PERIPYHTIC DIATOM COMPOSITION AND DIVERSITY IN RELATION TO PHYSICOCHEMICAL PARAMETERS IN A SEGMENT OF RIVER GALMA, ZARIA, KADUNA STATE, NIGERIA

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BY

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DEPARTMENT OF BIOLOGICAL SCIENCES, FACULTY OF SCIENCE
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JUNE, 2015.

DEDICATION

This work is dedicated to God Almighty for his inspiration, Late Dr Tiseer .F.A.and my family.

DECLARATION

I declare that this work in the thesis entitled "**PERIPHYTIC DIATOM COMPOSITION AND DIVERSITY IN RELATION TO PHYSICOCHEMICAL PARAMETERS IN A SEGMENT OF RIVER GALMA, ZARIA, KADUNA STATE, NIGERIA"** has been performed by me in the Department of Biological Sciences under the supervision of Dr Chia Mathias and Professor S.P Bako. The information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree in any University.

Danlami Mangut KOSOM _____ _____

Signature Date

CERTIFICATION

This thesis entitled "**PERIPHYTIC DIATOM COMPOSITION AND DIVERSITY IN RELATION TO PHYSICOCHEMICAL PARAMETERS IN A SEGMENT OF RIVER GALMA, ZARIA, KADUNA STATE, NIGERIA"** by Danlami Mangut KOSOM meets the regulations governing the award of Master of Science degree (Educational Biology) of Ahmadu Bello University, Zaria.

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ABSTRACT

Diatom composition and diversity in relation to physicochemical parameters in a segment of River Galma was studied from November 2012 to April 2013 to establish baseline information about the diatom composition, diversity and water status. Physicochemical parameters such as pH, EC, Temperature and TDS were determined using Hannah meter, NO_3-N, PO_4-P, SO_4 were determined spectrophotometrically, Ca, Mg, Cl and Hardness were determined titrimetrically, BOD, DO were determined by Modified winklers Azide method, and Zn, Co, Cu, Cd, Pb, NH_4, K and Na were determined using AAS method. Biological parameters were obtained from stones (Epilithic), sand (Epipsamic), Silt/clay (Epipelic) and plants (Epiphytic). The result revealed the dominance of the species composition by the family Fragilariaceae. CCA showed that *Gomphonema, Tabellaria, Pinnularia* and *Synedra* were closely related to BOD, TDS and EC, *Epithemia*, *Navicula, Eunotia* and *Cymbella* to SO_4 and PO_4-P, *Denticula, Fragilaria, Frustulia* and *Gyrosigma* to Hardness, Temperature and Nitrate-Nitrogen. The periphytic diatom percentage composition result indicated the following: Fragilariaceae (35.36), Naviculaceae (34.43), Coscinodiceae (9.30), Cymbellaceae (9.20), Gomphonemaceae (5.74), Achnanthaceae (2.52), Plagiotropidiceae (2.12), Eunotiaceae (0.77), and Epithemiaceae (0.54). The variation in the population of periphytic diatoms may be due to abiotic factors such as the water chemistry (nutrient concentration), light, temperature, current velocity, substrate and biotic factors such as grazing, predation in the aquatic environment and all depend on the geology, lithology, topography and land use pattern. The relatively low concentration of most of the measured physicochemical parameters in this study is responsible for the relatively few diatom families and shows

that the water is clean and suitable for agricultural and domestic purposes. Therefore, there is need for effective control of anthropogenic activities in the river to sustain and conserve it status.

Keys: River Galma; Physicochemical Parameters; Periphytic Diatoms; Water quality

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Water is a major constituent of the human body, diet and one of the most widely used natural medium inhabiting both plants and animals and due to the use which it is put to by man, its quality is of significant concern to mankind everywhere (Maitland, 1978; Hassan, 1998).The inter-play between the physical, chemical and biota of a given water body determines its quality because it exerts selective action on the flora of water. The effects produced could be used to establish biological indices of water quality (Palmer, 1980; Balarabe, 2001). Stent (1981) and Chia (2007) maintained that, monitoring of biological and physicochemical characteristics of a given water body serve as important measures in evaluation of both short and long term trends in its hydrological regime by enabling appropriate decision to be made and remedy application geared towards minimizing deteriorating effects. The quality of a given water body is governed by the physical, chemical and biological factors all of which interact with one another and greatly influence its productivity (Chia, 2007).

The productivity of any aquatic system depends on the content of organisms present (Guy, 1992). In order to assess the potentials of such aquatic ecosystems for their essential management and effective utilization, there is the need to study these influences with a view to controlling and maintaining them within the optimum range (Balarabe, 2001). A study of physicochemical influence also provides an insight into why problems occur and helps to discern the trends and assess potentials. The maintenance of proper

community structure and functioning diatom assemblages in the face of encroaching human development and climate change, among other threats, is therefore important in river health management (Taurai and Tundisi, 2010). Aquatic organisms particularly diatoms are excellent indicators of human impacts on stream ecosystems because they provide valuable services and integrate the effects of multiple stressors over time and space, which would be difficult to assess if only considering water chemistry (Nathan, 2010).

