

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

**THE EUTROPHICATION POTENTIAL OF WATER AND SEDIMENTS OF
THE TATAFO STREAM IN THE MAMPONG MUNICIPALITY OF GHANA**

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**A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND
APPLIED BIOLOGY, COLLEGE OF SCIENCE, KWAME NKRUMAH
UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER
OF SCIENCE DEGREE IN ENVIRONMENTAL SCIENCE.**

BY

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DECLARATION

I hereby declare that this Thesis is the result of my own field work towards the MSc. and has been composed under supervision. It has not been submitted previously either wholly or partially for a degree in the Kwame Nkrumah University of Science and Technology or elsewhere, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to the Almighty God and to my beloved late father Mr. Robert Kwasi Wiafe.

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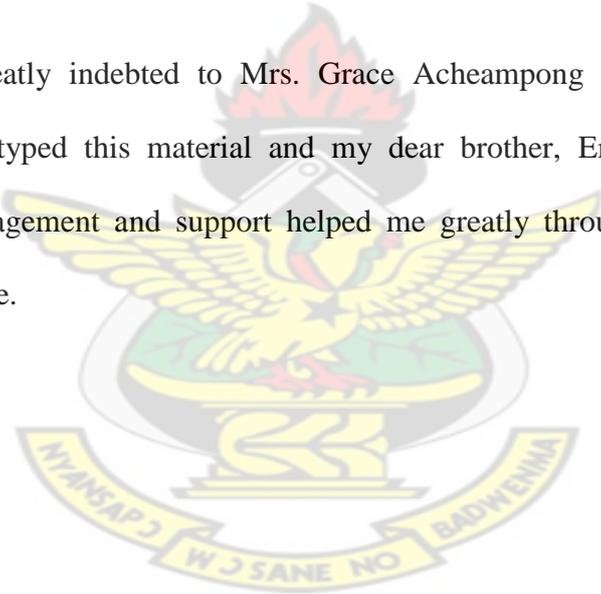


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ABSTRACT

Eutrophication results from increased nutrient loads specifically, nitrogen and phosphorus enrichment in water bodies. The Tatafo stream is one of the direct sources of drinking water for some people in the Mampong-Ashanti municipality and surrounding communities. The stream has been encroached by vegetable growers mainly carrot farmers resulting in pollution of the water body. The Eutrophication potential of both water and sediments of Tatafo stream within the Mampong – Ashanti Municipality was assessed. The levels of pH, electrical conductivity, Total dissolved solids, total suspended solids, biochemical oxygen demand, dissolved oxygen, turbidity, phosphate and nitrate in water, phosphorus and nitrogen in sediments, among others were determined. Three sampling sites were selected along the stream and studied over a period of five months.

The results of the study revealed high levels of nitrate above the WHO limits of (5.0 mg/l), upstream samples recorded 7.02 mg/l, 7.33 mg/l in the midstream and 6.61 mg/l in the downstream along the sections of the stream. The findings also revealed that the values of organic matter (0.18%) and organic carbon (0.58%) varied significantly ($P < 0.05$). However, Turbidity values of 53 NTU at the upstream, 67.9 NTU at midstream and 38.4 at down stream and Total Suspended Solids values ranging from a mean 27.40 mg/l to 132.6 mg/ were all above the World Health Organization limits of 5 NTU and 20 mg/l respectively.

Adverse impact on the physico-chemical parameters as a result of vegetable crop farming along the stream poses an environmental and health risk to the people in the Mampong town and nearby communities who rely directly on the stream as the source of water for their domestic use. There is the need for the intervention of appropriate regulatory agencies to check the activities of farmers along the stream and educate people who directly depend on the stream.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Eutrophication is the enrichment of water bodies with nutrient such as nitrate and phosphate which support plant growth. Continuous nutrient loading of water bodies from domestic and agricultural activities may enhanced the rate of eutrophication in water bodies. Eutrophication of water bodies caused by over-enrichment with Nitrogen and Phosphorus has been found to cause toxic algal blooms, loss of oxygen, fish deaths, loss of biodiversity and other degradation of aquatic environments (Carpenter *et. al.*, 1998.).

There are a lot of water resources such as streams, rivers, lakes, dams, water falls, underground and rain water in Ghana (Allotey, 1991). However, Ghana's water resources have been under increasing threat of pollution in recent years. This threat can be attributed to improper planning of human settlements and anthropogenic activities such as farming very close to water bodies. These activities are very common in rural and peri-urban areas.

Water, the source of life and human civilization has become one of the major issues of the 21st century. It is probably the most valuable natural resource available to man, without which nothing can survive. Unfortunately, in many areas of the world, it is not possible to obtain a ready source of pure drinking water. In addition to this, no other public health issue affects a large proportion of the population than that of drinking water. Thus, through the ages, the contamination of drinking water by both point (e.g. sewage disposal) and non-point (runoff from agricultural farms) sources

of pollution have resulted in several catastrophes and human death. Thus, currently, water pollution has become a major subject of public concern the world over. Despite the large volume of water that covers the surface of the earth, only 1% is inland or fresh and easily available for human use (Bockris, 1978).

In Ghana, only 30% of Ghanaians have access to safe drinking water. Over 50% of Ghanaians use naturally “unprotected” source of water (Ministry of Health, Accra).

Mamapong – Ashanti in the Ashanti – Region of Ghana is no exception. The nature of the area has made it such that the indigenous population uses surface waters such as rivers, streams, ponds and springs as their only source of potable water. The qualities of these water bodies vary naturally and widely, depending on climate, season, and the geology of the local bedrock.

Uncontrolled domestic wastewater discharge into streams has resulted in eutrophication of streams as evidenced by substantial algal bloom and dissolve oxygen depletion in the subsurface water. This has led to large fish kill and other oxygen requiring organism (Pandey, 2003).

Sediment deposit of stream can function as either a source or a sink for many of the essential nutrients to the overlying water body. Sediment environment is very complex consisting of quasi-stable physical system which numerous physicochemical and microbiological gradients exist and interact. Inorganic and organic substances both of natural and anthropogenic origin, partition between sediments, interstitial water, overlying water, and resident biota (Burton et. al, 1990).

Continuous nutrient loading of these water bodies from rural and agricultural activities as enhance the rate of eutrophication in our water bodies. Discharged nutrients are generally tied up in algal cells and aquatic macrophytes (Yount and Crossman, 1970), upon death or ageing, this tissue is deposited on the stream eventually resulting in buildup of organic matter (Sonzogeni et al, 1982).

The Tatafo stream is one of the major sources of drinking water for people in the Mampong-Ashanti municipality and its surrounding communities. The Tatafo stream has been encroached upon with various human activities such as vegetable farming (especially carrots farming) due to population increase in the municipality.

1.2 STATEMENT OF THE PROBLEM

Eutrophication has been a problem in Europe and North America for decades and is today problem that has spread more widely (WHO, 1999). According to a study conducted by ILEC/LBRI (1988-1993), 54% of the lakes in the Asia Pacific region are eutrophic, which is a significant number compared to Europe (53%), Africa (28%), North America (48%) and South America (41%). The hydrological differences between lakes and rivers imply that nutrient enrichment processes vary between them (WHO, 1999). However, the large proportion of eutrophication in lakes is a sign of a widespread degradation of water bodies in general and around the world.

The provision of safe drinking water for the world's 1.3 billion deprived populations has become one of the topmost priorities of many governments in recent years. In the year 2000, more than a hundred and fifty governments the world over launched an ambitious plan to halve the number of people without access to safe drinking water by the year 2015 (World Resources Institute, 2000).

The Tatafo stream which is one of the major streams that serves as a source of drinking water for some of the people in Mampong-municipality and nearby surrounding communities is being impaired as a result of the activities of carrot farmers along the stream.

1.3 JUSTIFICATION OF THE STUDY

The assessment of water quality especially nutrient loads of streams is essential because they are often one of the main sources of water for human consumption. It is therefore necessary to assess the quality of water in the stream to ascertain the levels of nutrient loads. This will provide accurate information for finding appropriate solution to problems that may arise as a result of eutrophication within the stream which may affect human and other aquatic organisms that depends on the stream.

Problems of water management in Ghana is mostly attributed to the paucity of accurate and reliable data on the water resource itself including some other related factors.

Sediments of streams can act as sink for pollutants that are formed by soil erosion or decomposition of plants and animals. The stability of the compounds formed during sedimentation affects some water quality parameters. These parameters include pH and salinity (Waide, 1986).Sediment characteristics such as organic carbon, organic matter, nitrogen, phosphorus and pH determine the amount of nutrient contained in the overlying water. As a sink, some of these parameters are released into the overlying water and it is therefore necessary to measure these parameters in

sediments so as to provide information about the content of various parameters contributed by the sediments in the nutrient load capacity of the stream.

Potential parameters in relation to water quality monitoring that leads to eutrophication have never been captured on the Tatafo stream. There is therefore the need to acquire data for the assessment of water quality in the Tatafo stream, in order to raise awareness of the urgent need to address the consequences of the present and the future threats of eutrophication and high cost of water treatment of the stream. This will serve as a basis for mitigation or control measures.

1.4 OBJECTIVES OF THE STUDY

The main objective of the study was to assess the eutrophication potential of sediments and water of the Tatafo stream in the Mampong municipality.

The specific objectives were to determine:

- i. the concentration of nitrate and phosphate of the stream.
- ii. the levels of BOD, DO, pH and colour of the stream
- iii. total suspended solids, Total dissolved solids and Turbidity of the stream.
- iv. the levels of organic matter, organic carbon, nitrogen, pH and phosphorus of the stream sediments.

CHAPTER TWO

LITERATURE REVIEW

2.1 SURFACE WATER

Precipitation that does not evaporate or infiltrate into the ground runs as surface water, which may accumulate to form streams, and streams join to form rivers. Lakes are inland depressions that hold standing freshwater. Ponds are generally considered to be small temporary or permanent bodies of water shallow enough for rooted plants to grow over and at the bottom. While lakes contain nearly one hundred times as much water as all rivers and streams combined, they are still a major component of total World water supply (Mallard, 1982).

2.2 FACTORS THAT AFFECT THE QUALITY OF WATER

The quality of stream water is never constant because its constantly changing in response to daily, seasonal and climatic conditions. The physical, chemical and biological characteristics of the surrounding environment also affect the quality of the water. The nature of soil and rocks on which the water flows can also affect the water quality. For example, water flowing on soil overlying limestone will be alkaline with hardness depending on the amount of dissolved calcium and bicarbonate ions it contains, (Hesterberg, 1998). Seasonal rise in the level of water also drown vegetation and their decay also makes the water acidic (Svobodova *et al.*, 1993).

2.3 WATER POLLUTANTS

Water pollutants that occur in streams include physical, chemical and biological inputs. Many of the chemical pollutants found in the water are very toxic to human

and aquatic life. The physical and chemical properties of the water including colour, temperature, acidity, conductivity and eutrophication are easily altered in water bodies.

2.4 FORMS OF WATER POLLUTION

Water quality can be affected by different forms of pollution: chemical, biological and physical pollution. These polluting factors can influence natural and human environment whether directly or specific purposes. Indicators of water quality degradation include physical, chemical and biological parameters. Examples of biological parameters include species diversity and abundance. Examples of physical and chemical parameters include dissolved solids, pH, suspended solids, turbidity and nutrient concentration

2.5 RISKS OF NITROGEN AND PHOSPHORUS IN WATER.

Eutrophication of water bodies caused by over-enrichment with Nitrogen and Phosphorus has been found to cause toxic algal blooms, loss of oxygen, fish deaths, loss of biodiversity and other degradation of aquatic environments (Carpenter *et. al.*, 1998.). The critical nutrients levels at which eutrophication occur vary from one aquatic environment to another (Di and Cameron, 2002).

Toxic algal blooms and cyanobacteria are possible consequences of eutrophication and highly decrease the possibility to use water for drinking and recreational purposes.

Eutrophication has been a problem in Europe and North America for decades and is today a problem that has spread more widely (WHO, 1999). According to a study conducted by ILEC/LBRI (1988-1993), 54% of the lakes in the Asia Pacific region

are eutrophic, which is a significant number compared to Europe (53%), Africa (28%), North America (48%) and South America (41%).

2.6 WATER QUALITY AND MONITORING

Water quality is a term used here to express the suitability of water to sustain various uses or processes. Water quality is affected by a wide range of natural and anthropological (human) influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quality and quantity of water available.

The main elements of water quality monitoring are on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results and the reporting of the findings. Some of the common water quality monitoring strategies is Ambient Monitoring, Baseline Monitoring and Compliance or regulatory monitoring. The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Some chemical elements have a strong affinity for particulate matter and, as a result of precipitation/dissolution and adsorption /desorption reactions, they may be found in only trace amounts in solution. Other elements, however, are highly soluble and rarely, if ever, present in water in particulate form. The tendency for a chemical to be present in the soluble form rather than associated with particulate is expressed as the Soluble Transport Index.

In small watersheds, local geological conditions can lead to wide variations in the concentration of trace elements in particulates and that within any one water body quality.

2.7 NATURAL PROCESSES AFFECTING WATER QUALITY

Although degradation of water quality is almost invariably the result of human activities, certain natural phenomena can result in water quality falling below that required for particular purposes. Natural events such as torrential rainfall and hurricanes lead to excessive erosion and landslides in affected rivers and lakes (Balek, 1977).

The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Some chemical elements have a strong affinity for particulate matter and, as a result of precipitation/dissolution and adsorption /desorption reactions, they may be found in only trace amounts in solution. It is very difficult to identify, let alone monitor and control urban wastewater, Agricultural runoff and urban runoff. Point sources include industrial discharges, hazardous waste facilities, mine drainage, spills and accidental releases. Point discharges associated with a facility are usually regulated.

2.8 ANTHROPOGENIC FACTORS OF EUTHROPHICATION

Water eutrophication can be greatly accelerated by human activities that increase the rate of nutrient input in a water body, due to rapid urbanization, industrialization and intensifying agricultural production. For lake aquatic ecosystems, human activities in the watershed can lead to loss of dominant species and functional groups, high nutrient turnover, low resistance, high porosity of nutrients and sediments, and the loss of productivity (Liu and Qiu, 2007). For example, aquaculture is one of many human activities contributing to the environmental decline of coastal waters and the collapse of fisheries stocks worldwide (Alongi *et*

al., 2003). Because the influence of the human activities, excessive nitrogen, phosphorus and other nutrients are loaded into water bodies like lake, reservoirs, embouchure and bay, which could cause negative ecological consequences on aquatic ecosystem structures, processes and functions, result in the fast growth of algae and other plankton, and deteriorate water quality.

2.9 ENVIRONMENTAL FACTORS OF EUHROPHICATION

Some factors directly govern the growth, diversity and density of the biotic components. From the conception of ecology, exquisite change of temperature may cause the subrogation of biological communities, thus leading to algal bloom when other environment conditions are adequate (Wang *et al.*, 1996). The reduction of light reaching the lake floor also inhibits submerged and rooted macrophytes, and sediments become anoxic as large amounts of planktonic biomass are added to them (Kant and Raina, 1990).

Hence, it is essential to consider the effects of climate change on the context of individual estuarine function to successfully manage eutrophication (Howarth *et al.*, 2000). There are other factors like pH and dissolved oxygen affecting water eutrophication (Khan and Ansari, 2005). The minima and maxima in the concentration of dissolved oxygen are found to be directly related to the maxima and minima of the phytoplankton. The direct relationship between phytoplankton and dissolved oxygen content has been observed by a number of researchers (Khan and Ansari, 2005).

