution until colour changes from red to green. The volume of the titer was recorded (Merck, 1958,)

CALCULATION

Pb (mg/l) = titer× 10

1ml of 0.1M Triplex = 20.721mg of Pb

3.1.10 NITRATE -NITROGEN DETERMINATION

Fifty milliliters of water sample was put in to a distilled flask and 0.5g of MgO and 0.2g of Devardda's alloy were added to the sample in the flask. The heater was put on and NH_4 was collected (NO_3 converted into NH_4 by reducing agent – Devardda's alloy) in boric acid (20ml) having mixed indicator into a conical flask which was connected with the distillation apparatus. The distillation process was continued where about 35-40 ml of the distillate was collected. The distillate was removed first then switch off the heating system. The distillate was titrated against 0.02M H_2SO_4 until the pink colour appears. Titration was repeated until a consisted titer was obtained. The value of the average titer was recorded. (Motsara and Roy, 2008)

RELEVANT CALCULATION:

$$NO_3^{-}N\ (\text{mg/litre}) = \frac{(X-Y)\times 0.56}{50(ml\ of\ sample\ )} \times 1000$$

Where:

X = Volume (ml) of 0.02M H_2SO_4 Consumed in sample titration

Y = Volume (ml) 0.02M H_2SO_4 Consumed in blank titration

0.056 = factor. 1 litre 1M H_2SO_4 = 28g N; therefore:

1ml of 0.02M H_2SO_4 = $\frac{28 \times 0.02 \times 1000}{1000}$ mg N = 056 mg N

3.1.11 DETERMINATION OF TOTAL COLIFORM COUNT

One milliters of water (undiluted) was added to three tubes of MacConkey broth. A fresh sterile pipette tip was used for each dilution aseptically. One milliters of each of the dilution was added to the water samples to 5ml of the MacConkey broth provided. Addition of 1ml of 10^{-1} dilution to MacConkey broth was carried out. Finally, 1ml of 10^{-2}dilution was added to three MacConkey broth and methods continued to 10^{-4} dilution. The bottles and tubes of MacConkey broth contain inverted Durham tubes for the collection of gas before incubation of samples. Tubes were labeled with river names and dilution and incubation were at 37ºC and 48 hours. After 48 hours, recorded tubes with gas inverted Durham tubes shown a colour change from pink to yellow which are described as positive. Tubes with no change in colour are described as negative. This analysis will indicate whether or not there was growth or No growth along the streak line. Total coliforms were estimated using a three-tube most probable number method (MPN).

3.1.12 DETERMINATION OF COLOUR

The HACH DR/2010 portable Data logging Spectrophotometer was used to determine the apparent and true colours of the sample collected. The pH of the samples was adjusted to 7.6 after it was filtered. Water samples which had their pH value less than 7.8 were 6 adjusted with 1 or 2 drops of 1.0 NaOH depending on the pH. Water samples which had their pH value greater than 7.6 were adjusted with 1 or 2 drops of 1.0 HCl depending on the pH. The wavelength used for the color determination was 465nm. The stored program was calibrated in color units based on the APHA recommended standard of 1 colour unit equal to 1 mg/L platinum out suspended particles, but for apparent color measurement the samples were not filtered (APHA,1998).

3.1.13 QUALITY ASSURANCE

Samples were taken in duplicates and the average of each result was taken for the analysis. All instrument used in this study were calibrated with standard and known concentrations.
Calibration curves were prepared separately for all the metals by running suitable concentration of the standard solutions. Concentration of the analyst samples were determined from the calibration curves. Average values of two replicates were taken for each determination. Suitable blanks were also prepared and analyzed in the same manner.

3.1.14 STATISTICAL ANALYSIS

All statistical analysis was carried out using Microsoft Excel 2007 Edition, statistical package for social science (SPSS), Analysis of Variance (ANOVA) and Minitab-16 package to determine the differences in the means of the values. Correlation was also run for all the Biological and Physico-Chemical Parameters to determine their relationship.

CHAPTER FOUR

RESULTS

3.1 pH Values

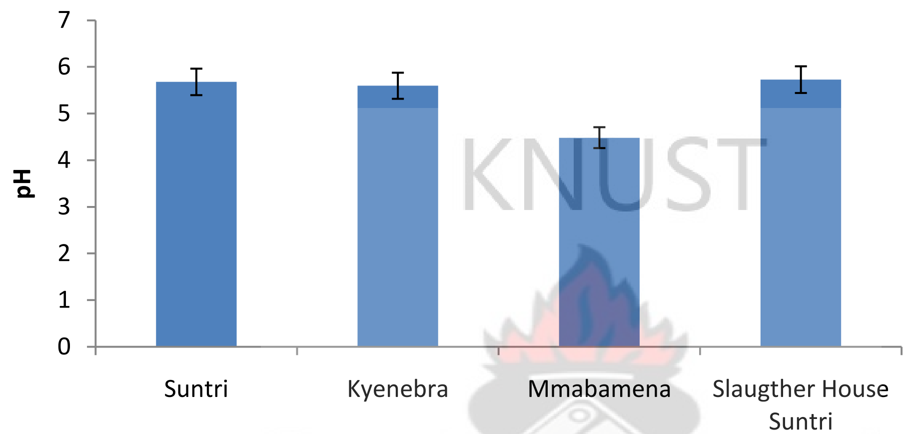

Figure 4.1: Mean pH values recorded at the various sampling sites. The error bars indicate ± Standard deviation

All the sampling sites had mean pH values below the WHO Guidelines value of 8.5 and EPA-GH Guideline value of 9.0 pH units. Maximum mean pH was recorded at Slaughter house Suntri with a value of 5.73 ± 0.10 followed by Suntri river of value 5.68 ± 0.72. Kyenebra River recorded value of 5.595 ± 0.35 and least value of 5.48 ± 0.04 was recorded at Mmabamena. There were no significant differences ($p > 0.05$) in pH between the rivers.

4.2. Temperature Values

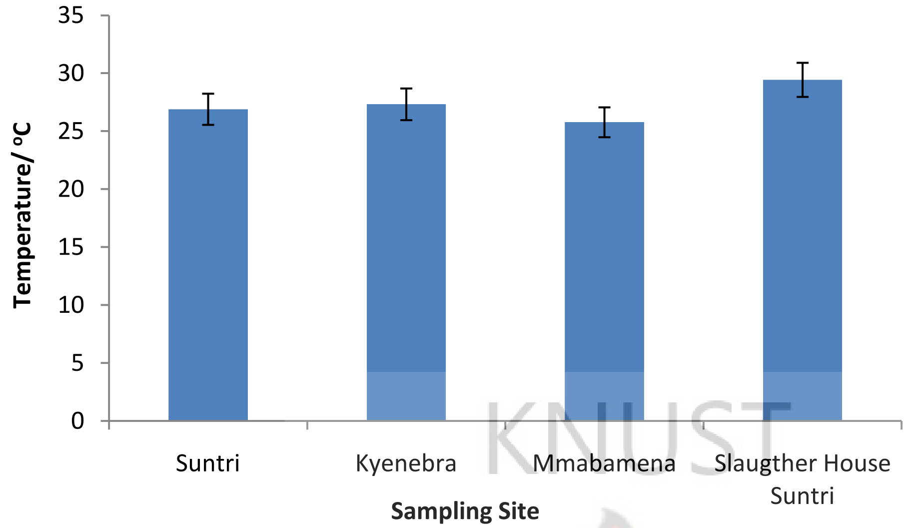

Fig.4.2 Mean Temperature (^{0}C) values recorded at the various sampling sites. Error bars indicate ± Standard deviation.