Diatoms grow abundantly in rivers rich in nutrients colonizing almost all suitable habitats. Agriculture contributes to the concentrations of nutrients, conductivity, and pH of streams; all of which are important to the presence and abundance of diatom species. Diatoms are extensively in studies related to the monitoring of river quality. Study by Descy *et al*. (1990) on diatoms in rivers, considered that, diatom indices, diversity and abundance provide excellent information of water quality, especially with widespread increasing eutrophication. Many studies have linked changes in algal assemblages, particularly diatoms to changes in water chemistry such as pH, Phosphorus and Nitrogen (Winter *et al*., 2000). The use of diatom tolerance values in water quality monitoring traces its history to Europe, where it has been used for a century (De la Rey *et al*., 2004). Diatoms are reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Cattaneo *et al*., 2004) as well for general water quality (AFNOR 2000).The light regime and velocity of water are two factors which determine the diatom community in rivers and streams. The light regime affects diatom structure (Kawecka 1986) and influenced organism's response to pollution (Guasch and Sabater, 1997). Physical, chemical and biological parameters have been

used to assess quality of running water (Lobo *et al*., 2004). Classic physical and chemical monitoring reflects instantaneous measurements while biotic parameters provide better evaluation of environmental changes. Fish, macro-invertebrates, and algae are the most common assemblages used in biological assessments and each responds differently to environmental variables (Passy *et al.*, 2004; Johnson *et al*., 2006). Algae, particularly diatoms, are preferred more than other organisms as good indicators of water quality because they indicate early pollution impact and habitat restoration (Round,, 1993).The chemical and physical characteristics of water body is more reliably and easily determined by the diatom found in it (Cholnoky, 1962).

The significance of water to human and other biological systems cannot be over emphasized (Garba *et al*., 2010). Water constitutes approximately 70% to 90% of all living cells and almost 75 percent of the surface of the Earth (Wetzel, 2001). Most species of plants and animals depend directly or indirectly on water to sustain their lives. Living things can go for days without food but cannot do without water for a day. Globally, 505,000 cubic kilometers of renewable fresh water shifts from the sea to the land every year as rain or snow via the hydrological cycle; but only 47,000 cubic kilometers per year is accessible for human use (Gleick, 2000). What is available is now increasingly coming under pressure from several directions at once. The availability of water in terms of quality and quantity is essential for the very existence of mankind.

According to Gore (1993), human beings are made up of water in roughly the same percentage as water in the surface of the earth. Our tissues and membranes, brains, and hearts, our sweat and tears, all reflect the same recipe for life. Water is essential for the

development and maintenance of the dynamics of every ramification of the society (United Nations Development Program, 2006). Water is indeed life and is the most important natural resource second only to oxygen need to be conserved, protected and jealously managed by all, without which life would be non-existent. Such a life supporting substance has been abused and exposed to several natural and human-induced stressors (Schindler, 2001). All over the world today, water bodies have become the primary dump sites for wastes containing great toxic like pesticides and heavy metals thereby altering the physical, chemical and biological nature of the receiving water body (Adekunle and Eniola, 2008). In developing countries, more than 90 percent of wastewater and 70 percent of industrial wastes are discharged into coastal waters without being treated (Creel, 2003).These wastes from industries, intensive and careless agricultural practices ,markets and several other factors combine contribute to the decline in water quality, which decreases the availability of domestic water supply (Davies and Day, 1998).

Availability of safe and reliable source of water is an essential prerequisite for sustained development (Asonye *et al*., 2007). Safe drinking water is a human birthright – as much a birthright as clean air. Of the 6 billion people on earth, more than one billion lack accesses to safe drinking water and, about 2.5 billion do not have access to adequate sanitation services (TWAS, 2002). Today 31 countries representing 2.8 billion people, including China, India, Kenya, Ethiopia, Nigeria and Peru confront chronic water problems. Within a generation, the world's population will climb to an estimated 8 billion people. Yet, the amount of water will remain the same (Bishnoi and Arora, 2007). The challenge is as clear and compelling as pristine water cascading down a mountain stream:

We must find new and equitable ways of saving, using and recycling the water that we have (Atalay *et al.,* 2008). The quality of water, whether it is used for drinking, irrigation or recreational purposes, is significant for health in both developing and developed countries worldwide. The common sources of water that are available to local communities in Nigeria are fast being degraded by a number of anthropogenic factors, of which pollution remains the most prominent problem (Haylamicheal and Moges, 2012). Even if no sources of anthropogenic contamination exist, natural sources are also equally potential to contribute higher levels of metals and other chemicals that can harm human health. This is high-lighted recently in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population (Anawara *et al*., 2002). Pollution and water quality degradation interfere with vital and legitimate water uses at any scale, i.e. local, regional or international (Meybeck *et al.*, 1989).

Water pollution occurs when unwanted materials with potentials to threaten human and other natural systems find their ways into rivers, lakes, wells and streams. Consequently, fishes, bottom-dwelling animals and even aquatic plants can be contaminated and/or killed, creating significant disruption in the food chain and dynamics in the community structure. The major problem is that most of these harmful substances re-concentrate in natural food chain because the primary producers algae are aquatic (Osuide, 1990) .Polluted river water is mostly the source of water for irrigating dry season agricultural plants like cabbage, carrots, tomatoes and onions consumed even by those with access to clean and safe water. when this contaminated water is directly consumed without proper treatment (a common practice to local communities), spread of diseases such as typhoid, dysentery, cholera, hepatitis cancer and new generation diseases like stroke,

hypertension, weak erection and diabetes to mention few occur. The world health organization in 2006 reported that, water related problems accounts for most deaths than HIV/Aids, malaria and tuberculosis combined. Various types of water borne diseases kill on an average more than 6 million children each year i.e. about 20,000 children a day (TWAS, 2002).

The major issues of interest are how these water pollution problems could be fully assessed and mitigated. The demand for fresh water is fast increasing at a rate greater than the world's population growth. Access to safe water supply is a serious issue across the globe. Recent statistics (WHO 2012) indicates that 1.2 and 2.4 billion people suffer from lack of safe water supply and secure sanitation respectively. In many developing countries, Nigeria in particular, more than half of the population is affected. On 1 August 2010, the United Nations (UN) General Assembly resolution declared that access to clean water and sanitation is a fundamental human right (WSS 2000).