2.10 HEALTH RISK OF EUTROPHICATION

Eutrophication can impair the use of water for drinking and recreation purposes because of bad taste, odour, toxic algal blooms, and increased nutrient concentration among others (Carpenter *et al.*, 1998.). Toxins produced by cyanobacteria are a risk to human health when ingested or on skin contact (WHO, 1999). In the tropics, the risks to human health are greater than in temperate regions because there is less replacement of cyanobacteria with other (non-toxic) phytoplankton due to climate differences (WHO, 1999).

Not only toxic algal blooms but also a high nutrient content, such as nitrate pollution in drinking water, is harmful to humans and other mammals (Carpenter *et al.*, 1998). High concentrations of nitrate (NO₃) can interfere with the oxygen transport in the blood in infants younger than one year, causing the blue-baby syndrome (Di and Cameron, 2002). High concentrations of nitrate are also toxic to cattle and can cause abortions in carrying females.

2.11 CULTURAL EUTROPHICATION

Cultural eutrophication is the process that speeds up natural eutrophication because of human activity. Due to clearing of land and building of towns and cities, land runoff is accelerated and more nutrients such as phosphate and nitrate are supplied to lakes and rivers, and then to coastal estuaries and bays. Extra nutrients are also supplied by treatment plants, golf courses, fertilizers, and farms.

Cultural eutrophication occurs when excessive fertilizers run into lakes and rivers. This encourages the growth of algae (algal bloom) and other aquatic plants. Nutrient pollution is a major cause of algal blooming, (Burkholder *et al.*, 2011)

2.12 NITROGEN AND PHOSPHORUS TRANSPORT

Leaching, erosion, and runoff of fertilizers, livestock waste, and land applied wastes have been linked to nutrient contamination of ground and surface water (NRCS, 1997). However agriculture is only one of many causes of water quality impairment from nutrients. Nutrients may move through soil and then to the surface water or percolate into ground water.

Phosphorus also losses attributed to runoff and erosion are estimated to be as high as 75-90% of total phosphate lost from agricultural systems (NRCS, 1997). Conversely loss from leaching is relatively low, especially in dry lands. Factors affecting surface phosphate loss include fertilizer source and chemical form, tillage practice, fertilizer application rate, timing, and placement, slope, soil test phosphorus (STP), and rainfall intensity, duration and time after application.

2.13 SOURCES OF EUTROPHIED NUTRIENTS

In order to gauge how to best prevent eutrophication from occurring, specific sources that contribute to nutrient loading must be identified. There are two common sources of nutrients and organic matter: point and nonpoint sources. (Carpenter *et al.*, 1998).

Point sources are directly attributable to one influence. In point sources the nutrient waste travels directly from source to water. For example, factories that have waste discharge pipes directly leading into a water body would be classified as a point source. Point sources are relatively easy to regulate. (Novonty and Olem, 1994)

Nonpoint pollution is that which could potentially come from large areas. Nonpoint sources are difficult to regulate and usually vary temporally (with season, precipitation, and other irregular events).

General human presence brings with it a variety of nonpoint sources. It has been shown that Nitrogen transport is correlated with various indices of human activity in watersheds (Cole *et al.*, 1993, Howarth *et al.*, 1996.) and with amount of development (Bertness *et al.*, 2001).

2.14 NUTRIENT IN SOIL SEDIMENTS

Nutrients from human activities tend to accumulate in soils and remain there for years. It has been shown (Sharpley *et al.*, 1996.) that the amount of Phosphorus lost to surface waters increases linearly with the amount of Phosphorus in the soil. Thus any nutrient loading onto soil will eventually make its way to water. Furthermore, phosphorus has the capacity to be released from the soil after a lag time of 10 years. Nitrogen, similarly, has a turnover time of decades or more.

Nutrients from human activities tend to travel from land to either surface or ground water. Quite simply, this is because water is human's primary waste disposal system; nitrogen is removed through storm drains, sewage pipes, and other forms of runoff.

Common agricultural practices require a large input of nutrients into fields in order to sustain production. Farmers frequently over-fertilize, and nutrient inputs to crops far exceed outputs (Buol, 1995). It has also been shown that regulations on agricultural runoff are far less stringent than those placed on sewage treatment (Carpenter *et al.*, 1998).

2.15 WATER SEDIMENT

Sediment is the loose sand, clay, silt and other solid particles that settle at the bottom of a body of water, (United States Environmental Protection Agency). It can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice help carry these particles to rivers, lakes and streams. Sediment comprises an important component of an aquatic ecosystem, providing habitat for a wide range of benthic and epi-benthic organisms. Exposure to certain substances in sediments represents a potentially significant hazard to the health of these organisms. Effective assessment of this hazard requires an understanding of the relationship between concentrations of sediment-associated chemicals and the occurrence of adverse effects.

Due to the effects of the physical, chemical and environmental conditions on the interface of water and sediments, the proportion of phosphate compounds could be modified and phosphate compounds that have already accumulated within sediments could be partly released. As permanent phosphate exchange takes place within this interface, over time the water-sediment interface can act as an internal source of phosphorus for the overlying water (Lijklema, 1986; Ramm and Scheps, 1997; Zhou, *et al.*, 2001.)

2.16 ECOLOGICAL EFFECTS OF EUTHROPHICATION

When a body of water experiences an increase in nutrients, algae experience a massive population boom. Algal blooms tend to disturb the ecosystem by limiting sunlight to bottom-dwelling organisms and by reducing the amount of dissolved oxygen available in the environment. Under eutrophic conditions, dissolved oxygen is reduced by the dense population, and additional oxygen is taken up by microorganisms feeding on dead algae. When dissolved oxygen levels decline,

especially at night when there is no photosynthesis, hypoxia occurs and fish or other marine animals may suffocate. As a result, creatures such as fish, shrimp, and especially immobile bottom dwellers die off (Horrigan *et al.*, 2002).

For instance, an increase in nitrogen might allow new, more competitive species to invade and out-compete original species, (Bertness *et al.*, 2002.)

Some algal blooms, otherwise called "nuisance algae" are toxic to plants and animals. As stated above, this toxicity can lead to decreased biodiversity, or it can manifest itself in primary producers, making its way up the food chain. As a result of these toxic algae, marine animal mortality has been observed (Anderson, 1994). Freshwater algal blooms also pose a threat to livestock. When these blooms die or are eaten, neurotoxins- and hepatotoxins are released which can kill animals and may pose a threat to humans (Lawton and Codd, 1991, Martin and Cooke, 1994).

2.17 CHEMICAL AND PHYSICAL POLLUTION

2.17.1 TOTAL DISSOLVED SOLIDS (TDS)

TDS are correlated fairly well to the total mineral content of the water (deposits left after evaporation of a water sample), primarily salts, carbonates and metals. Organic compounds may also be dissolved solids. A high concentration of TDS is an indicator of possibly high volume contamination and further investigation may be recommended.

2.17.2 TOTAL SUSPENDED SOLIDS (TSS)

Suspended Solids originate from ploughed fields, construction and logging sites, urban areas, strip- mined land, and eroded stream banks when it rains. As these sediments enter rivers, lakes coastal waters, and wetlands, fish respiration is

impaired; plant productivity and water depth are reduced. Aquatic organisms and their habitats are smothered and our aesthetic enjoyment of the water is reduced (WHO, 1993).

Total suspended solids (TSS) concentrations indicate the amount of solids suspended in the water, whether mineral (e.g. soil particles) or organic (e.g. algae). However, the TSS test measures an actual weight of material per volume of water.

High concentrations of particulate matter can cause increased sedimentation and siltation in a stream, which in turn can ruin important habitat areas for fish and other aquatic life. Suspended particles also provide attachment places for other pollutants, such as metals and bacteria. High suspended solids readings can be used as "indicators" of other potential pollutant.

2.17.3 NITRATES

The Nitrate anion (NO_3^-) is not adsorbed by soil and moves with infiltrating water. Nitrates are present in water particularly in regions where agriculture fertilization is intense. Other important routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feedlot discharges from car exhausts and wastewater from car washing bay. The nitrate level in drinking water is extremely important with infants, because of their high intake of water with respect to body weight. Nitrates in the infant are converted by the body to nitrites that oxidize blood haemoglobin to methaemoglobin. The altered blood cells can no longer carry oxygen, which can result in brain damage or suffocation. Water with nitrite levels exceeding 1.0 mg/l should not be used for feeding babies. Epidemiological studies show a correlation between high nitrate levels and gastric and stomach cancers in humans (WHO, 1993).

Nitrate ion (NO_3^-) is the common form of nitrogen in natural waters. Nitrite (NO_2^-) will oxidize into nitrate after entering an aerobic regime; $\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{NO}_3^- + 2 \text{H}^+$ Plants and microorganisms will reduce nitrate into nitrite but nitrite ion will quickly oxidize back into nitrate once it reenters the water. Natural sources of nitrate are igneous rock, plant decay and animal debris. Nitrate levels over 5 mg/L in natural waters normally indicates man made pollution, 200 mg/L is an extreme level. Man made sources of include, fertilizers, livestock urban runoff, septic tanks, and waste water discharges.

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2.17.4 TURBIDITY

Turbidity is the material in water that affects the transparency or light scattering of the water.

The measurement unit used to describe turbidity is Nephelometric Turbidity Unit (NTU). The range for natural water is 1 to 2000 NTU. There are a number of manual field methods for measuring TSS, such as Secchi discs where a metal disc is lowered in the water with a calibration line. The depth at which the disc disappears is directly correlated to turbidity. In situ electronic turbidity sensors measure the backscatter of infrared light to determine the NTU of the water. Turbidity materials are made up of fine clay or silt particles, plankton, organic compounds, inorganic compounds or other microorganisms. These suspended particles range in size from 10 nm to 0.1 mm although in standardized laboratory tests, Turbidity compose of material that cannot pass through a 45 μm diameter filter. Solids particles suspended in water absorb or reflect light and cause the water to appear “cloudy”. These particles are suspended inorganic minerals or organic matter picked up over or under the ground. Since the earth acts as an excellent filter, the water from deep well is usually clear

without significant amounts of turbidity. This problem is more common in the water from surface supplies. The major problem with turbidity is aesthetic, but in some cases suspended matter can carry pathogens with it.

Large amounts of organic matter can also produce stains on sinks, fixtures, and laundry (WHO, 1985). Turbidity measures the amount of light scattered from a sample (more suspended particles cause greater scattering).

2.17.5 PHOSPHATE

Phosphates are less soluble and less volatile, therefore, phosphates will form salts with sodium and calcium and fall out of solution to accumulate in the sediment. Phosphates ions in natural waters will exist in solution in its ionized form, as salts, in organic form or as a particulate species. Higher concentrations rarely occur, because after it enters a water system, it will be rapidly up taken by plants (Tonnia, 1949).

Man made sources of phosphate in the environment include domestic and industrial discharges, agricultural runoff where fertilizers are used, and changes in land use in areas where phosphorous is naturally abundant in the soil.

The main environmental impact associated with phosphate pollution is eutrophication causing large algae blooms in lakes, streams and rivers. High levels of phosphorus will be quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidities. These impairments will kill or harm fish and other aquatic organism.

2.17.6 BIOCHEMICAL OXYGEN DEMAND

This is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at

certain temperature over a specific time period. The term also refers to a chemical procedure for determining this amount. This is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a robust surrogate of the degree of organic pollution of water.

Biochemical oxygen demand is the amount of oxygen required for microbial metabolism of organic compounds in water. This demand occurs over some variable period of time depending on temperature, nutrient concentrations, and the enzymes available to indigenous microbial populations. The amount of oxygen required to completely oxidize the organic compounds to carbon dioxide and water through generations of microbial growth, death, decay, and cannibalism is total biochemical oxygen demand (total BOD). Total BOD is of more significance.

2.17.7 DISSOLVED OXYGEN

Dissolved oxygen (DO) is essential to all forms of aquatic life including the organisms that break down man-made pollutants. Oxygen is soluble in water and the oxygen that is dissolved in water will equilibrate with the oxygen in atmosphere. Oxygen tends to be less soluble as temperature increases. The DO of fresh water at sea level will range from 15 mg/l at 0° C to 8 mg/l at 25° C. Concentrations of unpolluted fresh water will be close to 8 mg/l.

When microbial activity increases, oxygen will be consumed out of the water by the organisms to facilitate their digestion process. The water will then be depleted from oxygen.

In waters contaminated with fertilizers, suspended material, or petroleum waste, microorganisms such as bacteria will break down the contaminants. The oxygen will be consumed and the water will become anaerobic. Typically DO levels less than 2 mg/l will kill fish and those less than 5 mg/l would prevent fishes from laying eggs.

2.17.8 SALINITY

Salinity refers to the presence of dissolved inorganic ions such as Mg^{+} , Ca^{+} , K^{+} , Na^{+} , Cl^{-} , SO_2^{4-} , HCO_3^{-} and CO_3^{2-} in the aqueous solution or soil matrix. The salinity is quantified as the total concentration of soluble salts and is expressed in terms of electrical conductivity. There exists no in-situ salinity probe that can distinguish between the different ions that may be present. When salts such as sodium chloride are in their solid form, they exist as crystals

2.17.9 COLOUR

Coloration in groundwater is the occurrence of iron (Fe) or manganese (Mn) in the water. Red and brown colors are due to iron; black to manganese or organic matter and yellow to dissolved organic matter such as tannins.

The yellow color associated with natural dissolved organic matter (e.g., tannins) may result when rainwater or runoff leaches this organic matter from leaves, roots, and other vegetative matter, and flushes it down to the aquifer. The coloration both from iron and manganese and from dissolved organic carbon may occur seasonally.

In streams, lakes, and ponds, color most commonly is caused by suspended sediments, algae, microbes, and organic debris. Water color may vary widely depending on the water bodies.

Colour is an important physical property of water because of its implications for water supply, and the need to reduce it to acceptable levels by water treatment is highly recommended.

Increase in the colour of water in reservoirs results in increases in treatment cost. 15 Hz is the WHO recommended limit for no risk of colour. Colour in natural water usually results from the leaching of organic materials and is primarily the result of dissolved and colloidal humic substances, primarily humic and fulvic acids. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. Highly coloured water may be due to decaying vegetation. (McCutcheon, 1983).

2.18 ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) in natural waters is the normalized measure of the water's ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. The common unit for electrical conductivity is Siemens per meter (S/m). Most freshwater sources will range between 0.001 to 0.1 S/m. The source of EC may be an abundance of dissolved salts due to poor irrigation management, minerals from rain water run off, or other discharges. EC is also the measure of the water quality parameter "Total Dissolved Solids" (TDS) or salinity. At about 0.3 S/m is the point at which the health of some crops and fresh water aquatic organisms will be affected by the salinity.

Field measurements of EC reflect the amount of total dissolved solids (TDS) in natural waters.

2.19 PHOSPHORUS IN SEDIMENT

Concentrations of Phosphate in water sediments depend on its concentrations in the water, the transport of soluble phosphate between solid components, adsorption, desorption mechanisms, the chemisorptions ability of the sediments, and biological uptake (Andersen, 1975; Søndergaard *et al.*, 1992; Koski-Vähälä & Hartikainen, 2001; Koski-Vähälä *et al.*, 2001).