Maximum mean Temperatures were recorded at Slaughter house Suntri with a value of 29.44 ±0.53 and Minimum value of 25.78 ± 1.09^{o}C was recorded at Mmabamena sampling site. Suntri recorded a value of 26.090 ± 0.96 followed by Kyenebra. There were significant differences ($p < 0.05$) between the temperatures of the rivers.

4.3 Apparent and True Colour

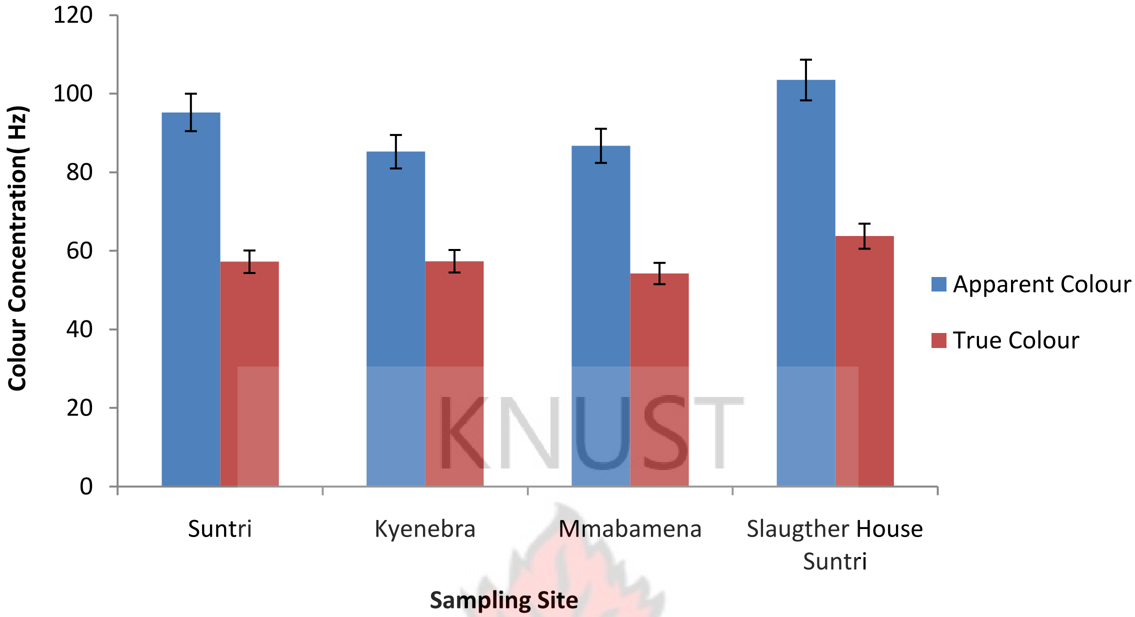

Fig.4.3 Mean Apparent and True Colour (Hz) values recorded at sampling sites. Error bars indicate ± Standard deviation.

Mean Apparent and True Colour (Hz) values (fig.4.3) recorded at all the sampling sites were all above the normal range as enshrined in the WHO Guidelines for drinking water of 15 Hz. Maximum mean Apparent colour and True Colour were recorded at Slaughter Suntri with a value of 103.5 ± 0.53 mg/L and 63.75 ± 0.3 mg/l. Minimum Apparent Colour of 85.25 ± 0.25 mg/l was recorded at Kyenebra and Minimum True Colour values of 54.25 ± 0.26 mg/l was recorded at Mmabamena.

4.4 Turbidity Values

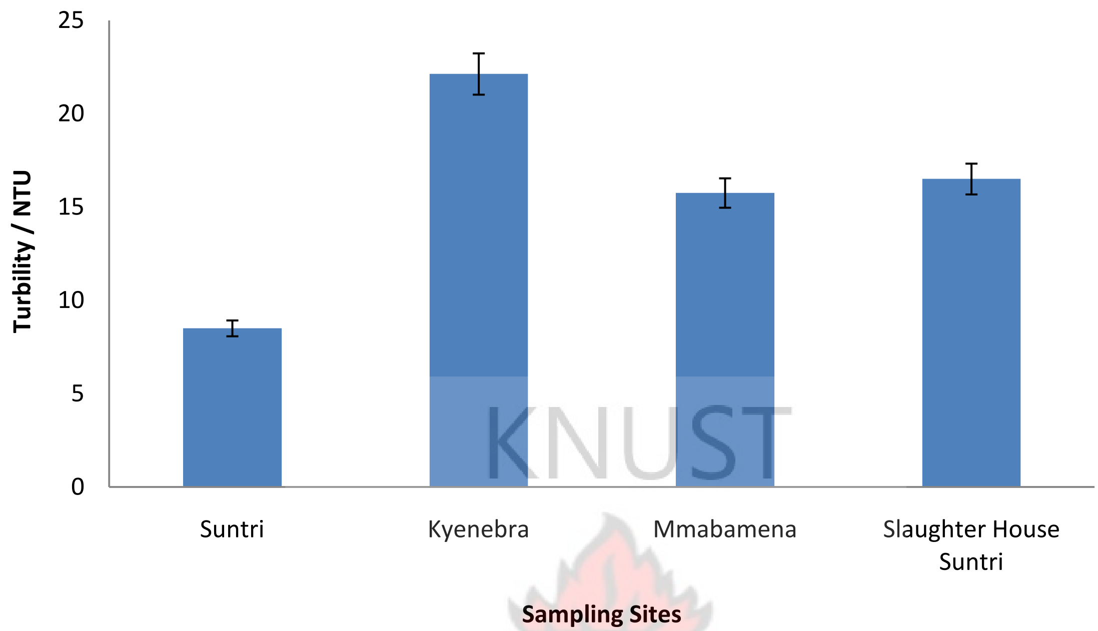

Fig.4.4 Mean Turbidity values recorded at various sampling sites. Error bars indicate ± Standard deviation.