Water quality management is a continuous process, when the physical and chemical conditions of ecosystems are changed beyond their normal ranges, significant changes may be expected to occur in individual organisms, population and communities of the ecosystem (Akinoriola, 2003; Kadiri, 2006). Traditionally, water quality evaluation focused only on physical and chemical measurements (Ramachandra *et al*. 2007). According to EPA (1999), water quality can be assessed by measuring physical, chemical and biological indicators such as nutrients, algal growth, pH and salinity. Biological monitoring techniques is introduced as part of routine monitoring programme to compliment the traditional approach due to certain shortcomings in standard physical and

chemical methods. Among the limitations are the difficulty and cost of chemical analyses of every potential pollutant in a sample of water, and of interpreting results in terms of impact severity.

Accurate information on trends of water quality is required as a basis for economic and social development, and for the development and maintenance of environmental quality. The productivity of any aquatic system depends on the amount of organisms present (Guy, 1993). Based on this, there is the need on the use of indicators to monitor change in water quality. Indices or values obtained from these parameters are the most effective tools to communicate information on the quality of water to the concerned citizens and policymakers (Bhaven *et al.*, 1998). Ikeda (2005) proposed the adoption of biological indicators and introduction of community based monitoring of water quality. The conventional biological methods developed use organisms such as benthic algae, macrophytes, invertebrates and fishes. Among these, diatoms are more preferred than other algae, macrophytes, invertebrates and fishes as bio –indicators of water quality because they remain in their location unless disturbed by some catastrophic events like big floods (Gonzalo and Maria, 2012). Diatoms are used for water quality assessment all over the world because they are more precise than water chemistry due to their ability to integrate stressor effects over time and range of ionic content and composition (Stevenson and Smol, 2003). Biological approach is cheap and advantageous because it examines organisms whose exposure to pollutants is continuous. Thus species present in riverine ecosystems reflect both the present and past history of the water quality in the river, allowing detection of disturbances that might otherwise be missed (Eekhout *et al.*, 1996).

1.2 Statement of Research Problem

Water available to the surrounding community is severely stressed by poor management. Water pollution is the greatest problem for human beings which deteriorate water quality. Most of the harmful pollutants re-concentrate in natural food chain. There is a serious undesired change in the physical, chemical and biological characteristics of water causing significant impact on the structure and function of the communities in the aquatic ecosystem. The increase in human population, industrialization and urbanization has led to increase in demand for good quality water for both domestic (to prevent diseases and improve life) and industrial purposes. There is an economic and technological constraint to adequately treat the available water before use. Water, the vital resource for life is increasingly been polluted in the wake of population growth, poor land use system, agricultural activities and industrialization.

Water contamination by effluents from various sources is associated with heavy disease burden and this could influence the current shorter life expectancy in the developing countries compared with developed nations (WHO, 2002). Due to ineffectiveness of purification systems, water quality and the risk to water borne diseases are critical public health concern in many developing countries.UNICEF/WHO 2012 observed that close to a billion people mostly in developing world don't have access to safe and adequate water. Waste water is dangerous accumulating toxic products in receiving water bodies, with potential serious consequences on the ecosystem. The level of several heavy metals of fresh water bodies especially Lakes and Rivers is of great concern because they produce

water of chronic poison no longer safe for aquatic animals and human consumption (Omoregie *et al*., 2002).

1.3 Justification

Studies on diatom assemblages in relation to water quality have been carried out in temperate regions while only few studies have been carried out in tropical regions. Adoption of research from temperate region studies to tropical regions can lead to erroneous interpretation of water quality because there are limited overlaps in species composition between two regions, or at least some ecological characteristic of the key taxa vary among the regions (Taurai and Tundisi, 2010).

River Galma which originates from shere near a western edge in Jos plateau and fall into magami village Kaduna is a major source of water in Zaria metropolis. The people depend on it for drinking, fishing, farming, rearing of animals and other commercial purposes. It is important to regularly monitore the quality of the water against contamination and varied water borne diseases. Information on diatom composition and diversity of other ponds in Zaria is available but scarce on a segment of River Galma. Knowledge of the periphytic diatom community structure of a segment of the river is imperative to provide baseline information for future reference.

Accurate information on the condition and trends of water resources quantity and quality is required as a basis for economic and social development, and for the development and maintenance of environmental quality (Bhaven *et al.,* 1998). Most of the river ecosystems in Nigeria are threatened by anthropogenic activities (Ibrahim *et al*. 2009). Rivers mostly in developing countries are the ends of effluents discharged from industries. The good

ecological status of a water body is assessed by considering both the anthropogenic pressures on an ecosystem, and the quality of the environment (biological and physicochemical parameters (Lepon *et al*., 2009). Heavy metals are potential hazards to the health of humans, animals and plants. Their environmental levels is of global interest for the purpose of setting background values of these elements (Oyekunle *et al.,* 2012).

Diatoms are the richest and most abundant microalgae occurring in vast array of shapes and sizes. Monitoring of water quality using diatoms is inexpensive, fast and reliable. Diatoms are very sensitive to the environment they live and any alteration in the environment leads to the change in the diatom communities in terms of tolerance, abundance, diversity and dominance in the habitat. The composition and abundance of periphyton in any water body clearly indicates the health status of the water body (Rabiu *et al.,* 2014)

1.4 Aim of The Study

To determine the physicochemical parameters and periphytic diatom composition and diversity in a segment of River Galma, Zaria, Nigeria to provide a better insight on the water status of the river ecosystem.

1.5 Objectives of The Study

The objectives of this study are to:

1. Determine the physicochemical characteristics of the water in a segment of River Galma.
2. Determine the relationship between diatom assemblages and the physicochemical characteristics of the stream.