The most important inorganic Phosphate pools seem to be NaOH-Phosphorus and HCl-Phosphorus (Golterman, 2004).

Due to the effects of the physical, chemical and environmental conditions on the interface of water and sediments, the proportion of Phosphate compounds could be modified and Phosphorus compounds that have already accumulated within sediments could be partly released. As permanent Phosphate exchange takes place within this interface, over time the water sediment can act as an internal source of phosphorus for the overlying water (Lijklema, 1986; Ramm & Scheps, 1997; Zhou *et al.*, 2001).

2.20 ORGANIC MATTER OF SEDIMENT

Organic matter in sediment consists of carbon and nutrients in the form of carbohydrates, proteins, fats and nucleic acids. Bacteria quickly eat the less resistant molecules, such as the nucleic acids and many of the proteins. Sediment organic matter is derived from plant and animal detritus, bacteria or plankton formed in the water body, or derived from natural and anthropogenic sources in catchments. Sewage and effluent from food-processing plants, pulp and paper mills are examples of organic-rich wastes of human origin. (Nixon, 1995)

The amount of organic matter found in sediment is a function of the amount of various sources reaching the sediment surface and the rates at which different types of organic matter are degraded by microbial processes during burial. (Bender *et al.*, 1979)

2.21 ORGANIC CARBON OF SEDIMENT

Organic carbon in water and sediments can be classified as particulated organic carbon and Suspended organic carbon in suspension. The suspension consist of detached flora and fauna elements, compounds and organic substances adsorbed on mud and clay. Organic carbon measurement can be used to provide information on all organic substances in sediments including organic matter (Aremu *et al.*, 2011).

Particulated organic carbon decomposition, associated with its content in water column and sediments, plays an important role in river water and sediment quality such as decreasing dissolved oxygen concentration and increasing biochemical oxygen demand.

2.22 NITROGEN IN SEDIMENT

Nitrogen dissipation in water bodies that receive excess nitrate is limited in part by the ability of nitrate to move from the water column to sediment denitrifying microsite.

In stagnant water bodies, these transports are diffuse in nature and therefore slow. Surface- subsurface interfacial exchange delivers surface water nitrate to sediment denitrifying microsite, a process that can account for up to 70% nitrate removal in stream to underlying sediment. This exchange is facilitated through advective flow

over benthic porous obstacles such as overlaying water velocity, substrate saturated conductivity, porosity and obstacles height.

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CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

Mampong-Ashanti lies in the transitional zone, located in the Ashanti Region (Figure 1). It is 55 km north-east of the city of Kumasi along Kumasi Ejura road. It is bounded to the north by Atebubu District in the Brong – Ahafo region, east by Sekyere-Central, south by Sekyere-South and Ejura-Sekyeredumasi to the west .The municipality covers a total land area of 782 km².The mean annual rainfall is between 800 mm and 1500 mm and is bimodal and fairly distributed, (Mampong-Ashanti Municipal, 2006).The Municipality is partly situated on the Mampong scarp which runs eastwards. The highest point of the municipality is 2400 m above sea level, while the lowest is about 135 m.

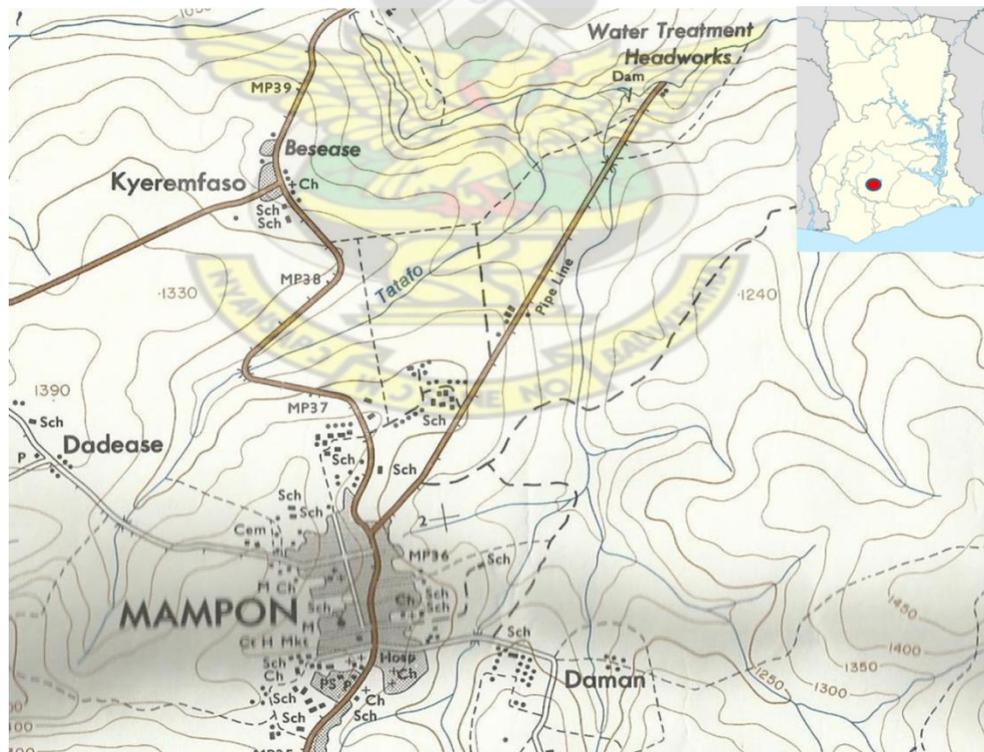


Figure 1: Section of the Mampong Municipal Map showing the Tatafo Stream (Insert: Map of Ghana showing the location of the Mampong Municipality)

3.1.2 Drainage

The Mampong-Ashanti municipality study area is drained by a number of seasonal streams and perennial rivers. The seasonal streams and rivers include Tatafo, Kyeremfa, Sumampa, Subiri, Afram and Tarzan. The choice of surface water for the study is a Tatafo stream in the municipality. The Tatafo stream lies in longitude 0.05 degrees and 1.30 degrees to the west and latitude 6.55 degrees and 7.30 degrees to the north. The Tatafo stream is a vital source of potable water for the Mampong people from within and around the study area. The Tatafo Stream serves as a means of irrigation for carrots farmers around the water body, washing of vehicles by the drivers from the town and serving as a means of water source for the people in the municipality and also as a receiving of runoff effluents from domestic activities of the town. (Mampong-Ashanti Municipal, 2006).

3.1.3 Vegetation

The municipality is part of the savannah transitional zone of Ghana, with vegetation being savannah woodland, with patches of tall elephant grasses to the north and mixed patches of dry forest and grassland to the south. There are four forest reserves covering a total of 11.59 km² namely abrimasu, Aboma, Offin Headwater and Ongwami reserves, (Ministry of Food and Agric -Mampong Ashanti, 2011).

3.1.4 Soil type

The soil associations identified within the study area, are the Budewa-Sutewa, Ejura-Denteso, Nyankpala-kelesawgu, Denteso-Sene, Dukusen-Bramba land surfaces association, (Mampong-Ashanti Municipal, 2006). Intensive farming activities for the production of both plantation and food crops and other human activities within this

densely populated area, have greatly influenced the nature of the soils resulting in nutrient depletion, soil erosion, pan formation and land degradation.

Agricultural production is the main economic activity for the people in the Mampong municipality and is practiced mainly on subsistence level with a more of the farmers engaged in vegetable crop production specifically carrots, onions, green pepper and cabbage. About 61% of the total populations of the people in the municipality are engaged in farming, (Ministry of Food and Agriculture-Mampong –Ashanti, 2011).

3.2 SAMPLING SITES

Three sites were selected along the Tatafo stream for eutrophication monitoring; the upstream (UPS), midstream (MDS) and downstream (DWS). The three sampling sites were selected purposively in relation to accessibility and where potential areas of pollution threats were identified. The midstream was selected about 500 m from the upstream and the downstream was also selected about 800 m from the midstream. The sampling was done on monthly basis for a period of five consecutive months (June 2012– October 2012).

3.2.1 Water Sampling

Monthly water samples were collected from Tatafo stream (Plate 3.1, 3.2 and 3.3) in duplicate amounting to ten water samples from each different section in all for the five months. Plastic sample bottles of 1.5 L were washed with non-ionic detergent and well rinsed with tap water. Before sampling, the bottles were rinsed three times with sample water before being filled with the water. Sample bottles were submerged to a depth of 20-30 cm opened, filled, corked and removed. Samples collected were immediately placed in an ‘ice chest’ in ice packs and transported to

the laboratory where analyses were performed within six hours. The physicochemical parameters of the water samples were done at the Faculty of Natural Resources, KNUST and environmental laboratory AngloGold Ashanti, Obuasi.



Plate 1: Collection of water and sediments samples at some portion of the stream



Plate 2: Collection of water samples at the midstream



Plate 3: A vegetable farmer working on his farm along the stream

3.2.2 Sediment Sampling

The sediment samples were collected in duplicate from three sections of the stream for five months. The samples were collected and subsequently analyzed starting from June 2012 to October 2012. Sediment samples were collected by hand-pushing plastic core tubes (7 cm diameter) as far as possible into the sediment. The sediments were kept cool in icebox and transported to the laboratory. They were then ground manually to a fine powder in an alumina mortar; it was passed through a 2-mm mesh screen and stored in polyethylene bags for further analysis. The physicochemical analysis of the parameters of the sediment samples was carried out at the Faculty of Natural Resources, KNUST and environmental laboratory of AngloGold Ashanti, Obuasi.

3.2.3 Measurement of pH of water

pH was measured using a pH meter (JENWAY 3071, model pH 82; degree of accuracy 0.01) equipped with a temperature probe. The pH meter was initially calibrated by dipping the electrode into a buffer solution of known pH (pH 4) and the

asymmetric potential control of the instrument altered until the meter reads the known pH value of the buffer solution. The standard electrode after rinsing with distilled/deionized water was then immersed in a second buffer solution (pH 9) and the instrument adjusted to read the pH value of this buffer solution. With the pH meter calibrated, it was immersed in the water sample, allowed to stabilize and the pH value read from the instrument. The beaker and the electrode were washed in between samples with deionized water in order to prevent contamination by other samples.

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3.2.4 Measurement of Electrical Conductivity (EC)

A high powered microcomputer conductivity meter JENWAY 40710 model HI 9032 with a degree of accuracy of 0.01 μ S/cm was used to measure the conductivity of the water samples in the laboratory. The instrument was initially calibrated using standard solution of conductivities 500 μ S/cm and 1500 μ S/cm. Duplicate values were taken.

3.2.5 Measurement Total Dissolved Solids (TDS)

TDS was measured using a JENWAY 40710, model HI 9032 (0.01 degree of accuracy). One hundred milliliters of the sample was poured into a 250 ml beaker. The probe was then immersed into the sample and the value read on the digital screen.

3.2.6 Measurement of Total Suspended Solids (TSS)

TSS was measured by means of a TSS meter (PELICAN 1500, Model 3150). The water sample was stirred thoroughly and 25 ml of the sample was immediately

poured into a sample cell. A Twenty five milliliters pupil of distilled water (the blank) was filled into the sample cell. The blank was then placed in the cell holder and the light shield was closed. The zero buttons was pressed and the suspended solids value of the sample was displayed on the digital screen in mg/l.

3.2.7 Measurement of Turbidity

Turbidity of the water samples was measured in the laboratory with a microprocessor turbid meter JENWAY 3071, model HI93703 (0.0001NTU degree of accuracy). The instrument was first calibrated by dipping the probe into standard solution with turbidity values of 0.00 and 10.00 Nephelometric Turbidity Unit (NTU) and calibrated as described above before using the turbidity values of the samples.

3.2.8 Measurement of Nitrate

Nitrate – Nitrogen

The Devarda's alloy method which involves oxidation, distillation and titration was used to determine the concentration of Nitrate-Nitrogen in all the samples. In this method, Nitrate was reduced to Ammonia by Nascent hydrogen, by the use of Devarda's alloy (59% 48 Al, 39%Cu, 2% Zn). The resulting ammonia is distilled and its concentration determined by titration.

The distillation flask, splash head and condenser were thoroughly cleaned before assembling the apparatus. In order to free the apparatus from possible contamination by ammonia, about 350 ml water was added to the flask (ammonia-free) and distilled until the distillate showed to be free from ammonia by testing with Nester's reagent.

Two hundred milliliters of the water sample was then measured and 10 ml of 10 mol l⁻¹ Sodium hydroxide solution was added. This was evaporated in the distillation

flask to 100 ml and the residue was allowed to cool. Sufficient ammonia-free water was added to the cooled residue to bring the volume in the distillation flask to about 350 ml. One gram Devarda's alloy was added and the flask was immediately connected to the condenser.

The distillation was then started, keeping the lower end of the delivery tube from the condenser below the surface of the liquid in the receiver throughout the distillation process. Fifty milliliters (50 ml) of Boric acid solution was placed in the receiver and was distilled at a rate of about 10 ml per minute. When the absorbent solution changed color, it was titrated with $0.00714 \text{ mol l}^{-1}$ HCl acid until a permanent pink colour was produced in the solution. At the completion of the titration, the receiver was removed from the apparatus before the source of heat was withdrawn. Blank determination was also carried out. The total Nitrate- nitrogen was then calculated using the formula below:

$$\text{Nitrate-(asN)} = (a-b) \times 100v - (\text{mg/l})$$

Where:

a = volume of Hydrochloric acid used for titration of the distillate of sample (ml).

b = volume of Boric acid solution used for titration of the blank (ml).

n = concentration of Nitrite – nitrogen (as N) mg l^{-1} N, determined separately.

V = Volume of the undiluted sample (ml)

n = Concentration of nitrite nitrogen in mg/l N, determined separately.

(The result is reported as Nitrate-nitrogen {N} mg/l and is rounded off to two significant figures.

3.2.9 Measurement of Biochemical Oxygen Demand (BOD)

The BOD test took 5 days to complete and was performed using a dissolved oxygen test kit. The BOD level was determined by comparing the DO level of a water sample taken immediately with the DO level of a water sample that has been incubated in a dark location for 5 days. The difference between the two DO levels represents the amount of oxygen required for the decomposition of organic material in the sample and is a good approximation of the BOD level.

Two samples of water were taken. The DO level (ppm) of one was immediately recorded using the method described in the dissolved oxygen test. The second water sample was then placed in an incubator in complete darkness at 20°C for 5 days. After 5 days, another dissolved oxygen reading (ppm) was then taken using the dissolved oxygen test kit. The Day 5 reading was then subtracted from the Day 1 reading to determine the BOD level. The final BOD result was recorded in (ppm).

3.3.0 Measurement of phosphate

To 50 ml of the filtered sample, 4ml of ammonium molybdate reagent and about 4-5 drops of stannous chloride reagent was added. After about 10 min but before 12 min, the colour developed was measured photometrically at 690 nm and calibration curve was prepared. A reagent blank was always run with same treatment with distilled water as sample. The value of phosphate was obtained by comparing absorbance of sample with the standard curve and expressed as mg/l.

Calculation:

$$\text{Phosphates (as mg/L)} = \frac{\text{Absorbance of sample} \times \text{Conc. of Std} \times 1000}{\text{Absorbance of Std.} \times \text{Sample taken}}$$

3.3.1 Measurement of Dissolved oxygen

The samples were collected in BOD bottles, to which 2 ml of manganous sulphate and 2 ml of potassium iodide were added and sealed. This was mixed well and the precipitate allowed to settle down. At this stage 2 ml of conc. sulphuric acid was added, and mixed well until all the precipitate dissolves. Sample was measured into the conical flask and titrated against sodium thiosulphate using starch as an indicator. The end point is the change of colour from blue to colourless.