Mean Turbidity values at all the sampling sites were above the WHO recommended Guidelines of 5 NTU for drinking water. Maximum mean Turbidity was recorded at Kyenebra with a value of 22.13 ± 2.17 NTU and Minimum value of 8.5 ± 1.51 NTU was recorded at Suntri. Mmabamena sampling site recorded a value of 15.75±2.053. Slaughter house Suntri recorded value of 16.50 ± 2.879. There were significant differences ($p < 0.05$) between the turbidity of the rivers.

4.5 Phosphate Concentration

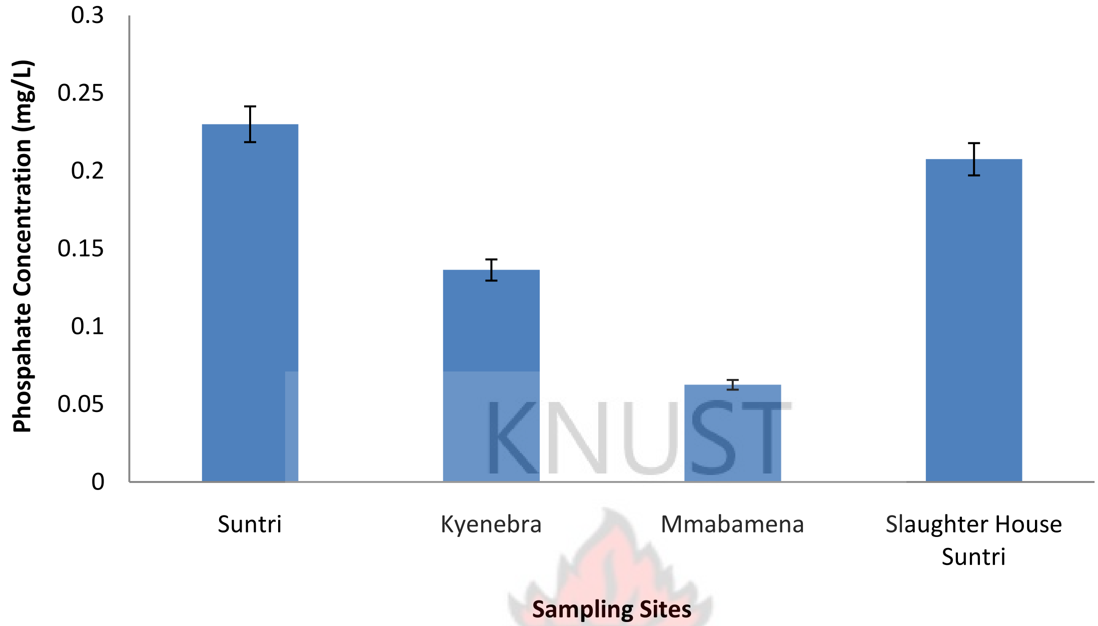

Fig.4.5 Mean Phosphate Concentration values recorded at sampling sites. Error bars indicate ± Standard deviation.

Mean Phosphate Concentration values at all the sampling sites were below the WHO recommended Standard of 0.29 mg/l for drinking water. Maximum mean Phosphate Concentration was recorded at Suntri with a value of 0.23± 0.17 mg/L and Minimum value of 0.063 ± 0.03 mg/L was recorded at Mmabamena. There were significant differences ($p < 0.05$) between the mean phosphate concentrations of the rivers.

4.6 Nitrate Concentration

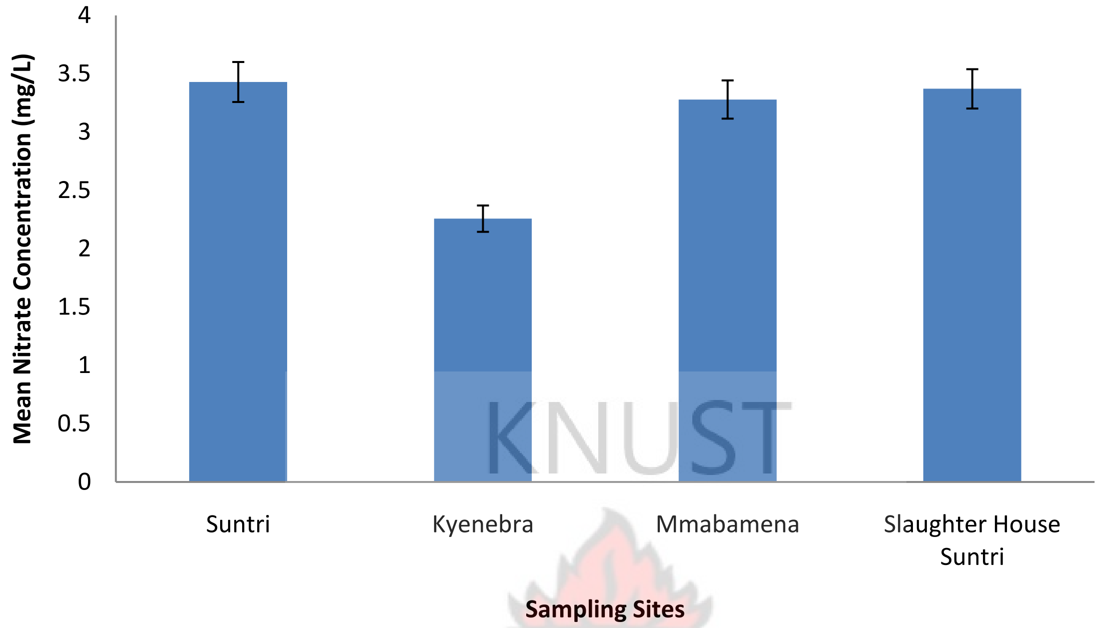

Fig.4.6 Mean Nitrate Concentration values recorded at sampling sites. Error bars indicate ± Standard deviation.

Mean Nitrate Concentrations values at all the sampling sites were below the WHO recommended guideline of 50.0 mg/l for drinking water. Maximum mean Nitrate Concentration was recorded at Suntri with a value of 3.43± 0.32 mg/l and Minimum value of 2.26 ± 0.14 mg/l was recorded at Kyenebra, There were significant differences ($p < 0.05$) between the mean Nitrate concentration of the rivers.