3. Determine periphytic diatom composition and diversity over time and space.

1.6 Hypotheses

1. There is no significant difference in the physicochemical characteristics of the stream.
2. There is no significant relationship between physicochemical characteristics and diatom assemblages.
3. There is no significant relationship between diatom composition and diversity over time and space.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Algae

Algae are important indicators of ecosystem health and integrity because they form the base of most aquatic food chains. Virtually all aquatic animals are dependent on this primary producer. Algae are also an excellent indicator of water quality, as their abundance and community composition most often reflects the aquatic ecosystem health (Huynh and Serediak, 2006). The importance of algae to riverine ecology is easily appreciated when one considers their role as primary producers and transformers of inorganic nutrients into organic forms useable by other organisms (Mulholland, 1996). Structurally, algae stabilize the substrate and create mats that form habitat for fish and invertebrates. Some invertebrates use algae to construct cases (Bott, 1996). Algae are photosynthetic organisms that have a relatively simple structure compared to vascular plants. The main characteristic that distinguishes algae from other plants is sexual reproduction. Algae are nearly ubiquitous, and may grow in waters of varying salinity, in intertidal regions, in soils, on buildings, living mutualistically within other organisms telling a lot about the health of the ecosystem. For example, a community of *Euglena, Scenedesmus* and *Selenastrum* likely indicates a eutrophic water body even on desiccated sand and rocks in deserts and on the snowy slopes of mountains. Algae are found in all aquatic habitats. In most streams and rivers, algae are the most diverse assemblage of organisms that can be sampled easily and identified readily to species level (Stevenson and Smol, 2003).

Algal species are excellent indicators of water quality and environmental change. Knowledge about algae can provide valuable insights into water quality, indicating concerns such as pollution to waterways, reduction in water flow, or a health and safety risk, as some algal species are highly toxic(neurotoxin and hepatotoxin) to humans and livestock (Huynh and Serediak, 2006). Proliferation of harmful organisms, particularly species should be monitored. Phytoplankton studies and monitoring are useful tools for assessing the physicochemical and biological conditions of aquatic ecosystem (Whitton and Patts, 2000). The dynamics of phytoplankton (algae) are a function of some environmental processes that affect species diversity (Roelke and Buyakates, 2002).

2.2 Biology and Ecology of Diatoms

Diatoms are unicellular microalgae universally distributed in all types of aquatic environment forming majority of floating algae (Planktonic) in marine and fresh waters. Diatoms are important components of the photosynthetic organisms that form the base of the aquatic food chain (Sverdrop *et al.*, 2003). They account for 40 to 45 % of water bodies' primary production making them more productive than the entire world's rainforests. They are important in cycling of Silica and Carbon globally and at the same time sustain fisheries. Diatoms multiply rapidly and show high variation in sexual reproduction thereby maintaining a dynamic. They have the richest species group among algae with tens of thousands of species (Mann, 1999). There are currently over 260 genera of living diatoms with over 100 000 species (Round *et al.*, 1990). Diatoms are the most abundant microalgae constituting approximately 40 % in the world, occurring in vast array of shapes and sizes. The success of diatoms as dominant aquatic primary producers has been related to the genetic diversity accumulated during a complex

evolutionary series of endosymbiotic events. These included an ancient acquisition of a significant nuber of diatom nuclear genes from green algae, plastids from red algae, and by successive gains or losses of genetic material (Armbrust, 2009). These features have likely helped diatoms to adapt to new ecological niches during evolution and are expected to determine the success of some species in the current changing environmental conditions (Moustafa *et al.,* 2009).

The distribution, abundance, species diversity and species composition of diatoms are used in assessing water quality (Kumari *et al*., 2008; Davies *et al.,* 2009). Diatoms are sensitive to changes in nutrient concentrations, and growth response is directly affected by changes in the prevailing nutrient concentration and light availability. Each taxon has specific optimum tolerance for nutrient such as phosphorus, nitrogen, and this is usually quantifiable. They reflect the nutrient status of the environment and because they do not have control over their movements and cannot escape pollution, they have the potential of nutrient uptake and bind both organic and inorganic substances which make them good indicators of pollution (Rabalis, 2002; Raybaund *et al*., 2009). Because of the limited power of locomotion, their growth and distribution depends on the carrying capacity of the environment and nutrient concentration (Odiete, 1993). Stressors, such as nutrients, and natural variation in chemistry and parameters such as light, temperature, and hydrology can fluctuate greatly, which influences periphyton taxonomic composition and structure (Merovich *et al.,* 2007; Pillsbury and Bryrne, 2007). Diatoms show seasonal variations, with higher abundance and diversity in the dry season (Ezra, 2001; Tiseer *et al*., 2008).

Diatoms belong to the division Bacillariophyta and class Bacillariophyceae, found in fresh water, marine water, soils and on damp surfaces. The silicon used by diatoms conferes higher growth rates than other microalgae of corresponding size occupying virtually every environment (Furnas, 1990). Most diatom live pelagically in open water, while some live as surface films on water sediment, benthic or even under damp atmospheric conditions. Diatoms are primarily photosynthetic while few are obligate heterotrophs which can live heterotrophically in the absence of light provided an appropriate carbon source is available. Storage products are chrysolaminarin and lipids (Horner, 2002).