Calculations:

203ml because $(200) (300) / (200-4) = 203\text{ml}$.

1ml of 0.025N Sodium thiosulphate = 0.2mg of Oxygen

$$\text{Dissolved Oxygen (as mg/L)} = \frac{(0.2) (1000 \text{ ml of Sodium thio sulphate})}{200}$$

3.3.2 Determination of colour

Colour was determined using HACH DR/2010 Portable Data Logging spectrophotometer. The water sample was filtered and their pH adjusted to 7.6. Water sample with their pH less than 7 were adjusted with 1.0 N NaOH and those with pH greater than 7 were also adjusted with 1.0 N HCL. A wavelength of light was used to pass through the water sample. The stored program was calibrated in colour units based on APHA recommended standard of on colour unit equal to 1mg/l platinum as chloroplatinate ion.

3.3.3 Measurement of Total Solids

A known volume of the well-mixed sample (50 ml) was measured into a pre-weighed dish and evaporated to dryness at 103° C on a steam bath. The evaporated

sample was dried in an oven for about an hour at 103-105° C and cooled in a desiccator and recorded for constant weight.

Calculation:

$$\text{Total solids (Mg/L)} = \frac{(W_1 - W_2) (1000)}{\text{Sample volume (ml)}}$$

W_1 = Weight of dried residue + dish

W_2 = Weight of empty dish

3.3.4 Measurement of organic carbon and organic matter

Loss of weight on ignition was used as a direct measure of the organic matter contained in the soil. It can also be expressed as the content of organic carbon in the soil. It is generally assumed that, on average, OM contains about 58 percent organic Carbon. Organic matter and organic carbon can also be estimated by volumetric and colorimetric methods.

10.0 g (to the nearest 0.01 g) of soil sample of sieved (2 mm) was weighed into an ashing vessel (50-ml beaker).The ashing vessel with soil was placed in a drying oven set at 105 °C and dried for 4 hours. The ashing vessel was removed from the drying oven and placed in a dry atmosphere. When cooled, it was weighed to the nearest 0.01 g. The ashing vessel with soil was placed into a muffle furnace to reach a temperature of 400 °C. Ashing was done in the furnace for 4 hours. The ashing vessel was then removed from the muffle furnace, cooled in a dry atmosphere, and weighed to the nearest 0.01 g.

The percentage of OM was calculated by:

$$\text{Percent organic matter (OM)} = (W_1 - W_2)/W_1 \times 100$$

Where:

- W_1 is the weight of soil at 105 °C;

- W_2 is the weight of soil at 400 °C.

The percent of organic C is given by: % OM \times 0.58.

3.3.5 Measurement of nitrogen in Sediment

10 g air dry sample was weighed into 500 ml long-necked Kjeldahl flask and 10ml distilled water was added to moisten the sample. 1 spatula full of Kjeldahl catalyst (mixture of 1 part selenium + 10 parts CuSO_4 + 100 parts Na_2SO_4), was then added followed by the addition of 20ml conc. H_2SO_4 . The solution was digested until the solution became clear and colourless. The flask was allowed to cool and it was decanted into a 100ml volumetric flask and was make up to the mark with distilled water. 10 ml aliquot fluid was transferred from the digested sample by means of a pipette into Kjeldahl distillation flask. 90 ml of distilled water was added to make it up to 100 ml in the distillation flask. 20ml of 40% NaOH was added to the content of the distillation flask. Distillate was then collected over by 10 ml of 4% boric acid and 3 drops of mixed indicator in a 200 ml conical flask. The presence of nitrogen gave a light blue colour. Distillate collected (100 ml) was titrated with 0.1N HCl till a blue colour changes to grey and then suddenly flashes to pink.

Calculation

Weight of sample used, considering the dilution and the aliquot taken for distillation

$$= 10 \text{ g} \times 10 \text{ ml}/100 \text{ ml} = 1 \text{ g}$$

$$\% \text{ N} = 14X (A-B) \times NX 100/ (1000X1)$$

Where,

A=volume of standard HCL used in sample titration

B= volume of standard HCL used in blank titration

N=normality of standard HCL

% Crude Protein (CP) = % Total Nitrogen (NT) X 6.25 (protein factor)

3.3.6 Measurement of phosphorus in sediments

The Murphy and Riley spectrophotometric method (measure of absorbance at 880nm) was used to measure the phosphate. All the reagents used were of high purity (95%). All glassware and plastic ware were cleaned in phosphate free detergent, soaked in 24h in 1.2 mol, HCl and air dried before use. The residue was allowed to dry (in the tubes) in ventilated at 80 degree celcius. The tube was put in an ultrasonic bath for 10 s and was transferred to porcelain crucible. It is then calcinated at 450°C for three hours. The cool ash was poured into a centrifuge tube. 20 ml of 1 mol L-1HCl was added with a pipette. The tube was covered and stirred overnight. 2000 g of solution was centrifuge for 15 minutes. The extract was then collected in a test tube for phosphate analysis.

Calculation

The concentration of C, in mg-l is given by

$C = SV/1000$ m where

S=P concentration in the extract in mg

V=Volume of Reagent used for the extraction (20 ml)

M= mass of the test sample (200 mg dry mass)

For NAIP, $C = S \times 14 \times V / 1000 \times 10 \times m$

3.3.7 Measurement of pH in sediments

The pH meter was calibrated using two buffer solutions. A buffer solution with neutral pH solution (7.0) and the other was chosen based on the range of pH in sediment. The buffer solution was poured in beakers. The electrode were alternatively inserted in the beakers containing the two buffer solution and the pH adjusted .The instrument indicating the pH as per the buffers was then ready to test the samples. 10g of sediments was placed into 50 ml/100 l beaker and 20 ml of CaCl₂ solution was added. The sediment was allowed to absorb the CaCl₂ solution without stirrings, then it was stirred thoroughly for 10 seconds using glass rod. The suspension was then stirred for 30 minutes and the pH on the pH scale was recorded.

3.3.8 Statistical analysis

(ANOVA) was used to analyze the data. The data was further subjected to Kruskali-Wasllis Test and Dunn's Multiple Comparison Test for statistical comparison of all the parameters at different section of the stream. The level of significance was set at $P \leq 0.05$.

CHAPTER FOUR

4.0 RESULTS

4.1: PHYSICOCHEMICAL PARAMETER OF WATER

Generally some of the physico-chemical parameters of the Tatafo stream were below WHO standards (1996, 2004). Parameters such as colour, BOD, Dissolved oxygen, turbidity, total suspended solids, nitrate, phosphate etc were all statistically insignificant at the different sampling points ($p > 0.05$) [Table 1]. Nitrate mean values recorded at different sections of the stream were higher than the WHO standard of 5.0 mg/l [Table 1].

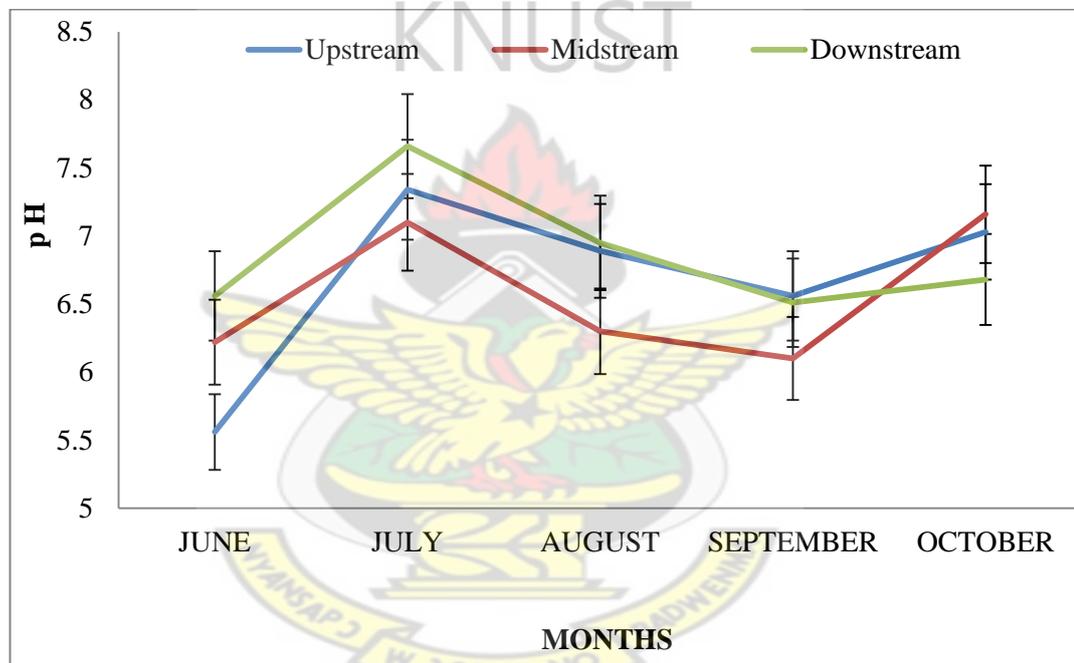
Table 1: The physiochemical characteristics of water from Tatafo stream

| PARAMETER | UPSTREAM | MIDSTREAM | DOWNSTREAM | WHO |
|---|-------------|-------------|-------------|------------|
| | Mean / SD | Mean / SD | Mean/SD | GUIDELINES |
| pH | 6.68 ±0.68 | 6.58±0.51 | 6.87±0.47 | 6.5 – 8.5 |
| Conductivity (µs/cm) | 43.95±9.10 | 54.00±12.88 | 52.30±5.16 | 700 |
| TDS (mg/l) | 22.00±5.42 | 26.30±5.76 | 25.90±2.13 | 20 |
| Salinity | 0.02 ± 0.05 | 0.02±0.00 | 0.02±0.00 | - |
| Dissolved Oxygen (mg/l) | 2.97±0.59 | 3.04±0.60 | 3.66±0.97 | 6 |
| Biochemical Oxygen Demand (mg/l) | 4.06±2.93 | 4.09±3.15 | 3.84±3.07 | - |
| Nitrate (mg/l) | 7.02±3.30 | 7.33±2.99 | 6.61±3.13 | 5 |
| Phosphate (mg/l) | 1.32±0.26 | 1.42±0.33 | 1.41±0.31 | 6.5 |
| Colour (TCU) | 36.38±22.79 | 26.33±12.46 | 30.65±22.63 | - |
| Turbidity (NTU) | 53.40±64.84 | 67.90±85.74 | 38.40±45.21 | 5 |
| Total Suspended Solids (mg/l) | 27.40±18.11 | 28.00±33.41 | 132.6±193.3 | 20 |

4.1.1 pH

Mean pH levels of the stream were 6.7 in the upstream, 6.6 in the midstream and 6.9 in the downstream. (Table 1) The lowest value of 5.6 was recorded at the upstream in June and the highest value of 7.7 at the downstream in July (Figure 2). These differences in pH for all the sections of the stream were not statistically significant ($p = 0.73$) (Appendix A).

Generally, the mean pH values of all the water samples were within the WHO guideline value of 6.5-8.5.



(Upstream)

(Midstream)

(Downstream)

Figure 2 Graphical representation of month pH at different sampling site

4.1.2 Electrical conductivity

Electrical conductivity mean levels recorded 43.95 $\mu\text{S}/\text{cm}$ at the upstream, 54.00 $\mu\text{S}/\text{cm}$ at midstream and 52.30 $\mu\text{S}/\text{m}$ at downstream (Table 1). The highest

conductivity value of 77.00 $\mu\text{S}/\text{cm}$ was recorded at the month of August at the midstream and the lowest mean of 38.50 $\mu\text{S}/\text{cm}$ at the upstream in the month of July and September (figure 3). These variations in conductivity within the sections of the stream were statistically not significant ($p = 0.1269$), [Appendix A]. However, the mean conductivity values recorded in all sections of the water bodies were comparatively lower and negligible as far as the WHO guideline value for drinking water quality of 700 $\mu\text{S}/\text{cm}$ is concerned.

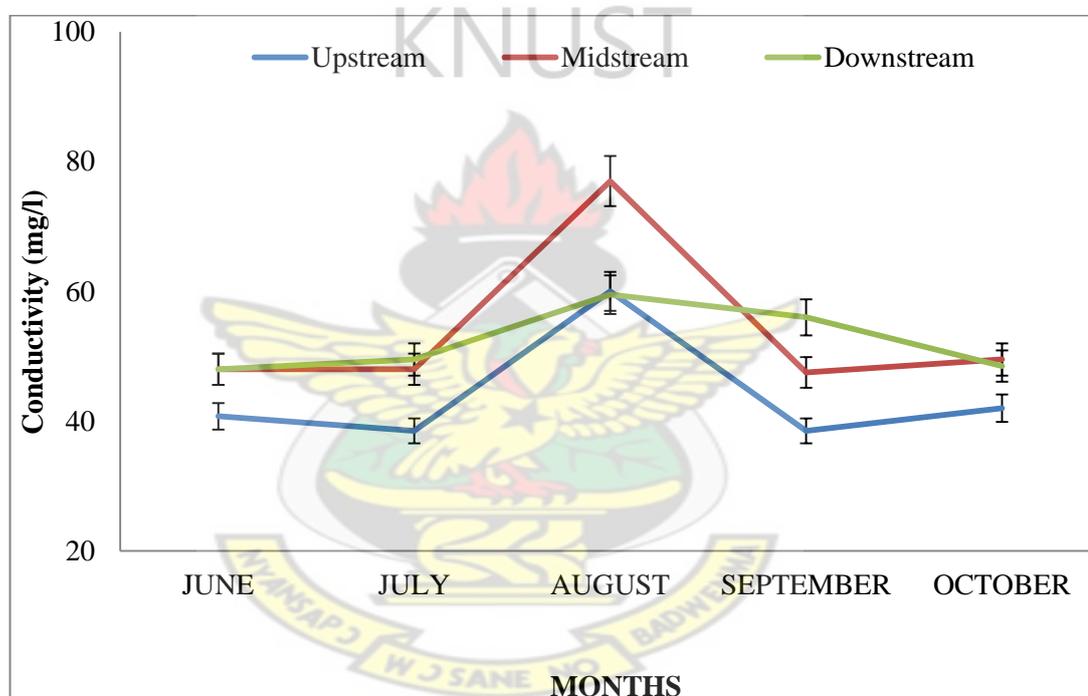


Figure 3: Mean variations of conductivity levels

4.1.3 Total Dissolved Solids (TDS)

The mean levels recorded the value of 22.00 mg/l at the Upstream, 26.30 mg/l at the midstream and 25.90 mg/l at the downstream (Table 1). The highest value of 36.50 mg/l was recorded in the month of August at the midstream and the lowest value of 16.00 mg/l at the upstream, in the month of September (Figure 4). These differences,

however, were not statistically significant ($p = 0.42$). The TDS mean values of all the portion of stream were higher than the WHO limit of 20.00 mg/l.