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4.7 Mercury Concentration

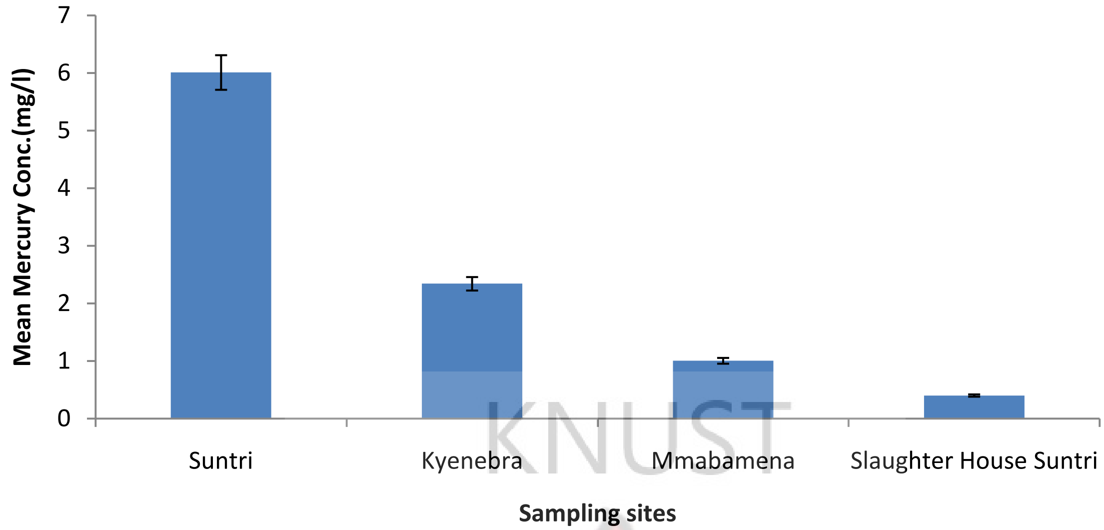

Figure 4.7 Mean Mercury Concentration values recorded at 4 sampling sites.

Mean values of Mercury Concentrations recorded at the Sampling sites are shown in figure 4.7. Error bars indicate ± Standard deviation.

Mercury Concentrations values at all the sampling sites were above the WHO recommended Guidelines of 0.01mg/L for drinking water. Maximum mean Mercury Concentration was recorded at Suntri with a value of 6.01± 0.34 mg/l, followed by Kyenebra with value of 2.34 ± 0.02 mg/l. The Minimum value of 1.003 ± 0.02 mg/l was recorded at Mmabamena with Slaughter House Suntri recording the least value of 0.4 ± 0.001 mg/l slightly above the WHO Guidelines. There were significant differences ($p < 0.05$) between the mean Mercury concentrations of the rivers.

4.8 Lead Concentration

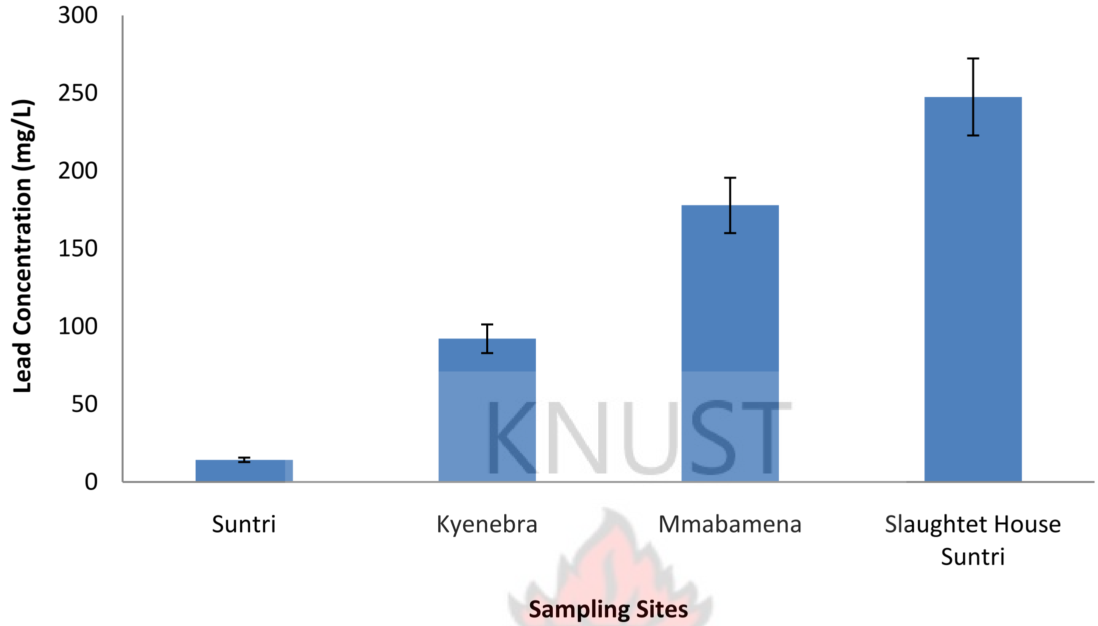

Fig.4.8 Mean Lead Concentration values recorded at sampling sites. Error bars indicate ± Standard deviation.

Mean Lead Concentration values at all the sampling sites were above the WHO recommended Guidelines values of 0.1 mg/l for drinking water. Maximum mean Lead Concentration at Slaughter House Suntri was 247.54 ± 9.17 mg/l followed by Mmabamena with a value of 177.825 ± 7.963 mg/L. A value of 92.110± 2.149 mg/l was recorded at Kyenebra with Suntri recording the least value of 14.26± 0.69 mg/L. There were significant differences ($p < 0.05$) between the mean Lead concentrations of the rivers.

4.9 Total Coliform Concentration

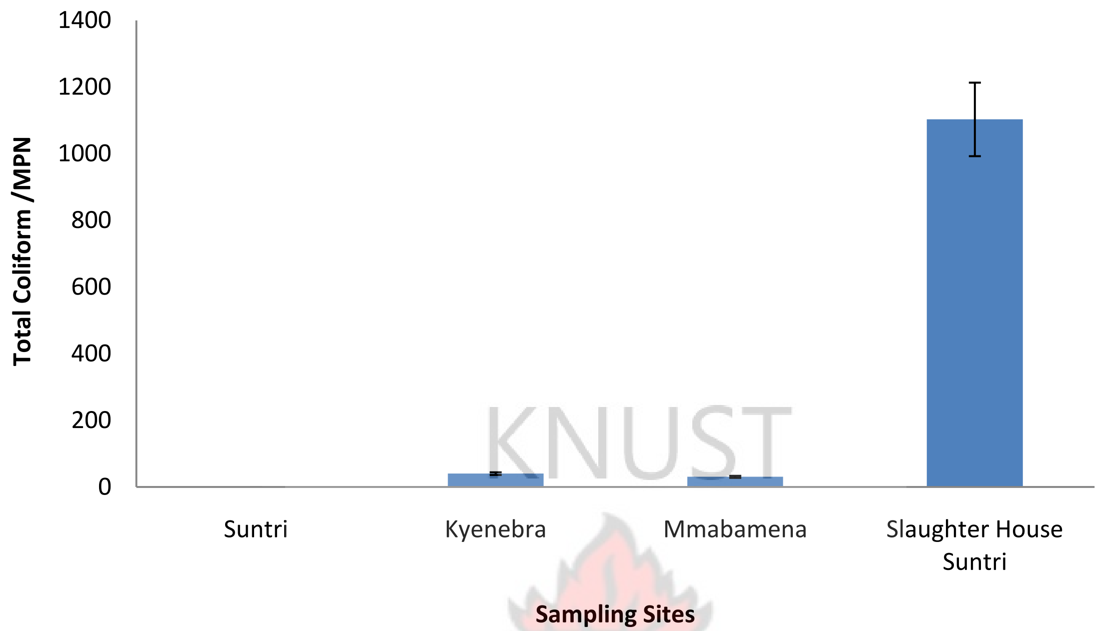

Fig.4.8 Mean Total Coliform (MPN) values recorded at sampling sites. Error bars indicate ± Standard deviation.