Diatoms occupy a wide variety of habitats from floating (Planktonic) to attached (Periphyton). The latter may be attached to rocks (epilithon), sand (episammon) mud (epipelon) or plants (epiphytic). The term metaphyton is used for diatoms, which are loosely attached to macrophytes or other submerged substrates. Further adding to the diversity of habitat is the epizoic diatom growing on living animals reported in several zooplanktons (John, 1991). There have also been reports of diatoms growing on the feathers of birds. A few members of benthic foramnifera harbor endosymbiotic diatoms which lack siliceous frustules or have only vestigal frustules (Lee and Xenophanes, 1990). The systematic of diatoms is exclusively based upon frustule characteristics, shape, size, symmetry, structure and density of striae, nature of raphe, copulae and processes on the valves. However, there is a trend towards ultrastructure and features of living cells such as chloroplastids, life cycle pattern and reproductive biology to be considered in the systematic (Round *et al*. 1990). Diatoms are divided into two groups based on overall symmetry of the cell walls; radially symmetrical forms are informally

called “centric” diatoms while bilaterally symmetrical forms are referred to as “pennate” diatoms. Diatoms are algae that reflect the biotic condition of rivers, streams, lakes and estuaries. Diatoms are important indicator organisms because they are sensitive to natural and human impacts, monitoring their condition provides information about ecosystem health. Accurate identification of taxa with information on geographical distribution is essential for the use of diatoms as reliable indicators. Details provided by diatom assemblages support palaeoecological investigations, historical reconstruction of water quality and the determination of prevailing water quality conditions (Taylor *et al*., 2005). Diatoms are cosmopolitan, with others being endemic to specific regions (Kelly *et al*., 1998; Potapova and Charles, 2003). Geographical location is not the determining factor in the distribution of diatom species and the composition of communities, but it is rather the specific environmental variables at a specific site that determine this distribution (Kelly *et al*., 1998).

2.3 Diatoms as Biological Tools For Assessment

Few people involved with ecohydrology and water resource management doubt the value of water quality assessment derived from the use of biotic indices, i.e. assessments based on observations of the resident flora and fauna communities (Bate *et al.*, 2002). Assuming requisite levels of ecological experience and taxonomic proficiency on the part of the assessor, such evaluation provide a description of the water quality that is often not achievable from elemental analyses alone. The value of an integrative biological response provided by the analysis of diatom association offsets the inconsistency of rapid changes in water chemistries that render the use of conventional analytical approaches inadequate. A further potential advantage is that the diatom based approach could obviate the need

for additional and expensive toxicity testing protocols particularly because of the attendance uncertainty of extrapolation to the environment of the responses of selected single species testing gauge under laboratory conditions. Ecological risk assessments are more appropriately based on biological endpoints in the field than on measures of chemical constituents (Karr and Chu, 1997). It is important to test indicators quantitatively in order to assess how closely they can be linked to the health of aquatic ecosystems (Walmsley, 2000). Diatoms have for some time and latterly increasingly so been used for the assessment of short and long term environmental change (Dixit *et al.*, 1992). The use of algae (diatom) for monitoring rivers has increased because of the limitation of benthic invertebrates and fish as indicators (Charles, 1996). Round (1991), list reasons why animal components of an ecosystem may not provide a satisfactory index system: Animals have complex reproductive cycles which are often linked to the seasons, animals are largely motile and this may cause difficulty during sampling, animals may have many different life stages and may undergo metamorphosis, animals have specific habitats and niches and are actively grazed. Animals are closely linked to flow conditions and thus will not usually be evenly distributed (Kwandrans *et al.*, 1998).

Diatoms are particularly interesting as potential indicators of water quality because of their occurrence in all aquatic environments, found at almost all levels of pollution, worldwide distribution, and their siliceous wall provide details for identification to be made. Diatoms show wide tolerance ranges for many environmental variables and respond rapidly to environmental change, making them ideal indicators (Reid *et al.*, 1995). Diatoms provide interpretable indications of specific changes in water quality (Mc Cormack *et al*., 1994). Diatoms show integrating response to ambient changes in water

quality which may sometimes not be observed by chemical analysis. It is well established that diatoms follow more closely the chemistry of river waters and other aquatic ecosystems (Poulkov *et al*., 2004; stinger *et al.,* 2007 and Tapia, 2008). Owing to its ubiquity, diatom assemblages and pollution indices are an integral part of many stream assessment programmed worldwide. As a result, they are recommended to be more useful and valuable as tools for monitoring aquatic ecosystems compared to micro invertebrates. They are suitable biological components of an aquatic ecosystem to describe natural and human produced disturbances (Venkateswarlu and Reddy, 2000).

In recent years, diatom based techniques have been incorporated in water quality monitoring and used successfully as indicators of the ecological quality of aquatic ecosystems in many countries worldwide (Leira and Sabater, 2005; Chen *et al*., 2008; Taurai and Tundisi, 2010). They are used in Europe (Prygiel and Coste, 1999), Australia (John 2000), Asia (Rothfritz *et al.,* 1997), Africa (Gasse *et al.,* 1995) and in the central region of Portugal during the 1980 and 1990 (Almeida and Gill, 2001). Different species of diatoms respond differently to metal and organic pollution because of their wide tolerance range to physical, chemical and biological changes in water bodies (Charles, 2003). The value of using diatoms lies in the fact that they reflects rather precisely the water quality at any one point and by monitoring changes in the flora, subtle changes in water quality conditions will be detected. Benthic periphytic diatoms are more reliable for this purpose because they remain in their location unless disturbed by some catastrophic event, like a big flood. As a result, they have the potential to track environmental disturbances and reflect the characteristics of the water from the area in which they live (Gonzalo and Maria, 2012). Reynolds (1998) reported that the

oligotrophic indicators of blooms were desmids; chrysophytes and diatoms while the eutotrophic indicators were cynobacteria and eugleniodes.