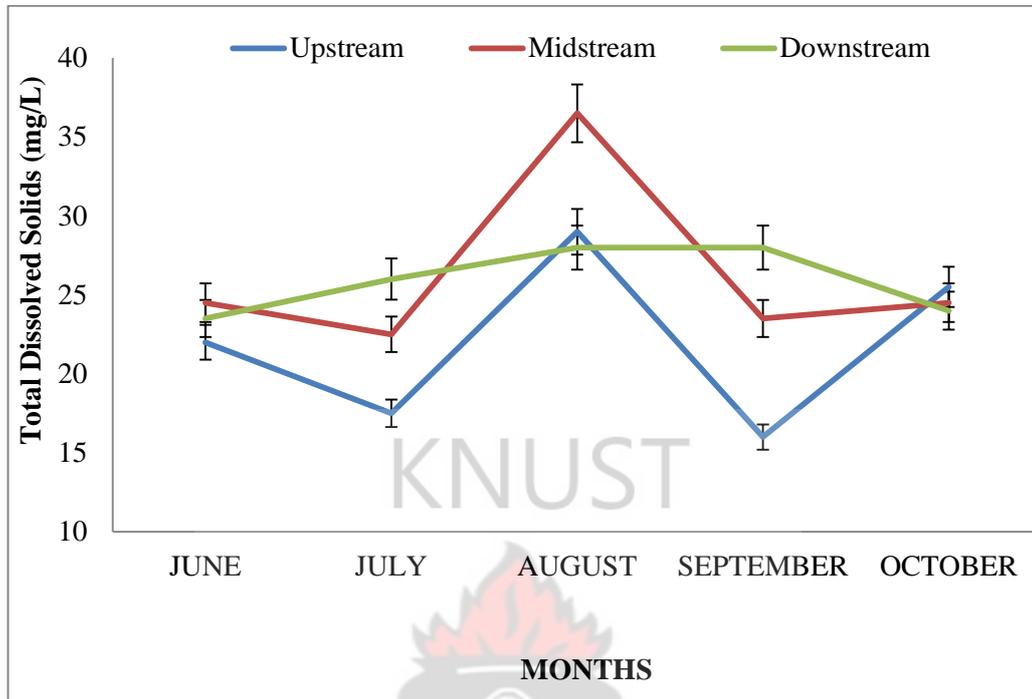


Figure 4: Total dissolved solids levels representation

4.1.4 Salinity

Salinity value of 0.022 mg/L was recorded at the various sections. The highest value 0.03 mg/l was recorded in all the three sections of the stream. (Figure 5). These values however, were not statistically significant ($P > 0.05$).

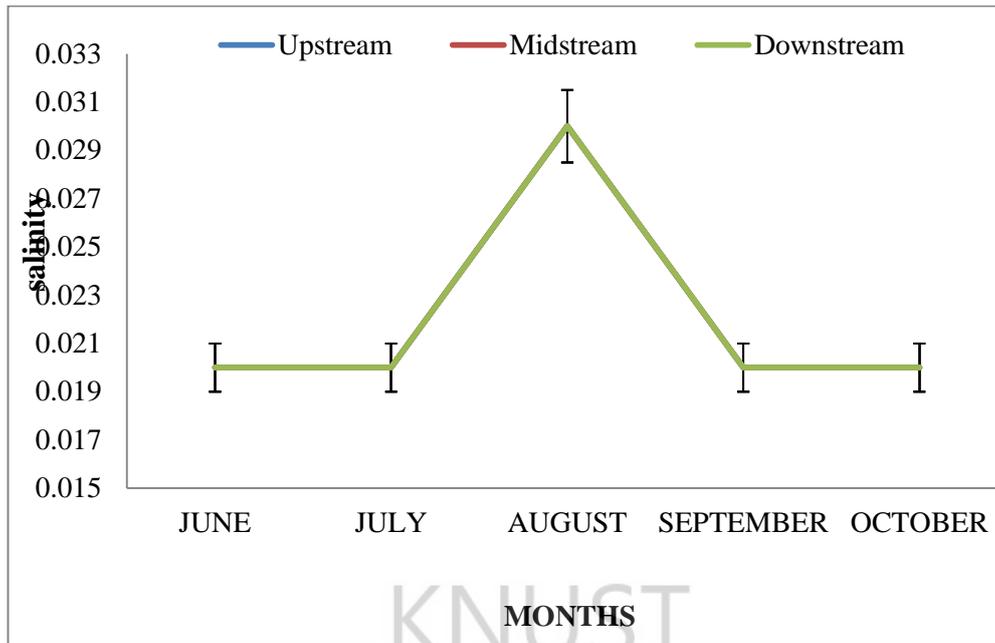


Figure 5: Graphical arrangements of salinity mean levels

4.1.5 Dissolved Oxygen (DO)

The Dissolved oxygen levels through the period did not vary significantly ($p = 0.47$) (Appendix A). The mean value 2.97 mg/l was recorded at the upstream, 3.04 mg/l at the midstream and 3.66 mg/l at the downstream, (Table 1). Highest value of 4.81 mg/l was recorded at the downstream in the month of September and the lowest value of 2.30 mg/l was recorded in both upstream and midstream in the month of July respectively (Figure 6). The Dissolved oxygen mean values were within the WHO mean limit of 6.0 mg/L.

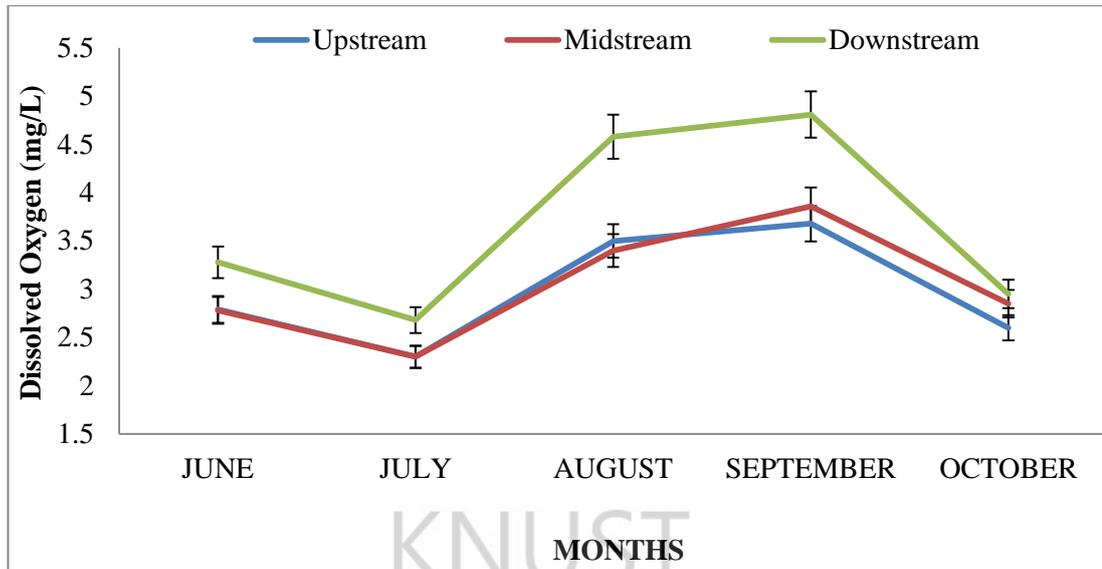


Figure 6: The mean levels of dissolved oxygen

4.1.6 Biochemical Oxygen Demand (BOD)

The Biochemical oxygen demand mean values recorded 4.06 mg/l at the upstream, 4.09 mg/l at the midstream and 3.84 mg/l at the down stream (Table 1). The highest value of 6.94 mg/l was recorded at the midstream at the month of August and the lowest value of 0.06 mg/l was recorded at the upstream in the month of July (Figure 7). However the differences between these values were not statistically significant ($p = 0.89$), (Appendix A).

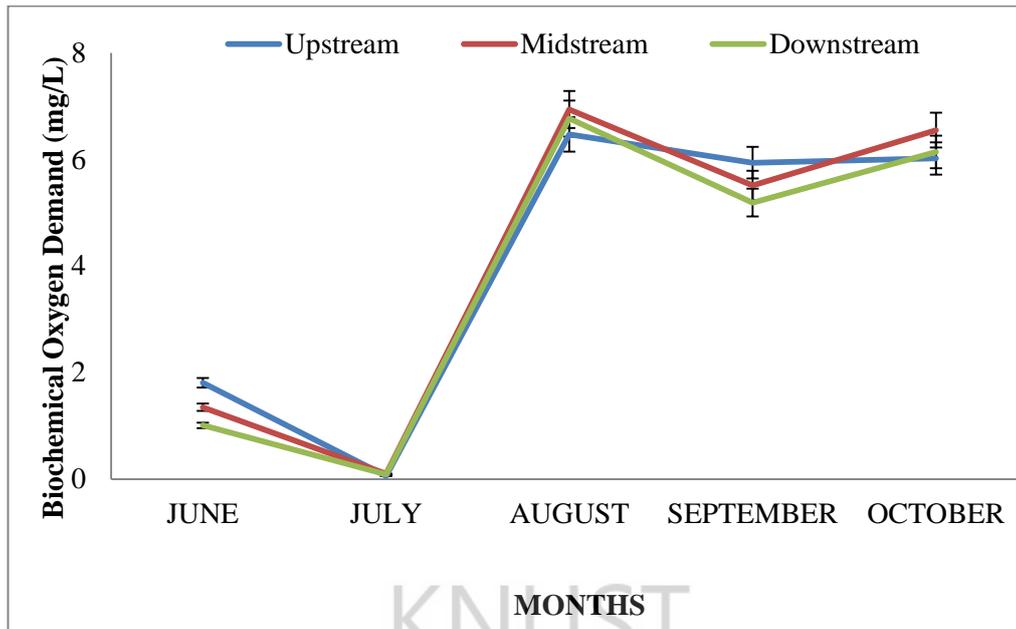


Figure 7: Monthly Variation of biochemical oxygen demand levels

4.1.7 Nitrate

The mean nitrate levels recorded were 7.02 mg/l , 7.33 mg/l and 6.61 mg/l respectively (Table 1).The highest value of 10.27 mg/l was recorded at the midstream in the month of August and the lowest value of 2.38 mg/l at the downstream in the month of June, (Figure 8). These higher differences in nitrate levels for sections of the stream were not statistically significant ($p = 0.73$). However the mean nitrate value exceeded the recommended WHO mean limits of 5.0 mg/l for water bodies.

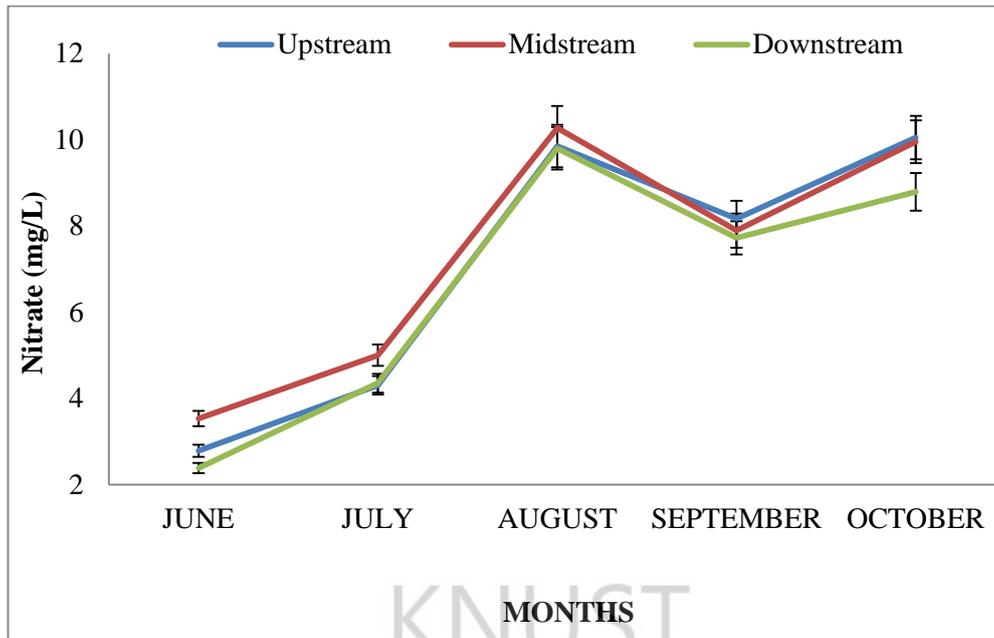


Figure 8: Representation of Mean levels of Nitrate during the sampling months

4.1.8 Phosphate

Levels recorded were 1.316 mg/l, 1.421 mg/l and 1.409 mg/l respectively (Table 1). Highest value of 1.75 mg/l was recorded in all the three sections of the stream in the month of July (Figure 9). The variations in the phosphate mean values were not significant statistically ($p = 0.99$) (Appendix A).

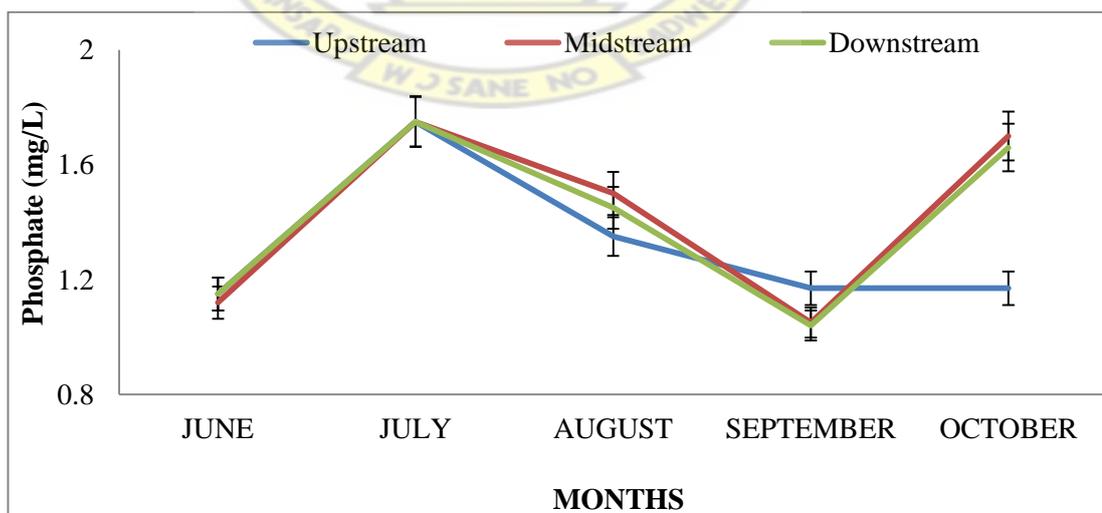


Figure 9: Phosphate levels in Tatafo stream

4.1.9 Colour

Mean of 36.38 mg/l, 26.33 mg/l and 30.65 mg/l were recorded respectively, (Table 1) .The highest value of 69.00 mg/l occurred at the upstream in the month of August whilst the lowest of 8.50 mg/l was recorded at the upstream in the month of June (Figure 10). Generally, the mean values recorded were statistically insignificant ($p = 0.88$) (Appendix A).