Mean Total Coliform numbers at all the sampling sites were above the WHO recommended Guidelines values of 0.00 MPN for drinking water. Maximum mean Total Coliform was recorded at Slaughter House Suntri with a value of 1102.8± 2.9 MPN followed by Kyenebra, 40.224 ± 0.373 MPN. The value of 30.573 ± 0.673 MPN was recorded at Mmabamena with Suntri recording the least value of 0.03 ± 0.03 MPN. There were significant differences ($p < 0.05$) between the Total Coliform of the rivers.

Table 4.1 Correlation Matrix for River Kyenebra parameters

Parameter	pH	Temp.	A. Col.	T. Col	Turb.	P	N	Hg	Pb
Temp.	-0.008								
App. Col.	0.610*	-0.304							
True. Col	-0.328	-0.157	-0.148						
Turb.	-0.383	0.677*	-0.043	0.207					
P	0.591*	0.537*	0.203	-0.427	0.173				
N	0.078	0.533*	0.13	-0.508**	0.512*	0.728*			
Hg	-0.269	0.821*	-0.708**	-0.043	0.387	0.264	0.291		
Pb	0.252	0.271	0.511*	0.006	0.449	0.621*	0.75*	0.002	
T. Coli	-0.250	0.718*	0.817*	-0.062	0.227	0.191	0.124	0.959*	-0.224

The above values represent positive and negative correlations for parameters investigated. *indicate the existence of positive correlations between two parameters.

Negative Correlations existed between Mercury and Apparent Colour as well as between Nitrogen and Total Coliform. However, Positive Correlation existed between Phosphorus and pH, Apparent Colour and pH, Turbidity and Temperature, Temperature and Phosphorus, Nitrogen and Temperature, Mercury and Temperature, Total Coliform and Temperature, Total Coliform and Apparent Colour.Phosphorus and Nitrogen, Phosphorus and Lead, Lead and Nitrogen and finally between Total Coliform and Mercury.

Table 4.2 Correlations Matrix for Mmabamena parameters

Parameter	pH	Temp.	A. Col	T. Col	Turb.	P	N	Hg	Pb
Temp.	0.678*								
App. Col	0.121	-0.452							
True Col	0.405	0.701*	-0.53**						
Turb.	-0.072	-0.061	0.147	-0.398					
P	0.558*	0.332	0.136	-0.127	-0.328				
N	0.090	0.255	0.047	0.280	0.589*	-0.66*			
Hg	0.654*	0.617*	0.118	0.119	-0.230	0.824*	-0.246		
Pb	0.388	0.781*	-0.66**	0.733*	0.229	-0.221	0.559*	0.095	
T.Coli	0.817*	0.819*	-0.323	0.451	0.144	0.334	0.270	0.459	0.700*

The above values represent positive and negative correlations for parameters investigated.

** indicate the existence of negative correlations between two parameters. *indicate the existence of positive correlations between two parameters.

Strongly Negative Correlations existed between Lead and Apparent Colour as well as between True Colour and Apparent Colour and between Nitrogen and Phosphorus. However, Strongly Positive Correlation existed between Temperature and pH, Phosphorus and pH, Mercury and pH, Total Coliform and pH, True Colour and Temperature, Mercury and Temperature, Temperature and Lead, Total Coliform and Temperature, Lead and True Colour, Turbidity and Nitrogen, Lead and Nitrogen and Total Coliform and Lead,

Table 4.3 Correlations Matrix for Suntri parameters

Parameter	pH	Temp.	A.Col	T.Col	Turb.	P	N	Hg	Pb
Tem	-0.76**								
App.Col	-0.019	0.479							
True Col.	-0.177	-0.200	-0.188						
Turb.	0.429	-0.063	0.483	-0.68**					
P	0.577*	-0.51**	-0.367	-0.084	-0.060				
N	0.325	-0.427	-0.211	0.003	0.174	0.735*			
Hg	0.072	0.005	0.420	-0.310	0.681*	-0.57**	0.139		
Pb	0.526*	-0.386	0.249	-0.005	0.337	0.356	0.261	-0.198	
T. Coli	0.868*	-0.499	0.027	-0.383	0.361	0.738*	0.424	-0.059	0.291

The above values represent positive and negative correlations for parameters investigated

** indicate the existence of negative correlations between two parameters.*indicate the existence of positive correlations between two parameters

Strongly Negative Correlations existed between Temperature and Lead, Temperature and Phosphorus, as well as between Mercury and Phosphorus. However, Strongly Positive Correlation existed between Lead and pH, Total Coli form and pH, Lead and pH, Phosphorus and Nitrogen, Total Coliform and Phosphorus

Table 4.4 Correlations matrix for slaughter house Suntri Parameters

Parameter	pH	Temp.	App.Col	True.Col	Turb.	P	N	Hg	Pb
Temp.	0.194								
App.Col	-0.065	0.775*							
True.Col	0.241	0.150	0.479						
Turb.	-0.002	0.666*	0.426	-0.422					
P	0.866*	0.288	-0.195	-0.098	0.182				
N	0.434	0.147	0.239	0.003	0.478	0.188			
Hg	0.406	0.754*	0.338	-0.042	0.676*	0.581*	0.339		
Pb	-0.133	0.345	0.410	-0.108	0.704*	-0.165	0.705*	0.540*	
T.Coli	0.621*	0.595*	0.144	-0.044	0.510*	0.837*	0.243	0.888*	0.247

The above values represent positive and negative correlations for parameters investigated

*indicate the existence of positive correlations between two parameters

No Strongly Negative Correlations existed between any of the Parameters. However, Strongly Positive Correlation existed between Phosphorus and pH, Total Coliform and pH, Apparent Colour and Temperature, Turbidity and Temperature, Mercury and Temperature, Total Coliform and Temperature, Lead and Turbidity, Total Coliform and Turbidity, Lead and Nitrogen, Lead and Mercury, Mercury and Total Coli form.