2.4 Diatom Diversity and Abundance

Diversity is a community attribute related to stability, productivity, trophic structure (Mcintosh, 1967; Tilman, 1997 and Lees, 2000). Diatom biotic indices, based on the estimation of diversity and relative abundance of diatom species in water bodies, is widely used for decades as water quality indicator tool (Zalack et al., 2010). Change in abundance and diversity of diatoms represent direct and profound responses to pollution in the water. The diversity and abundance of diatom is determined by the amount of nutrients and levels of pollution of the environment as a result of changes in the physical, chemical and biological conditions of the river. Studies showed that taxonomic composition and species diversity change with increasing nutrient levels and that these changes are related to differences among taxa in nutrient uptake, storage, growth and loss rates (Smith, 1990). The physical and chemical properties of water immensely influenced its uses, the distribution and richness of biota (Courtney and Clement, 1998; Unanam and Akpan, 2006).

Phytoplankton (diatoms) abundance and composition in an aquatic ecosystem are regulated by various abiotic or physicochemical factors such as pH, light, temperature, salinity, turbidity and nutrients (Buzzi, 2000; Lewis, 2000). Diversity and composition of algae in the Niger Delta water bodies varies seasonally with peak in dry season (Yakubu *et al.*, 2000). Phytoplankton (diatom) biomass declines throughout the summer but increases in winter (Smith and Wilson, 1996). Seasonal variations affect

the physicochemical variables thus causing variation in abundance and diversity of plankton. Human activities (agricultural and industrial) going on along Stream introduce wastes into it which could affect the physicochemical variables. These therefore cause variation in organisms' populations. Using diatom relative abundances into account, diversity depends not only on species richness but also on the evenness, or equitability, with which individuals are distributed among the different species. Variation in available substrata in the sampling sites is a factor responsible for diatom diversity and abundance because of species affinity to different micro habitats (Burkholder, 1996).

Diversity provides important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure. Understanding how these indices interact with physical-chemical parameters of the given environment is very useful to know. Parameters like temperature, dissolved oxygen, pH, ammonia and others are one of the few that are vital for diatom survival.
(http://craticula.ncl.ac.uk/EADiatomKey/html/environment.html, Access 14, October 2008).

Plankton abundance and diversity are tools used to measure water quality. Many diatom species display strong physical habitat specificities (Winter and Duthie, 2000b; Soininen and Eloranta, 2004 and Townsend and Gell, 2005), and diversity can differ significantly among substrata because of the different constraints associated with substratum types, such as sand, silt, and rocks (Potapova and Charles, 2005). As a result, habitat heterogeneity within streams is likely an important constraint to diatom community

composition and diversity. Research has suggested that multi-habitat samples may provide improved assessments of streams (Winter *et al*., 2000b).

2.5 Physicochemical Parameters

2.5.1 Water temperature

Water temperature is a controlling factor for aquatic life; it controls the rate of metabolic activities, reproductive activities and life cycles. If water temperatures increase, decrease or fluctuate too widely, metabolic activities may speed up, slow down, malfunction or stop all together. Water temperature influence the biomass composition, nutrient requirement and nature of biota. Change in temperature are considered more important than any environmental factor in influencing diatom growth. Various classes and species of algae (diatoms) have minimum, optimum and maximum temperature for growth. Water temperature affects the metabolic rate of plants because enzymes which work best at optimum temperature regulate every reaction in the organism. Photosynthesis and plant growth increases with increase in water temperature. There is a clear seasonal pattern of phytoplankton growth with respect to water temperature (Celtin and Yildirin, 2000; Akin-Oriola, 2003). Akin-Oriola (2003), reported that marked variation in temperature between the rainy and dry season affect the physicochemical characteristic of water in the tropics. Cold water has more dissolved oxygen than warm water, thus, as temperature increases less oxygen is available to the biota.

2.5.2 Water pH

pH is a measure of the hydrogen ion concentration of water used to indicate degree of acidity or alkalinity. pH is an important limiting chemical factor for aquatic life. The pH

ranges from 0-14 standard units. pH of 7 is considered neutral, with values less than 7 being acidic, and values greater than 7 being basic. Water that is too acidic or basic, the H^+ or OH^- ion activity may disrupt aquatic organism's biochemical reactions. Most biological processes operate between pH ranges of 6.5-8.5, outside this range, biological activity declines or ceases (Lind, 1979).

The pH value is influenced by changes in carbon (iv) oxide, carbonates and bicarbonates systems. Both the diurnal and depth variations of pH indicate the metabolic levels of the water and its productivity. When photosynthesis is high, pH increase to a high level by afternoon and hydroxyl alkanol is produced. Alkalinity in rivers is mainly determined by the bicarbonate and carbonate systems (Blazs *et al.*, 1991). The pH exerts a direct physiological stress on diatoms (Gensemer, 1991), and also strongly influence other water chemistry variables. pH affects solubility of trace metals (Stumm and Morgan, 1981). It also affect the solubility of trace metals and influenced the uptake of metals by phytoplankton (Zang and Xu, 2001).

2.5.3 Dissolved oxygen

Dissolved oxygen refers to the available oxygen in water. Oxygen is essential for the survival and propagation of aquatic organisms. If the amount of oxygen dissolved in water falls below the minimum requirements for survival, aquatic organisms may die. The amount of dissolved oxygen in water is not constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Ibe, 1993). Dissolved oxygen may be lower in dry season because of excessive organic load and higher in wet season because of the interaction of rain water with oxygen in the air as

it falls (Chia *et al*., 2008). Oxygen dissolve more easily at low altitude than high because of higher atmospheric pressure (Senese, 2005). Dissolved oxygen level below 5.0mg/L stresses aquatic life and fatal below 1-2mg/L (KYWWP, 2009). In rivers, dissolved oxygen distribution is important in the behavior, growth and distribution of aquatic organisms. Different organisms have different oxygen requirements and such dissolved oxygen concentration is an important factor which determines their distribution (Hawkes, 1975). Ball and Glucksman (1978), suggested wind circulation and conventional current created by local heating, may play a role in transporting high concentration of oxygen to the bottom of rivers.