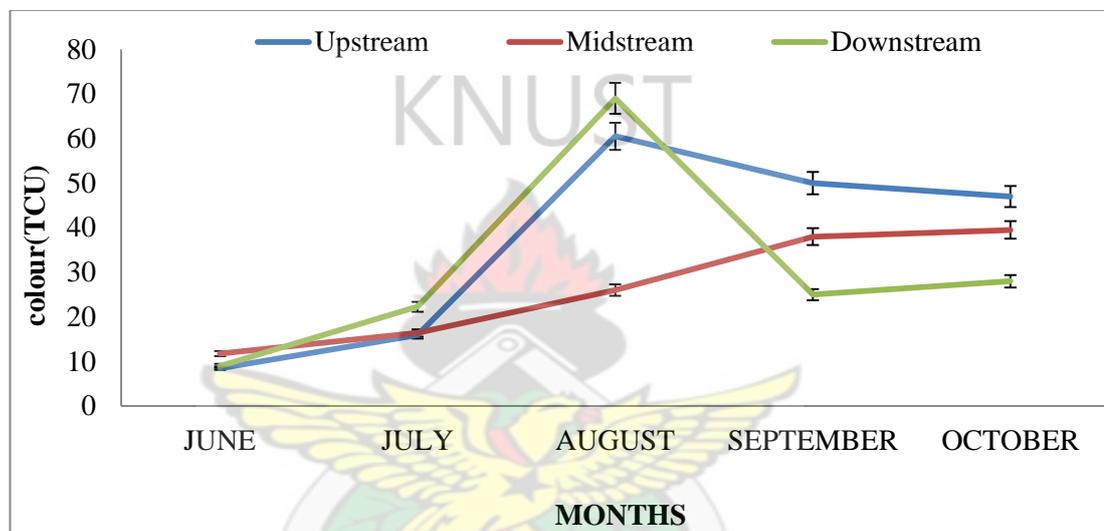


Figure 10: The levels of Colour in Tatafo stream.

4.2 Turbidity

Mean values of turbidity of the stream were 53.40, 67.90 and 38.40 NTU, respectively (Table 1). The highest value 177.00 NTU was recorded at the midstream in the month of June and the lowest value of 4.50 NTU was recorded at both upstream and downstream (Figure 11). Even though high mean turbidity values were recorded in all the water bodies, the variations within the sampling sites were not statistically significant ($p = 0.71$) (Appendix A). All mean values recorded in the study far exceeded the WHO guidelines for drinking water quality of 5 NTU.

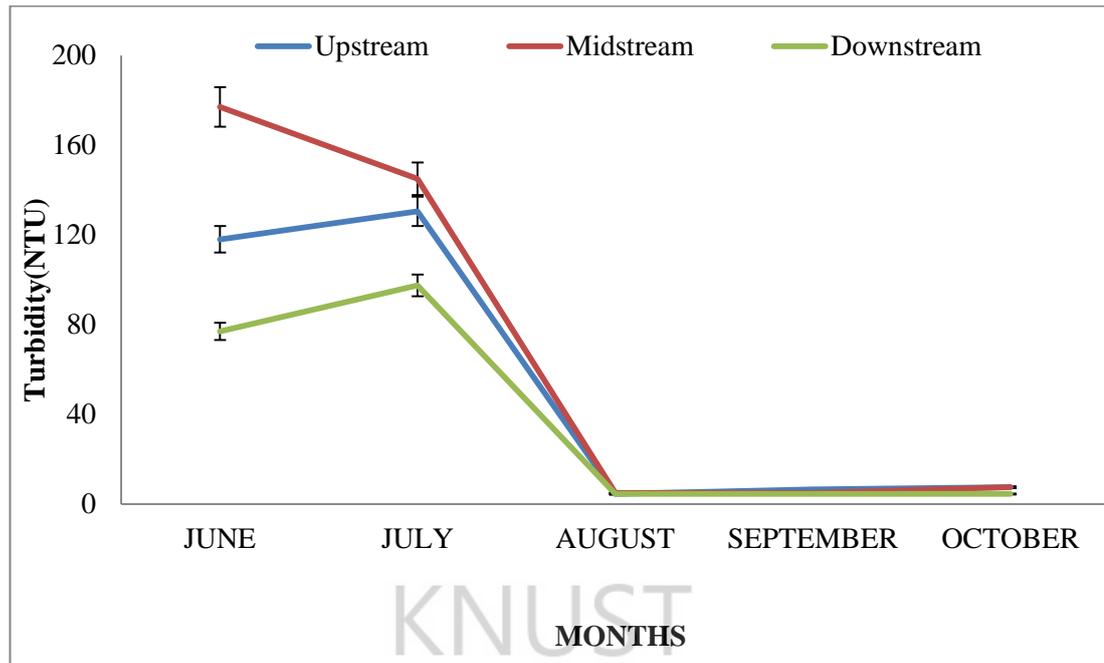


Figure 11: Variations of Turbidity levels in the Tatafo stream

4.2.1 Total Suspended Solids (TSS)

The mean levels of Total Suspended Solids (TSS) recorded 27.40 mg/l at the upstream, 28.00 mg/l at the midstream and 132.6 mg/l at the upstream, (Table 1). The highest value of 470.50 mg/l was recorded at the downstream in the month of July and the lowest value of 6.50 mg/l was recorded at the downstream in the month of September. However these variations were not statistically significant ($p = 0.65$) (Appendix A). Generally, the TSS mean levels of the water body were much higher than the WHO guideline value for drinking quality water of 20 mg/l.

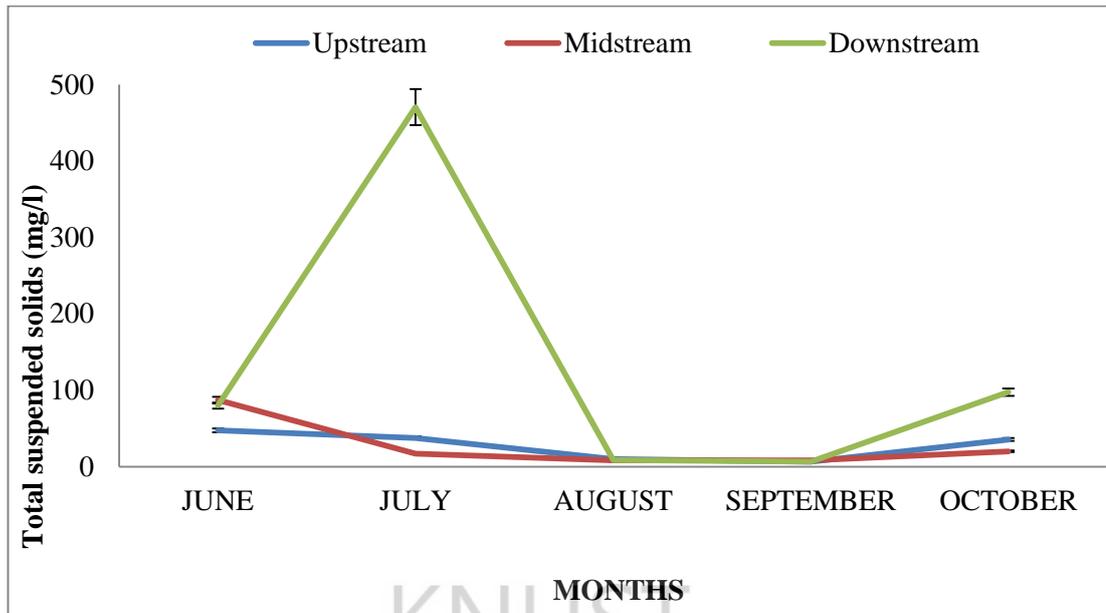


Figure 12: Total Suspended Solid Monthly Variation



TABLE 2: PHYSICO CHEMICAL PARAMETERS OF SEDIMENTS

Organic matter and organic carbon of the Tatafo varied significantly when sediments were analysed. Phosphorus, Nitrogen and pH levels were also determined.

Table 2: The means and standard deviation of physico-chemical parameters of sediments at the upstream, midstream and downstream portions of the Tatafo stream

| SEDIMENTS PARAMETERS | UPSTREAM Mean \pm SD | MIDSTREAM Mean \pm SD | DOWNSTREAM Mean \pm SD | CRITICAL LEVEL |
|----------------------|------------------------|-------------------------|--------------------------|--------------------------|
| Nitrogen (%) | 0.16 \pm 0.11 | 0.17 \pm 0.13 | 0.04 \pm 0.07 | 0.15 [Adebusuyi,1985] |
| Phosphorus | 0.01 \pm 0.002 | 0.01 \pm 0.004 | 0.02 \pm 0.02 | - |
| Organic Matter (%) | 0.39 \pm 0.24 | 1.18 \pm 0.39 | 0.28 \pm 0.16 | - |
| Organic carbon (%) | 0.22 \pm 0.14 | 0.58 \pm 0.22 | 0.13 \pm 0.11 | 1.0 [Aweto, 1981] |
| pH | 7.28 \pm 0.10 | 7.08 \pm 0.43 | 6.87 \pm 0.17 | 5.0 – 6.0 |

4.2.2 Organic Matter

The Mean levels recorded 0.39 % at the upstream, 1.18 % at the midstream and 0.28% at the downstream, (Table 2). The highest value of 1.65 % at the midstream in the month of August and the lowest value of 0.07 % at the downstream in the month of June. These variations in mean values at different water site were statistically significant ($p = 0.01$) (Appendix A).

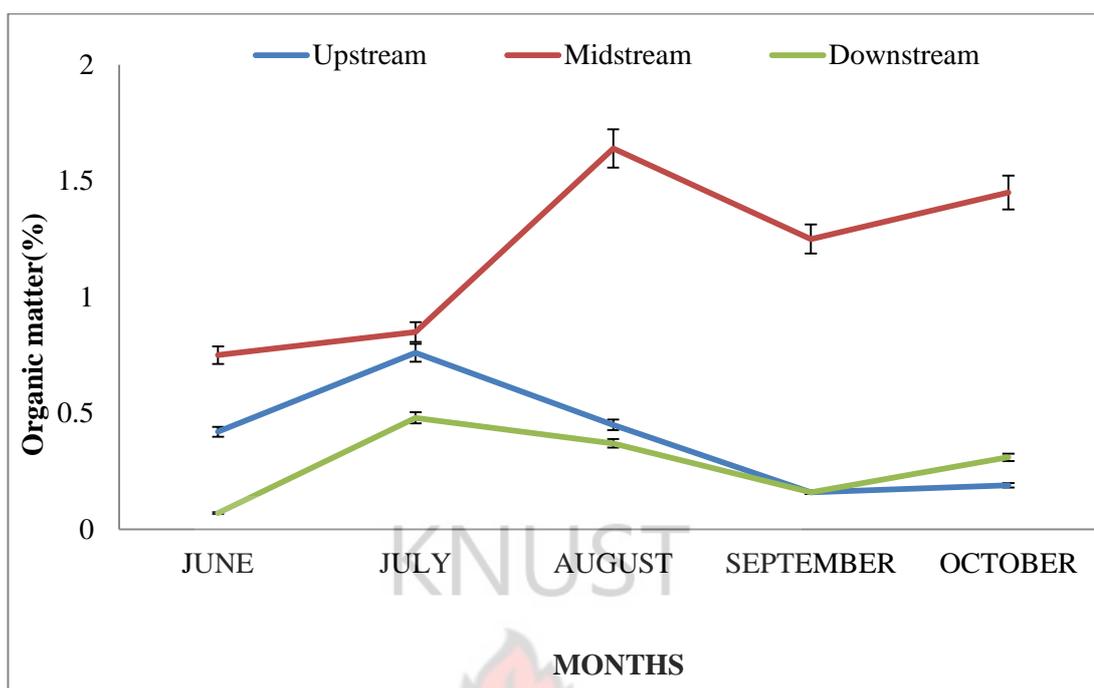


Figure 13: Monthly Variation of mean levels of organic matter

4.2.3 Organic Carbon

Organic carbon mean values recorded 0.22% at the upstream, 0.58% at the midstream and 0.13 % at the downstream, (Table 2). The highest value of 0.78% was recorded at the midstream in the month of August and the lowest value of 0.04% at the downstream in the month of June, (Figure 14). The mean values recorded are lower than the critical level of 1.0 % carbon in soil, (Aweto, 1981). Similarly, the variations in the mean concentrations were statistically significant ($p = 0.01$) (Appendix A).

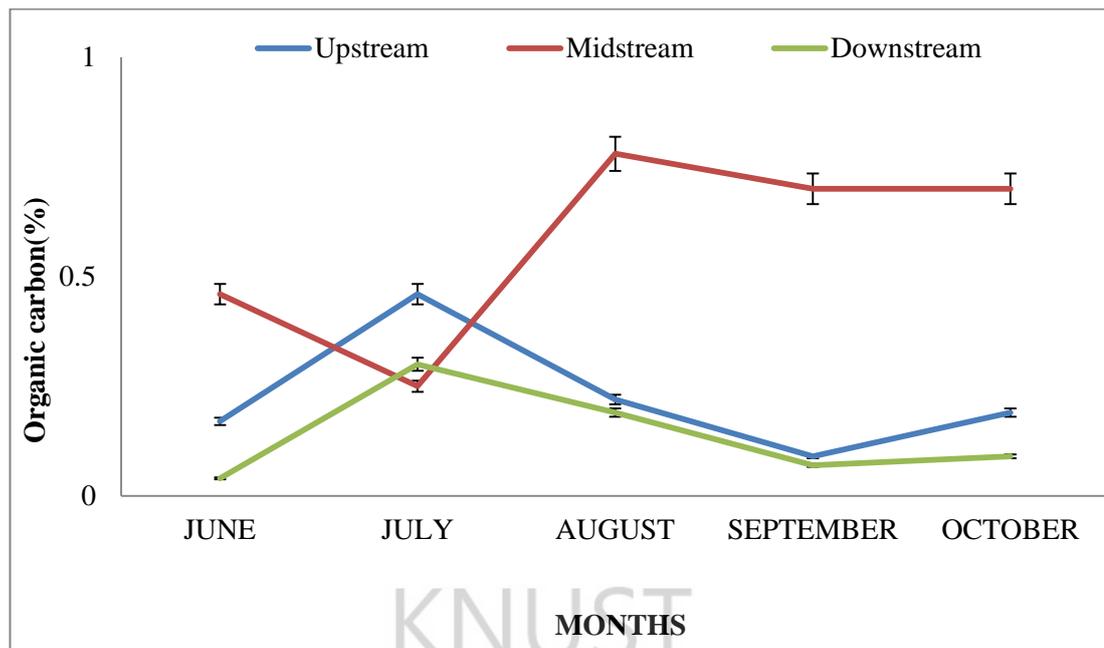


Figure 14: Graphical representation of Organic carbon of sediments

4.2.4 PH-Sediment

Mean pH levels of the stream sediments recorded 7.28 at the upstream, 7.08 at the midstream and 6.87 at the downstream, (Table 2). The highest value of 7.45 was recorded at the upstream in the month of October and the lowest value of 6.40 at the midstream in the month of July. These values are higher than the mean values of 5.32 ± 0.82 recorded at Owabi reservoir, (Abankwa Ernest, 2010). These differences in pH for all the sediment for the stream sections were not statistically significant ($p = 0.08$) (Appendix A).