CHAPTER FIVE

DISCUSSION

5.1 Physico-Chemical and Biological Characteristics of sampling sites

5.2. pH

Mmabamena recorded the lowest pH value of 5.48 ± 0.04 pH units (fig 4.1). The decrease in the pH value of the Mmabamena water samples below the WHO and EPA-Ghana Guidelines may be due to absence of dissolved carbonate and bicarbonate in the rivers, which is known to affect pH of almost all surface waters (Chapman, 1992). The decrease in pH below the Guidelines suggested that river Mmabamena was highly acidic which could affect organisms in the river as well as causing reduction of plant growth around it banks since some plants do not grow well in strongly alkaline soils due to some plants inability to absorb some element such as iron and manganese.

The correlation between pH and other parameters might be due to activities such as dumping of refuse and application of fertilizer for farming purposes closed to the bank of the rivers. The temperature of this river also depends on the pH value since the river is at times fed by rain or surface run-off which could flow into it to attain its temperature.

The increase in the pH value of Slaughter House Suntri below the WHO and EPA-Ghana Guidelines may also be due to absence of dissolved carbonate and bicarbonate in the rivers, which is known to affect pH of almost all surface waters (Chapman, 1992). Comparatively, the acid level of Mmabamena sampling point was slightly higher than Slaughter House Suntri. The difference in pH values might be due to differences in the extent of human activities around the river banks.

Increase in Total Coliform concentration in the rivers might be due to activities such as dumping of animal waste, application of fertilizer for farming purposes and citing of abattoir closed to the bank of the rivers.

The introduction of lead into this sampling site might be due to the burning of lorry tyres around the banks of this river as well as dumping of waste. The dumping of solid and liquid wastes around the banks of this river continues to threaten the survival of this river.

The presence of plants in and around the bank of this river can release colored organic compound into the river.

5.3 TEMPERATURE:

EPA- Ghana recommended Guidelines for Temperature of water ranges from $29–30^0C$. The lowest value of 25.78 ± 1.09^0C (Fig 4.2) recorded at Mmabamena indicate that the river was surrounded with stream vegetation which do not allow direct sunlight heating the surface of this river. The highest temperature at Slaughter house Suntri above the EPA- Ghana Guideline depicted the burning of lorry tyres as well as Slaughter house activities being carried out along the banks. Also, the temperature range is a reflection of its tropical status. Also, the slightly high mean temperature recorded in Slaughter house Suntri may be due to effluents dumped into the river. When people dump heated effluents into waterways, the effluents raise the temperature of the water. There was an increase in the rate of decay of organic matter in this river due to the increased temperature

5.4 THE APPARENT AND TRUE COLOUR

Generally, the color values of a water sample depend on the pH of the sample. It usually increases as the pH of the water increases. Colour measured in water containing suspended matter is defined as apparent colour (APHA, 1992). Natural waters range from 5mg/L Hz in very clear waters to 1200 mg/L Hz in dark peaty waters (Keyser, 1997).The presence of turbidity in the water sample caused the apparent color to be significantly higher than the true color.

The Apparent and True colour values that were recorded for Mmabamena Rivers were above the WHO Guidelines (15Hz). This indicates that all the rivers are not aesthetically acceptable. Water colour from rivers could have been influenced by the presence of humic substance from the soil, dissolved organic materials, animal or decaying plant material which are present in the river bodies. Colour is also strongly influenced by the presence of iron and other metals, either as impurities or as corrosion products. The high levels of colour organic matter recorded in the water of these streams may be due to decaying dead organic matter (Karikari and Ansa-Asare, 2006).

5.5 TURBIDITY

The highest mean values of 22.13 ± 0.77 NTU (figure 4.4) at Kyenebra that exceeded the WHO value of 5.0 NTU might be due the flow rate of fast running water that carries particles and large sized sediment in to the river. Therefore, during storm events, soil particles and debris from street and residential areas are washed into the river. The high levels mean turbidity recorded may also be due to soil erosion and decay of dead organic matter from improper disposal of domestic waste within the banks of the rivers. The elevated high turbid water is often associated with the possibility of microbiology pollution as turbidity makes it difficult to disinfect water properly (DWAF, 1998). An increase or decrease in turbidity will affect organisms according to their levels of tolerance.

The lowest mean values of 8.5 ± 1.512 NTU at Suntri also exceeded the WHO value of 5.0 NTU this might be due to the flow rate of fast running water that carries particles and large sized sediment in to the river. Therefore, during storm events, soil particles and debris from street and residential areas can be washed into the river. The high levels mean turbidity recorded may also be due to soil erosion and decay of dead organic matter from improper disposal of domestic waste within the banks of the rivers. The elevated high turbid water is often associated with the possibility of microbiology pollution as turbidity makes it difficult to disinfect water properly (DWAF, 1998).

Effluent from Wastewater can add suspended solids and organic material to rivers. The wastewater from houses contains food residue, human waste, and other solid material that when put down in drains leading to high turbidity of the rivers. High turbidity levels in water causes problem with water purification processes such as flocculation and filtration (DWAF, 1998).

5.6 THE NITRATE-NITROGEN CONCENTRATION

The lowest mean value of 2.26 ± 0.14 mg/l (fig 4.6) recorded at Kyenebra might be due to low farming activities that take place around the banks of this river. Also, the presence of plants in the river might have considerable ability to capture nitrogen through the process of absorption. The highest value of 3.43 ± 0.32 mg/l at Suntri might be due to gradual increase in the application of fertilizer used by farmers along the banks of this river than what pertains in river Kyenebra. The WHO maximum permissible limit for nitrate is 50mg/l (WHO, 2004) and therefore the low recorded values from these rives might be due to limited agricultural activities along the banks of these rivers.

5.7 THE PHOSPHATE CONCENTRATION

The lowest mean value of 0.06 ± 0.03 mg/l was recorded at Mmabamena. However in relations to EPA-Ghana and WHO recommended values of phosphate in surface water, all the rivers recorded a very low concentration of phosphate level. There were significant differences ($p < 0.05$) in all the sampling locations. The low levels mean phosphate concentrations recorded in the rivers indicate that a form of purification of the water before drinking is recommended. The low levels of phosphate concentration in the rivers could be due to low agriculture activities found along the banks of the stream (Sharpley *et al.,* 1989).

5.8 LEAD CONCENTRATION

In relation to EPA-Ghana and WHO recommended values of lead in surface water (0.1mg/l0); all the samples recorded a very high concentration of lead level.

The strong correlation between Lead and Total Coliform in Mmabamena indicate that, the high level mean lead concentrations recorded in the rivers indicate that, at levels greater than 0.01 mg/, possible neurological damage in foetus and young children may occur (WHO, 2004). These levels were exceeded in the rivers and the direct use of water from the rivers for domestic function without treatment could be harmful to pregnant women and young children. All the records from the samples indicate that all the rivers are not suitable for the maintenance of aquatic ecosystem, livestock and irrigation. The route of entry of lead into these streams may include surface erosion of lead contaminated soils, airborne drift of fine dust, and contamination of other sources of discharge into surface waters (USEPA, 1997). Other possible sources of lead pollution in the rivers could be from the geology of the catchment area.