Dissolved oxygen concentration in aquatic environment is a function of biological processes such as photosynthesis, respiration and physical processes such as diffusion, water movement and temperature (Goldman and Horne, 1983; Balarabe, 2001). Sudden and gradual depletion in dissolved oxygen can cause major shifts in populations of aquatic organisms from pollution in-tolerant species to pollution tolerant species (Chindah and Brailde, 2004).

2.5.4 Biochemical oxygen demand (BOD)

The Biological Oxygen Demand (BOD) is the amount of oxygen consumed by bacteria in the decomposition of organic material. It also includes the oxygen required for the oxidation of various chemical in the water, such as sulfides, ferrous iron and ammonia. BOD test tells how much oxygen is been consumed. Unpolluted, natural waters should have a BOD of 5mg/L or less. Raw sewage may have BOD levels ranges of 150-300mg/L (APHA, 1995). Five day biochemical oxygen demand (BOD_5) is a measure of

the amount of dissolved oxygen consumed by the decomposition of carbonaceous and nitrogenous matter in water over a period of five days.

The BOD test indicates the amount of oxidizable carbon and nitrogen that is present in waste water or in natural water. Matter containing carbon or nitrogen uses dissolved oxygen from the water as it decomposes, which can result in dissolved oxygen decline. According to Hach *et al*. (1990), measurement of BOD has long been the basic means of determining the degree of water pollution. Biological oxygen demand and chemical oxygen demand have been recognized as being specific chemical indicators of pollution and limits of 6mg/L and 10mg/L are set respectively by the World Health Organization as maximum allowable concentration in drinking water. However, the limit set for open aquatic habitat (streams, lakes and estuaries) are 40mg/L and 120mg/L respectively (Arienzo *et al*., 2000). While BOD is the amount of oxygen bacteria utilized from water on the oxidation of organic matter, COD measures the oxygen equivalent of the organic content of water sample that is susceptible to oxidation by chemical oxidants (APHA, 2002).

2.5.5 Total dissolved solids (T.D.S)

Total Dissolved Solids (TDS) are the dissolved organic and inorganic particulate matter in water. The total concentration of dissolved substances or minerals in the natural waters is a useful parameter in describing the chemical density as a fitness factor and as a general measure of edaphic relationship that contributes to productivity within the water body (Abolude, 2007). Total dissolved solid is affected by the total concentration of the major ions (both cations and anions) and their individual mobility in water (Beadle,

1974). Balarabe (2001), Abolude (2007) and Chia (2007) reported that electrical conductivity and concentration of the major ions increase with water depth. High penetrating concentrations of the inorganic ions and organic elements, fauna and flora fluctuation under autochthonous and allochthonous influence among others, cause remarkable changes in physicochemical and general biological characteristics of water, hence its quality for the purpose which it is intended (Hassan, 1998).

2.5.6 Electrical conductivity

Conductivity is the ability of water to receive and conduct electric current. It is an indicator of the number of inorganic ions present or dissolved in water or solution such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron and aluminium, which are almost proportional to the amount of dissolved matter. The presence of these substances increases the conductivity of a body of water. Lind (1979) explained that estimate of total matter in a solution or water body is related to its fertility. Electrical conductivity could be used to determine the potential yield of a water body (Ryder *et al*., 1974). At low level, Moss (1993) observed that major ions may determine the nature of fauna and flora. Electrical conductivity varies from time to time in aquatic systems within the same or different seasons (Akin-Oriola, 2003; Chindah and Brailde, 2004).

2.5.7 Water hardness

Water hardness is principally a measure of the quantity of calcium bicarbonate Ca $(HCO_3)_2$ dissolved in water. Hardness is frequently used as an assessment of the quality of water supplies. The hardness of water is governed by the content of calcium and magnesium salts (temporary hardness), when combine with bicarbonate and carbonate

and with sulphates, chlorides and other anions of minerals acids (permanent hardness) (Wetzel, 1983). Brown and Krygler, (1970), classified water hardness on the basis of concentration mg/L of $CaCO_3$ as 0 to 60 soft, 61 to 120 as moderately hard, 121 to 180 hard and 181 and above as very hard. Soft water has low buffering action while hard water has high buffering action (Seki, 1982). A much harder water sample will have more precipitation of toxic metals such as copper (Cu), Cadmium (Cd), Lead (Pb), and Chromium (Cr).

Generally, soft water is usually neutral to acidic while hard water is alkaline in nature. Inorganic salts which are present in non-industrial wastes causes water hardiness hard and make a stream or river undesirable for industrial, municipal and agricultural usage (Abolude, 2007). However soft water is generally less productive than hard water. Water hardness is higher during the dry season than the rainy season. This could be as a result of low water levels and the concentration of ions, and the lower rainy season value could be due to dilution. This agrees with the result of Kolo *et al*. (2004) for Shiroro Lake and Ufodike *et al.* (2001) for Dokowa mine lake.

2.5.8 Chloride

Chloride is the major halide in most freshwater algal cell. In most natural water, it combines with all common cations and dissociate as chloride ions (cole, 1979). Chloride ion is required by photosynthesizing cells for photolysis of water to release oxygen for A.T.P formation and for certain phosphorylation reaction (Goldsman and Horne, 1983). Chloride levels increase slightly below sewage discharges, although the levels produced

as a result of this does not cause serious effects on freshwater organisms (Templeton, 1995).