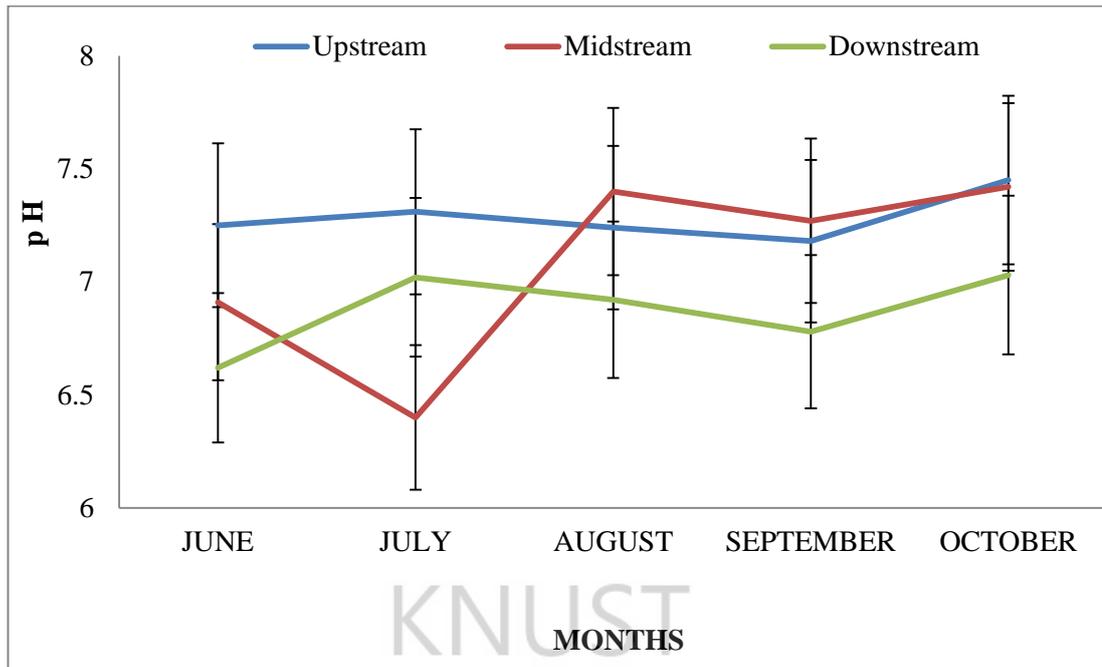


Figure 15: Levels of pH in Tatafo stream Sediment

4.2.5 Nitrogen content of Sediment

It was generally observed from the mean Nitrate-nitrogen concentrations of all the sediments samples that nitrate pollution in all the sediments of the stream sections was very negligible. The mean value recorded 0.15% at the upstream, 0.17% at the midstream and 0.04% at the downstream (Table 2). The highest value of 0.33% at the upstream in the month of July and the lowest value of 0.01 % at the upstream in the month of June and downstream portions in the month of August, September and October respectively. Most of the mean values recorded are higher than the critical level of 0.15 % of percentage nitrogen in soil, (Adebusuyi, 1985). However, the statistical variation within and between the sampling sites was not significant ($p = 0.08$) (Appendix)

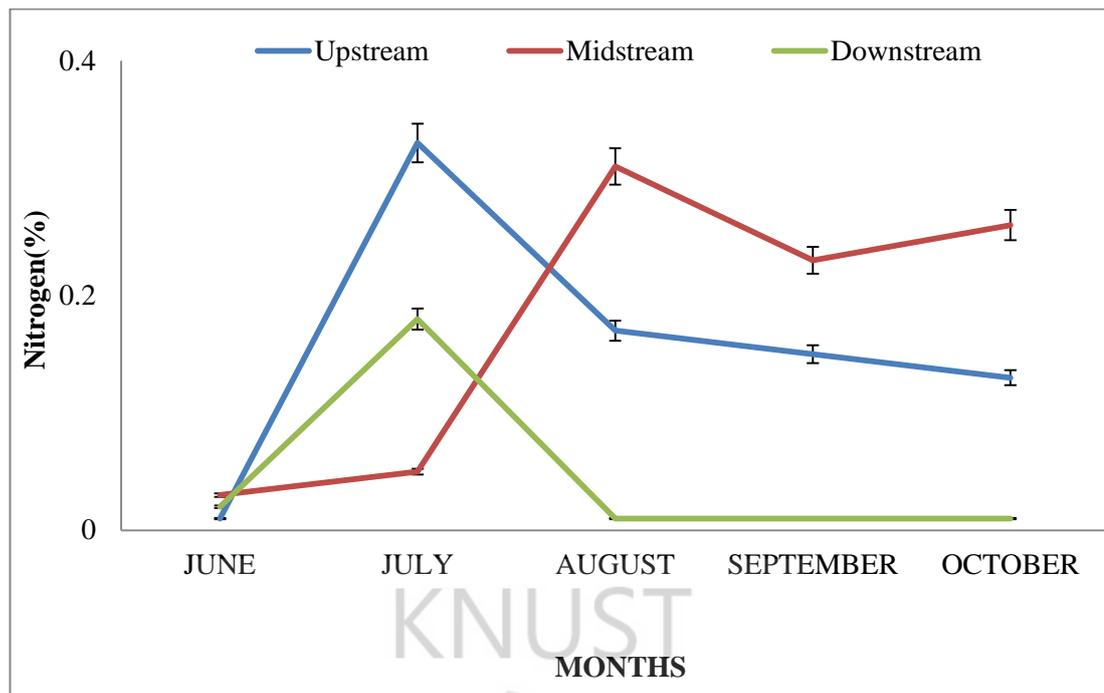


Figure 16: Graphical representation of monthly means content of Nitrogen

4.2.6 Phosphorus content of Sediment

Amount of phosphorus was also negligible in the sediments samples. The mean values of phosphorus recorded 0.01% at the upstream, 0.01% at the midstream and 0.02% (Table 2). The highest value of 0.05% recorded at the downstream in the month of July and the lowest value of 0.001% at the upstream in the month of June (Figure 4.16). The statistical variation within and between the sampling sediments was not statistically significant ($p = 0.32$) (Appendix A).

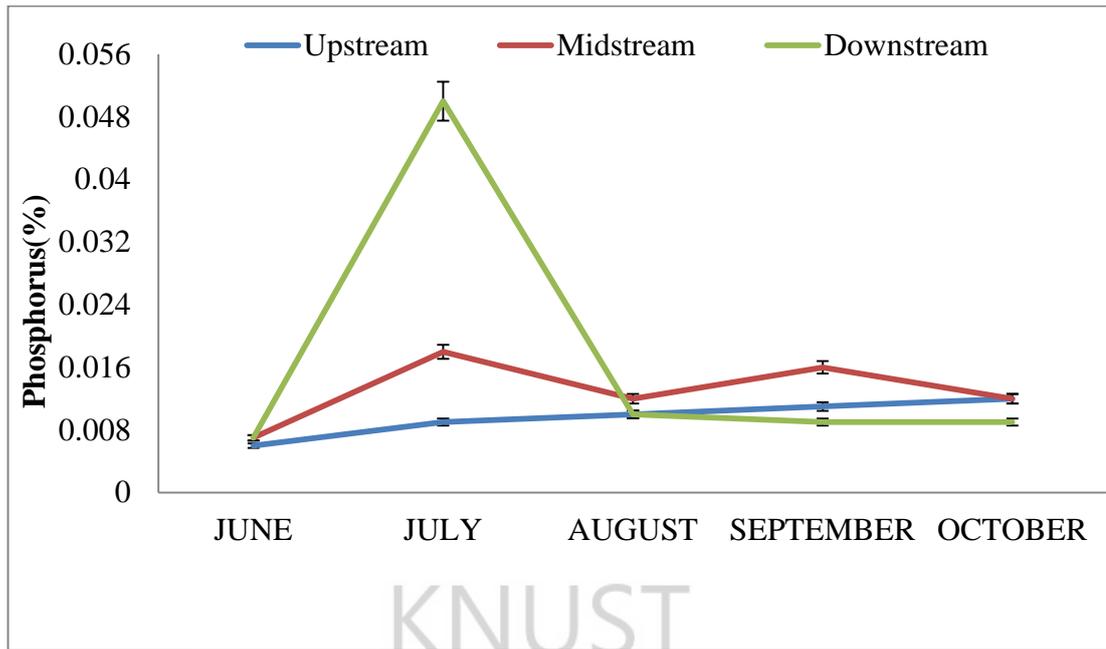
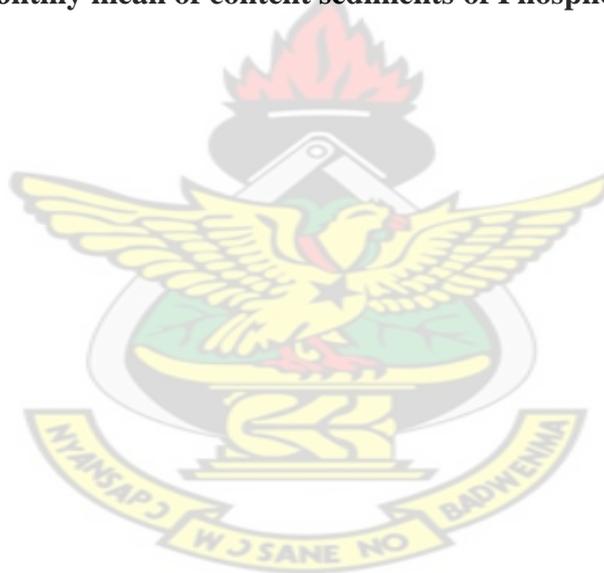


Figure 17: Monthly mean of content sediments of Phosphorus



CHAPTER FIVE

5.0 DISCUSSION

5.1 PHYSICO - CHEMICAL PARAMETERS OF WATER AND SEDIMENT OF TATAFO STREAM

Levels of Total Suspended Solids (TSS) were generally very high in all the three sections of the water bodies throughout the sampling period. The highest mean value of 132.6 ± 193.3 mg/l which occurred at the downstream was considerably in excess of the WHO recommended guideline value of 20 mg/l (WHO, 1993). Total suspended solids indicate the amount of solids suspended in the water, whether mineral (e.g. soil particles) or organic (e.g. algae). High levels of total suspended solids could be attributed to the runoffs from the surrounding vegetable farm carrying dirt and plant debris into the Tatafo stream.

The mean pH did not differ significantly ($p = 0.73$) in the stream throughout the study period. Generally, the highest obtained mean pH of 6.874 falls within the World Health Organization standard of 6.5 to 8.5 and for drinking water quality and water meant for full contact recreation (DWAF, 1996b; WHO, 1984; 1989). The water is slightly alkaline and good for drinking in accordance with WHO set standards for quality water. The pH also falls within the EU protection limits of 6.0 to 9.0 for fisheries and aquatic life (Chapman, 1996).

The turbidity mean profile did not varied significantly ($p = 0.71$) amongst the sections of the stream throughout the study period and it recorded the lowest mean of 38.4 NTU in the downstream in the month of August, September and October could

be due to the dry season. The turbidity values obtained from the sampling points were higher than World Health Organization standard of 5 NTU (WHO, 2004). None of the levels at the sections of the stream met the FEPA guideline of 0 to 1 NTU for turbidities in water for domestic use (DWAF, 1998). These values are grossly exceeded in the water samples and it disqualifies the stream for direct domestic use. Also, the excessive turbidity in water can cause problem with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998). High turbid waters were associated with the possibility of soil erosion from farm fields during raining and decay of organic matter especially dead plants debris. Inorganic solids such as clay silt and soil constituents are common in surface waters and these materials are often natural contaminants resulting from the erosive action of water flowing over natural vegetations that has been disturbed, (Peavy *et al.*, 1985). This may be due to the presence of clay, silt, finely divided organic matter, plankton and other microscopic organisms (Durance, 1986). The greater the turbidity, the higher the risk of gastro-intestinal diseases (Eric & Catherine, 1997).

Electrical conductivity recorded 43.95 $\mu\text{s}/\text{cm}$ at the upstream, 54.00 $\mu\text{s}/\text{cm}$ at the midstream and 52.30 $\mu\text{s}/\text{cm}$ at the downstream, (Table 1). The moderate conductivities recorded in all the stream sections could be ascribed to natural occurrences which introduced inorganic substances into the water but most of these mineral and metallic ions, bicarbonate and chloride ions might have precipitated out causing some of the ions to settle out of water due to adsorption resulting in the low conductivities. The self-cleansing ability of the water bodies came into play (USEPA, 1993).

Electrical conductivity is a useful indicator of mineralization and salinity or total salt in a water sample. The FEPA acceptable limit for conductivity in domestic water supply is 70 $\mu\text{s}/\text{cm}$ (DWAF, 1996). The conductivity values were found to be within international value in all the sections of the stream. Thus, the parameter does not give concern and it could make the water suitable for direct domestic use.

Unpolluted natural waters usually contain only minute amounts of nitrate (Jaji *et al.*, 2007). In this study, high levels of nitrate were recorded at all the sections (Table 1), were above the WHO limits of 5 mg/l. Nitrites are veritable indication of biological pollution in natural waters (Addo *et al.*, 2011). It is important to note that nitrate level in the stream is an indication of the potentiality of algae bloom, thus a source of eutrophication for the Tatafo water body as the obtained values exceeds both WHO limits and the recommended limit for FEPA. The effluent from the surrounded vegetable fertilizer applied farmlands during rainfall could be considered as a source of nitrate to the stream. The high nutrient levels in the upstream discharge point of the receiving water may be as a result of diffuse sources from settlement and agricultural runoff. These high levels of nitrate concentration in the water body can cause health risks such as methemoglobinemia or blue baby syndrome and the toxins produce by some algae can cause stomach cancer and liver problems in humans.

The dissolved oxygen profile through the period did not vary significantly ($p = 0.47$) and the mean values recorded 2.97 mg/l at the upstream, 3.04 mg/l at the midstream and 3.66 mg/l at the downstream. The DO mean levels content of the stream was very low and could be attributed to the presence of high degradable organic matter

which resulted in a tendency to be more oxygen demanding. Dissolved oxygen is an important factor used for water quality control. The oxygen balance of the system and its presence is essential in maintaining biological life within a system (DFID, 1999). Dissolved oxygen concentrations in unpolluted water normally range between 8 and 10 mg/L and concentrations below 5 mg/L adversely affect aquatic life (DFID, 1999; Rao, 2005).

Dissolved Oxygen standard mean levels for drinking purpose is 6 mg/l whereas for sustaining fish and aquatic life is 4-5 mg/l (Rao, 2005). The DO value from this study fell short of the recommended standard at all sections of the stream. For water quality variable such as dissolved oxygen, water quality criteria are set at the minimum acceptable concentration to ensure the maintenance of biological function.

A Biochemical Oxygen Demand test is the measure of the relative oxygen-depletion effect of a waste contaminant. The Biochemical oxygen demand (BOD) mean levels of the stream varied at the different sampling points of the stream (Table 1). The moderate mean values are within but close to the WHO limits of and this concentration may have negative effects on the quality of the stream especially fish, downstream (Morrison *et al.*, 2001). According to Ogunfowokan *et al.*, (2005), this increase in BOD could be attributed to an increase in the addition of both organic and inorganic substance from the environment, as well as organic contaminant entering the systems from the municipal runoff.

Phosphate is one of the nutrients in water bodies that facilitate eutrophication potential. The highest mean level of 1.42 ± 0.33 mg/l was within WHO permissible

limits of 6.5 mg/l. However these levels at all the sections of the stream could be attributed to the runoffs from the vegetable farmlands during raining.

Colour is one of the parameters that determine the nature of water bodies associated with eutrophication. It depends on the biological, physical and chemical characteristics of the water body. The mean value of colour recorded were 36.38 at upstream, 26.33 at the midstream and 30.65 at the downstream. These increases in colour values of the stream were attributed to suspended sediments, algae and organic debris from runoffs. High levels of colour can be attributed to the presence of decaying organic material, (Ansa- Asare, 1992).