5.9 MERCURY CONCENTRATION

The lowest mean mercury concentration value of 0.0021 ± 0.00010 mg/L(Fig. 4.5) was recorded at Slaughter house Suntri and highest of 6.01 ± 0.339 mg/L at Suntri. In relation to EPA-Ghana and WHO recommended values of mercury in surface water; all the samples recorded a very high concentration of mercury level. The highest level of mercury recorded in river Suntri was a manifestation of the fact that approximately 80% of mercury that enters the Suntri comes from natural sources as confirmed by Charest (1991).

There were significant differences ($p < 0.05$) in all the sampling locations. The high levels of mercury recorded in the rivers indicate that at levels greater than 0.01 mg/L could be harmful to human health. The rivers are not suitable for the maintenance of aquatic ecosystem, livestock and irrigation.

5. 10 TOTAL COLIFORMS

The presence of total coliforms generally does not imply an imminent health risk but does require an analysis of all water system facilities and their operation to determine how these organisms entered the water system. For water to be considered no risk to human health, the total coliform count in the water sample should be zero (WHO, 1987). The EPA-Ghana and WHO recommended values of Total Coliform in surface water is Zero.

In relation to EPA-Ghana and WHO recommended values of Total Coliform in surface water; all the samples recorded a very high Total Coliform count. The presence of high Total Coliform counts in Slaughter House Suntri was a sign of the extent of contamination of the river by pathogens or disease-causing organism due to human activities such as closeness of the abattoir to the banks of the river as well as the presence of huge refuse dump situated around the banks. Defecating and Dumping of animal wastes into Slaughter house Suntri River is common practice that prevailed around the banks. Therefore, the highest total Coliform recorded in this river goes to confirm the prevailing activities in the area.

5.11 CONCLUSION AND RECOMMENDATION

5.11.1 CONCLUSION

In general, almost all the physico-chemical parameter including some heavy metals and microbial load measured in the water samples from the selected rivers serving the community were above WHO and EPA-Ghana Guidelines. Currently, the rivers serving the community are contaminated and therefore, not suitable for drinking without treatment. Human activities along the banks are threatening the survival of these rivers and have adversely affected the water quality.

5.11.2 RECOMMENDATIONS

Since most of the rivers are used for of purposes such as drinking, fishing, irrigation and other domestic purposes without prior treatment, for sustainable management of the resources,

a. Constant monitoring of the river banks is required to ensure good water quality standards.
b. The Berekum Municipal Assembly should design sanitation programmes and propagate these through environmental education throughout the communities in the catchment to prevent pollution of water bodies and subsequent transmission of water-related diseases.
c. Farmers should be assisted in fertilizer application by agricultural extension officers of the Ministry of Food and Agriculture to avoid the incidence of high level nutrient in water samples.

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APPENDIX I

Field research results November, 2010 sampling period

Report of analysis								**date sampled:03-11-2010**
Parameters	S		K		M		SS	
pH	5.15	5.25	5.48	5.46	5.46	5.42	5.78	5.62
Temperature	26.80	27.50	26.60	27.40	25.4	24.60	29.1	29.0
Apparent colour	95.00	98.00	85.00	89.00	86.00	89.00	100.00	104.00
True colour	66.00	58.00	81.00	59.00	69.00	40.00	73.00	65.00
Turbidity	6.00	10.00	21.00	25.00	15.00	19.00	10.00	16.00
Phosphate	0.09	0.10	0.08	0.12	0.03	0.01	0.20	0.16
Nitrate	3.26	3.46	2.00	2.28	3.30	3.42	3.22	3.50
Mercury	5.92	6.12	0.101	0.201	0.201	0.0201	0.301	0.401
Lead	13.90	15.10	91.10	91.97	179.20	177.20	234.40	254.62
Total coliform	0.00	0.00	40.00	40.01	30.00	30.02	1100	1099.8

APPENDIX II

Field research results December, 2010 sampling period

Report of analysis **date sampled:03-12-2010**

Parameters	S		K		M		SS	
pH	5.13	5.23	5.45	5.44	5.49	5.46	5.68	5.63
Temperature	27.00	27.20	26.40	27.50	25.42	24.65	29.40	29.50
Apparent colour	89.00	97.00	85.00	87.00	84.00	87.00	99.00	101.00
True colour	57.00	54.00	46.00	53.00	62.00	38.00	56.00	60.00
Turbidity	7.00	9.00	19.00	23.00	13.00	15.00	16.00	18.00
Phosphate	0.20	0.11	0.09	0.13	0.06	0.08	0.21	0.17
Nitrate	3.16	3.36	2.20	2.28	3.20	3.12	3.13	3.40
Mercury	5.72	6.32	0.101	0.202	1.003	0.002	0.003	0.005
Lead	13.60	14.10	90.10	91.87	178.20	167.20	233.40	253.62
Total coliform	0.01	0.02	40.05	40.03	30.5	30.4	1101	1100

APPENDIX III

Field research results January, 2011 sampling period

Report of analysis								**date sampled:03-01-2011**
Parameters	S		K		M		SS	
pH	5.7	5.6	5.49	5.45	5.47	5.49	5.69	5.68
Temperature	28.00	27.50	27.40	28.50	27.42	25.65	29.50	30.50
Apparent colour	99.00	97.00	75.00	77.00	74.00	97.00	98.00	121.00
True colour	56.00	55.00	56.00	57.00	68.00	48.00	57.00	70.00
Turbidity	8.00	10.00	21.00	24.00	15.00	14.00	17.00	19.00
Phosphate	0.30	0.13	0.16	0.14	0.07	0.09	0.22	0.19
Nitrate	3.18	3.46	2.24	2.29	3.25	3.22	3.33	3.35
Mercury	5.62	6.52	0.004	0.008	0.004	0.005	0.003	0.003
Lead	14.50	13.20	90.30	91.57	188.20	167.20	253.40	253.64
Total coliform	0.05	0.04	40.6	41.00	31.01	30.05	1105	1104

APPENDIX IV

Field research results February, 2011 sampling period

Report of analysis **date sampled:03-02-2011**

Parameters	S		K		M		SS	
pH	6.13	7.23	6.45	5.54	5.57	5.50	5.8	5.93
Temperature	26.00	25.20	27.32	27.50	27.42	25.65	29.70	29.80
Apparent colour	92.00	95.00	95.00	89.00	88.00	89.00	100.00	105.00
True colour	59.00	57.00	48.00	59.00	67.00	42.00	66.00	63.00
Turbidity	8.00	10.00	20.00	24.00	17.00	18.00	17.00	19.00
Phosphate	0.60	0.31	0.19	0.18	0.07	0.09	0.25	0.26
Nitrate	4.16	3.39	2.27	2.50	3.40	3.32	3.23	3.80
Mercury	5.62	6.22	0.001	0.003	0.004	0.004	0.003	0.003
Lead	14.60	15.10	93.10	96.87	188.20	177.20	243.40	253.92
Total coliform	0.06	0.07	40.00	40.10	32.00	30.60	1107	1106