Amount of phosphorus was negligible in the sediments samples. The mean values of phosphorus level recorded 0.01% at the upstream, 0.01% at midstream and 0.02% at the downstream, (Table 2). The statistical variation within and between the sampling sediments was not statistically significant ($p = 0.32$) (Appendix A).

However, phosphorus concentration could caused enormous blooms of the Blue-Green Algae, a form of cyanobacteria, which can produce neurotoxins (affecting the nervous system) and hepatotoxins (affecting the liver). Percentages are normally released from the sediments into the overlying water body of the stream. Toxins produce by the Blue green algae can damage aquatic ecosystems, fisheries, and water quality. These algae blooms become so dense that they reduce the amount of sunlight available to submerged aquatic vegetation (Wagner, 1974; Lindsay et al., 1960).

Nitrogen concentration levels of sediments at all the sections of the stream were higher than the critical level of 0.15% nitrogen in soil, (Adebusuyi, 1985).The mean

levels were also lower compared to the value of 1.66 %, (Chandrakiran and Sharma, 2013). The mean levels recorded 0.15% at the upstream, 0.17% at the midstream and 0.04% at the downstream. However, the statistical variation within and between the sampling sites was not significant ($p= 0.08$) (Appendix A).

The highest mean concentration of nitrate of sediment was 0.17 % and these levels can be released into the overlying water body of the stream to increase the concentration of the nitrate thus, increase eutrophication. These levels may be attributed to sewerage-rich nitrate materials from the town and runoffs from vegetable farms along the banks of the streams practice by people in the Mampong municipality. Nitrate is the major nutrients in water for phytoplankton growth and biological productivity, which could lead to eutrophication of the aquatic ecosystem (McCutcheon *et al.*, 1983).

Organic carbon mean values of all the sections of the Tatafo stream sediments within Mampong area varied and recorded 0.22% at the upstream, 0.58% at the midstream and 0.13 % at the downstream (Table 2).

These variations in the mean concentrations were statistically significant ($p= 0.01$) (Appendix A). The organic carbon level recorded were lower than the critical level of 1.0 % of soil (Aweto, 1981). The mean values of organic carbon were attributed to high organic matter component and its rate of decomposition in the stream.

The mean levels of organic matter for the sections of the stream sediments were 0.39 % at the upstream, 1.18 % at the midstream and 0.28 % at the downstream, (Table 2). The highest organic matter value of 1.64 % was recorded at the downstream and the lowest value of 0.07 % was recorded at downstream. The mean values are

negligible as compared to that of the Owabi reservoir with level of $16.35\% \pm 2.05$ (Abankwa Ernest, 2010). The mean level are also lower compared to the level of $2.49 \pm 0.55\%$, (Chandirakiran and Sharma kuldeep, 2013). These variations of mean values of the different water sediments were statistically significant, ($p = 0.01$) (Appendix A). High concentration of organic matter was due to runoffs that carry debris to the stream and decomposed to become part of the Sediments organic matter. Sediments with organic matter values exceeding 1% are said to be organically rich (Chandrakiran and Sharma kuldeep, 2013)

Mean pH levels of the stream sediments recorded 7.28 at the upstream, 7.08 at the midstream and 6.87 at the downstream (Table 2). The lowest value of 6.40 was recorded in the midstream and the highest value of 7.45 was recorded in the upstream. These differences in pH for all the sections of the stream were not statistically significant ($p = 0.08$) (Appendix A). However these moderate levels may be release to increase pH of the overlying water body. Average sediment pH recorded was slightly alkaline though the minimum pH was 6.40. pH very often act as an index for reflecting conditions associated with release of nutrients, physical conditions of soil and potency of toxic substances.

Generally, the pH values of sediments of all the sections of the streams were higher than the critical level of soil pH of 5.0-6.0.

Anthropogenic activities especially vegetable crop farming along the stream has negatively impacted on the physico-chemical parameters thus posing a health risk to the people in the Mampong town and nearby communities who rely directly on the stream.

CHAPTER SIX

6.0 CONCLUSION

The research has shown that the, anthropogonical activities along the stream negatively imparts on the water body.

The research findings revealed that Nitrate, Turbidity, Total suspended solids, Total dissolved solids were the most prevalent physicochemical parameters found in the Tatafo stream.

Similarly, the concentration of organic matter and organic carbon mean values of the sediments varied significantly.

The study showed that, most of the defined water quality parameters of the Tatafo stream were below the WHO limits for quality water and, therefore, may be suitable for domestic purposes. However, the life and quality of the stream is at stake because high levels of nitrogen, Turbidity, Total suspended solids, Total Dissolved Solids were above the recommended values (WHO, 1996).

There is the need for the intervention by the appropriate regulatory agencies to check the activities of farmers along the stream and educate people that directly depend on the stream.

6.1 RECOMMENDATIONS

By virtue of anthropogenic activities on the Tatafo stream and to avert any possible future calamity of algae bloom, drying up of the stream and health risk, the following mitigation measures are seriously recommended to prevent or minimize any further deterioration of water quality within the Mampong municipality area of the Tatafo stream:

1. Due to the sloppy nature of land along the streams which has mostly been occupied by vegetable farmers along the stream from the point source to the downward portion farmers needs to practice good farming methods such as making carrots beds across the lands to prevent soil eroding into the streams during raining or irrigation.
2. As a proactive mitigation measure, new alternative sources of water supplies in the form of hand-dug wells or boreholes should be provided for communities whose traditional sources of drinking water could be potentially be affected by the feaces of grazing animals, eroded farming land water and sediments that contains high concentration of nitrate and phosphate which can leads to stomach cancer, liver problems, nervous system disorders and blue baby syndrome (Methemoglobinemia) (WHO).
3. There is also the urgent need to embark on an intensive educational campaign by the regulatory agencies to bring the findings of this research to the notice of the people of the study area to prevent them from using these untreated raw water body as a source of drinking water to prevent any future epidemics.
4. The accessibility to water bodies by domestic and grazing animals especially nomadic cattle should be restricted since their waste , can increase the nitrates content of the stream.
5. The vegetable farmers along the stream should revise their traditional methods of farming by practicing contour ploughing at areas that are sloppy to avoid plants debris and fertilizers being eroded. Also vegetable farming along the stream banks with its attendant application of nitrogen fertilizers should be stopped to reduce nitrate and phosphate levels as well as sediment

deposits into these streams which leads to bloom of algae, therefore causing drying up of the stream.

6. The Regulatory bodies of the municipality Assembly must regularly check any anthropogenic activities on the stream, to help reduce the use of fertilizers by vegetable farmers and stop grazing animals since an increase of nitrate leads to high cost of water treatment.

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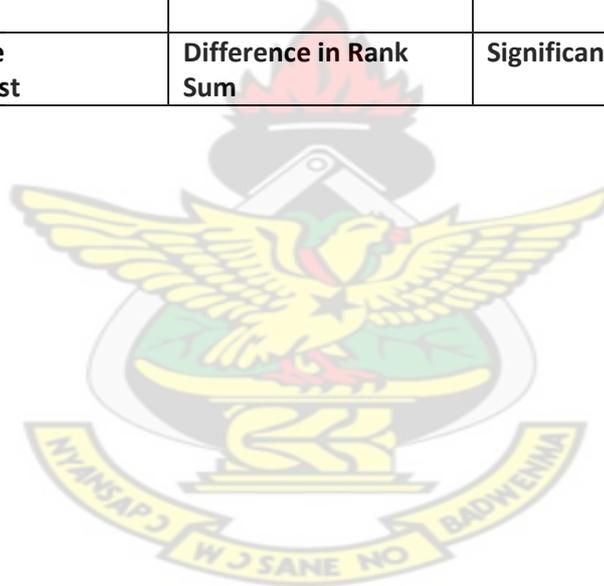
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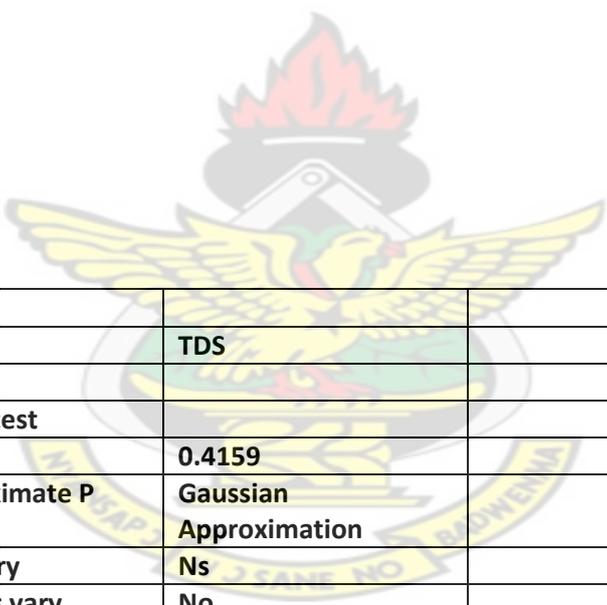
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APPENDIX A
ANOVA RESULTS

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | pH | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.7334 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.6200 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |



| | | | |
|--|------------------------|----------------------|---------|
| Table Analyzed | CONDUCTIVITY | | |
| Kruskal-Wallis test | | | |
| P value | 0.1269 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 4.129 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -4.100 | No | ns |
| UPS vs DWS | -5.500 | No | ns |
| MDS vs DWS | -1.400 | No | ns |

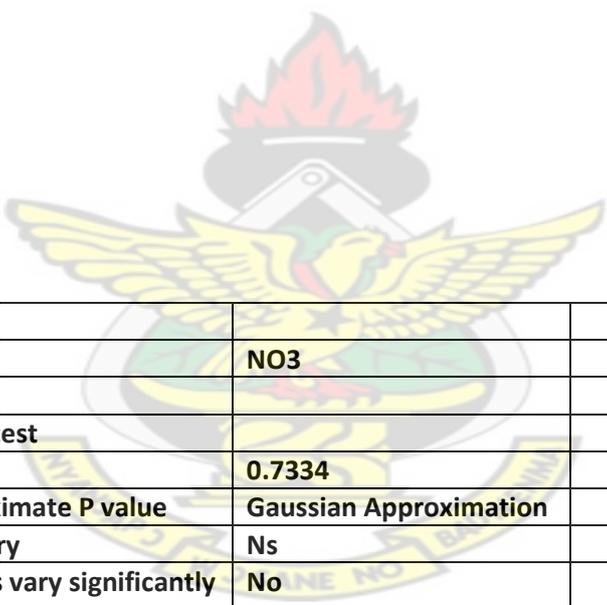


| | | | |
|--|------------------------|----------------------|---------|
| Table Analyzed | TDS | | |
| Kruskal-Wallis test | | | |
| P value | 0.4159 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 1.754 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | | No | ns |
| UPS vs DWS | | No | ns |
| MDS vs DWS | | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | SALINITY | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 1.0000 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.0000 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | 0.0000 | No | ns |
| UPS vs DWS | 0.0000 | No | ns |
| MDS vs DWS | 0.0000 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | DO | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.4677 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 1.520 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -0.4000 | No | ns |
| UPS vs DWS | -3.200 | No | ns |
| MDS vs DWS | -2.800 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| Table Analyzed | BOD | | |
| Kruskal-Wallis test | 0.8869 | | |
| P value | | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | NS | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.2400 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -1.200 | No | ns |
| UPS vs DWS | 0.0000 | No | ns |
| MDS vs DWS | 1.200 | No | ns |



| | | | |
|--|-------------------------------|--------------------------------|----------------|
| Table Analyzed | NO3 | | |
| Kruskal-Wallis test | | | |
| P value | 0.7334 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.6200 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -0.8000 | No | Ns |
| UPS vs DWS | 1.400 | No | Ns |
| MDS vs DWS | 2.200 | No | Ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | COLOUR | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.8781 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.2600 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | 1.400 | No | ns |
| UPS vs DWS | 1.000 | No | ns |
| MDS vs DWS | -0.4000 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | PO4 | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.9925 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.01514 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -0.3000 | No | ns |
| UPS vs DWS | 0.0000 | No | ns |
| MDS vs DWS | 0.3000 | No | ns |

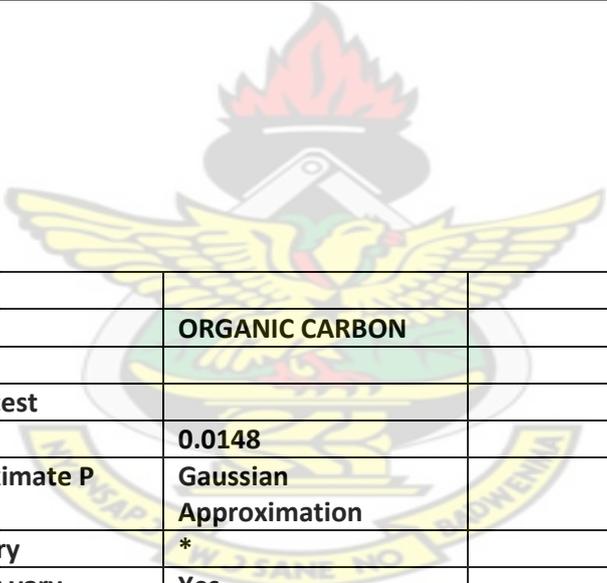
| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | TSS | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.6446 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.8781 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | 0.5000 | No | ns |
| UPS vs DWS | -2.000 | No | ns |
| MDS vs DWS | -2.500 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | TURBIDITY | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.7146 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 0.6722 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -1.000 | No | ns |
| UPS vs DWS | 1.300 | No | ns |
| MDS vs DWS | 2.300 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | NITROGEN | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.0805 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 5.040 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -1.200 | No | ns |
| UPS vs DWS | 4.800 | No | ns |
| MDS vs DWS | 6.000 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | PHOSPHORUS | | |
| | | | |
| Kruskal-Wallis test | 0.3237 | | |
| P value | | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 2.256 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -4.000 | No | ns |
| UPS vs DWS | -0.8000 | No | ns |
| MDS vs DWS | 3.200 | No | ns |

| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | ORGANIC MATTER | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.0104 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | * | | |
| Do the medians vary significantly (P < 0.05) | Yes | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 9.140 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -6.200 | No | ns |
| UPS vs DWS | 2.000 | No | ns |
| MDS vs DWS | 8.200 | Yes | * |



| | | | |
|--|-------------------------------|--------------------------------|----------------|
| | | | |
| Table Analyzed | ORGANIC CARBON | | |
| | | | |
| Kruskal-Wallis test | | | |
| P value | 0.0148 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | * | | |
| Do the medians vary significantly (P < 0.05) | Yes | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 8.420 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | -5.500 | No | ns |
| UPS vs DWS | 2.500 | No | ns |
| MDS vs DWS | 8.000 | Yes | * |

| | | | |
|--|------------------------|----------------------|---------|
| Table Analyzed | PH | | |
| Kruskal-Wallis test | | | |
| P value | 0.0846 | | |
| Exact or approximate P value | Gaussian Approximation | | |
| P value summary | Ns | | |
| Do the medians vary significantly (P < 0.05) | No | | |
| Number of groups | 3 | | |
| Kruskali-Wasllis static | 4.940 | | |
| | | | |
| Dunn's Mutiple Comparison Test | Difference in Rank Sum | Significant? P<0.05? | Summary |
| UPS vs MDS | 2.200 | No | ns |
| UPS vs DWS | 6.200 | No | ns |
| MDS vs DWS | 4.000 | No | ns |