APPENDIX V

ANOVA of field results at $p < 0.05$ significant level

Variable	p-value
pH	0.643
Temperature	0.000
Apparent colour	0.000
True colour	0.010
Turbidity	0.000
Phosphate	0.004
Nitrate	0.000
Mercury	0.000
Lead	0.000
Total Coliform	0.000

APPENDIX VI

World Health Organization (WHO) maximum permissible limits for potable water

Parameter	Unit	WHO 2004
pH	pH unit	6.5-8.5
Temperature	^{0}C	29
Apparent colour	HZ	15
True colour	HZ	15
Turbidity	NTU	5.0
Phosphate	mg/l	0.29
Nitrate –N	mg/l	50
Mercury	mg/l	0.01
Lead	mg/l	0.01
Total coliform	Cfu	0.00

APPENDIX VII

Environmental Protection Agency (EPA-Ghana) maximum permissible limits for potable water

Parameter	Unit	EPA, 1994
pH	pH unit	6.9-9.0
Temperature	◦C	29-30
Apparent colour	HZ	150(24 Hours)
True colour	HZ	150
Turbidity	NTU	75
Phosphate	mg/l	2.0
Nitrate –N	mg/l	11.5
Mercury	mg/l	0.01
Lead	mg/l	0.1
Total coliform	Cfu	0.00

APPENDIX VII

Mean, Standard Deviation, Standard Error and ranges of physical, chemical and Biological quality of various stream period.

pH Parameter

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
Suntri	8	5.6775	.71540	.25293	5.0794	6.2756	5.13	7.23
Kyenebra	8	5.5950	.34695	.12266	5.3049	5.8851	5.44	6.45
Mmabamena	8	5.4825	.04334	.01532	5.4463	5.5187	5.42	5.57
Slaughter House Suntri	8	5.7262	.10419	.03684	5.6391	5.8134	5.62	5.93
Total	32	5.6203	.39297	.06947	5.4786	5.7620	5.13	7.23

Ph

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.273	3	.091	.564	.643
Within Groups	4.514	28	.161		
Total	4.787	31			

Temperature

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Mini	Max
Suntiri	8	26.9000	.90554	.32016	26.1430	27.6570	25.20	28.00
Kyenebra	8	27.3275	.63632	.22497	26.7955	27.8595	26.40	28.50
Maababira	8	25.7763	1.09258	.38629	24.8628	26.6897	24.60	27.42
Slaughter House Suntiri	8	29.4375	.52355	.18510	28.9998	29.8752	28.80	30.50
Total	32	27.3603	1.55693	.27523	26.7990	27.9216	24.60	30.50

Temperature

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	56.295	3	18.765	27.875	.000
Within Groups	18.849	28	.673		
Total	75.145	31			

Turbidity

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
Suntri	8	8.5000	1.51186	.53452	7.2361	9.7639	6.00	10.00
Kyenebra	8	22.1250	2.16712	.76619	20.3132	23.9368	19.00	25.00
Mmabamena	8	15.7500	2.05287	.72580	14.0338	17.4662	13.00	19.00

Slaughter House Suntri	8	16.5000	2.87849	1.01770	14.0935	18.9065	10.00	19.00
Total	32	15.7188	5.34750	.94531	13.7908	17.6467	6.00	25.00

Turbidity

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	750.094	3	250.031	51.335	.000
Within Groups	136.375	28	4.871		
Total	886.469	31			

Phosphate

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Suntri	8	.2300	.17321	.06124	.0852	.3748	.09	.60
Kyenebra	8	.1363	.03962	.01401	.1031	.1694	.08	.19
Mmabamena	8	.0625	.02866	.01013	.0385	.0865	.01	.09
Slaughter House Suntri	8	.2075	.03536	.01250	.1779	.2371	.16	.26
Total	32	.1591	.10973	.01940	.1195	.1986	.01	.60

Phosphate

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.138	3	.046	5.461	.004
Within Groups	.235	28	.008		
Total	.373	31			

Nitrate

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
Suntri	8	3.4288	.31746	.11224	3.1633	3.6942	3.16	4.16
Kyenebra	8	2.2575	.13677	.04836	2.1432	2.3718	2.00	2.50
Mmabamena	8	3.2787	.10176	.03598	3.1937	3.3638	3.12	3.42
Slaughter House Suntri	8	3.3700	.20853	.07373	3.1957	3.5443	3.13	3.80
Total	32	3.0838	.52630	.09304	2.8940	3.2735	2.00	4.16

Nitrate

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7.373	3	2.458	56.719	.000
Within Groups	1.213	28	.043		
Total	8.587	31			

Mercury

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Mini	Max
Suntri	8	6.0075	.33991	.12017	5.7233	6.2917	5.62	6.52
Kyenebra	8	.0026	.00245	.00086	.0006	.0047	.00	.01
Mmabamena	8	.0030	.00151	.00053	.0017	.0043	.00	.01
Slaughter House Suntri	8	.0021	.00099	.00035	.0013	.0030	.00	.00
Total	32	1.5038	2.64674	.46788	.5496	2.4581	.00	6.52

Mercury

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	216.354	3	72.118	2496.623	.000
Within Groups	.809	28	.029		
Total	217.163	31			

Lead

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Suntri	8	14.2625	.68648	.24271	13.6886	14.8364	13.20	15.10
Kyenebra	8	92.1100	2.14951	.75997	90.3130	93.9070	90.10	96.87
Mmabamena	8	177.8250	7.96308	2.81538	171.1677	184.4823	167.20	188.20
Slaughter House Suntri	8	247.5450	9.16982	3.24202	239.8788	255.2112	233.40	254.62
Total	32	132.9356	89.49164	15.82004	100.6704	165.2008	13.20	254.62

Lead

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	247203.257	3	82401.086	2160.094	.000
Within Groups	1068.116	28	38.147		
Total	248271.372	31			

Total Coliform

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Mini	Max
Suntri	8	.0313	.02748	.00972	.0083	.0542	.00	.07
Kyenebra	8	40.2237	.37282	.13181	39.9121	40.5354	40.00	41.00
Mmabamena	8	30.5725	.67305	.23796	30.0098	31.1352	30.00	32.00
Slaughter House Suntri	8	1102.8500	2.97753	1.05272	1100.3607	1105.3393	1099.80	1107.00
Total	32	293.4194	475.04412	83.97673	122.1477	464.6910	.00	1107.00

Total Coliform

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6995608.262	3	2331869.421	986151.760	.000
Within Groups	66.209	28	2.365		
Total	6995674.472	31			