2.5.9 Nutrients

Nutrients are essential for survival, reproduction and growth of phytoplankton, and in an aquatic environment, it serves as bio-indicators (Welch,1992). Nutrients exist in the natural environment (water, soil and air) at all times and some of them are recycled naturally by decaying living organisms. Aqueous life depends on the availability of dissolved nitrogen and phosphorus. In tropical climates, high productivity is ensured in all seasons by efficient mixing of nutrients mediated by wind action. Frequent winds can induce interior regeneration and resuspension of nutrient pool (Cristofer *et al.,* 1994). The tropical status of a water body is the result of interaction of edaphic factors, morphologic features and climatic element. The rate at which nutrients are supplied may determine the rate of primary production (Valiela, 1991). Changes in nutrient regimes can have drastic effects on aquatic ecosystem (Butzler, 2002). Limiting nutrients such as nitrogen and phosphorus play a large role in determining the productivity of an aquatic system. This in turn, can affect the number of trophic levels in a food web and its stability (Kaunzinger and Morin, 1998), the abundance and composition of the species making up the community (Dodson *et al.*, 2000) and ecosystem functioning (Hooper *et al*., 1997). NRC (1998), Vitousek *et al.,* 1997) and Carpenter *et al*., (1998) submitted that because changes in the availability of nutrient can affect community properties. It is necessary to have a grasp of the role of nutrients within ecosystem to describe how natural communities assembly interact and function, as well as to apply this knowledge to address the cause, effect and reclamation of damages to ecosystem.

2.5.10 Phosphate-Phosphorus

Drainage from agricultural lands contribute large amount of phosphate to rivers (Mitchell, 1975). Phosphorus is often the limiting nutrient for plant growth, meaning it is in short supply relative to nitrogen. Phosphorus in most cases is the nutrient controlling maximum phytoplankton biomass (Vollenwelder, 1976). Phosphorus is often a limiting nutrient for plant growth; it is therefore in short supply relative to nitrogen. Russo (1978) reported that under anaerobic condition, some phosphates may be released from the sediments. Welch and Perkins, (1979) showed that the hypolimnetic oxygen correlates positively with phosphorus loading. OECD (1982) also reported a strong relationship between phosphorus loading and oxygen depletion. Phosphorus is one of the most common phytoplankton growth limiting factors. Dissolved phosphorus is the most important factor affecting water quality because it is needed for phytoplankton growth (Hossain, *et al*., 2006). The flux of phosphorus from the sediment is a significant source of phosphorus for phosphorus producers (Goldman and Horne, 1983).

2.5.11 Nitrate-nitrogen

Nitrogen is important to all life. Nitrogen occurs in natural waters in various forms, including nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3). Nitrate is the most common form tested. Test results are usually expressed as nitrate-nitrogen (NO_3-N), which simply means nitrogen in the form of nitrate. Ammonia is the least stable form of nitrogen and thus difficult to measure accurately. Nitrite is less stable and usually present in much lower amounts than nitrate. Comin *et al*. (1983), attributed increase in nitrate concentrations to input from agricultural land. High nitrate concentrations in streams was

similarly attributed to farmland drainage in areas of intense application of fertilizer (Hassan, 1998). Nitrates released in tropical waters come from sediments and the organism quickly use up continuous groundwater sources such that the dissolved nutrients water column pool is consistently small (Chindah and Brailde, 2004).

2.5.12 Ammonium-N

The three sources of nitrogen are urea, ammonium and nitrates. Ammonium is stable often obtain from the soil and air as a result of nitrification by nitrifying bacteria (Nitrosomonas and Nitrobacter) in the form of nitrogen. It is important for the synthesis of nitrogenous bases and chlorophyll. Ammonium may accumulate in the soil when nitrogen conversion is limited or stopped completely due to low soil pH conditions which substantially depress microbial ammonium oxidation, lack of oxygen especially in waterlogged soils and lack of organic matter source of carbon for bacteria among other factors (Mengel and Kirkby, 1987). Addition of ammonium as replacement for nitrates in substrate system can reduce the uptake of other cations like potassium, calcium and magnesium due to cation competition of ammonium and these cations (Sonneveld and Voogt, 2009).

2.5.13 Sulphates

In many natural waters, sulphate is the second most common anion derived from most sedimentary rocks. Sulphate concentration in drinking waters range from 5-50 mg/L. Drinking water with sulphate concentration greater than 250 mg SO_4 per liter may have cathartic action. Sulphates is the common form obtain from sulphur taken up by higher plants and algae. It is important for the synthesis of certain proteins in the protoplasm.

2.5.14 Alkali and alkaline earth metals

Calcium and magnesium are the two alkaline earth metals, which constitute the most abundant ions in freshwater bodies. The chemical activities of the elements are similar, particularly in the formation of carbonate salts and both may limit biological processes in streams or rivers (Reid, 1961). Calcium is important in biological productivity of water. It is a major constituent of the cell walls of aquatic plants and also the supporting structures of many animals such as bony fish, tissues of fish and shells of mollusks. It is considered a micronutrient for most algae, where it plays an important functional role in selective ion transport of the membranes (APHA, 1998).

Magnesium as an alkaline earth metal is a very important component of chlorophyll molecules (Reid, 1961). Magnesium like calcium is related to water hardness in the same manner. It is an important element required by plant for growth and development. Magnesium is needed for phosphate transfer by all cells involving adenosine triphosphate (ATP) and adenosine diphosphate (ADP) in every transfer reaction in living cells (Goldman and Horne, 1983).

Potassium is reported to originate naturally from the dissociation of evaporated salts and decomposition of silicates and therefore highly correlated with other cations and anions responsible for both water mineralization and conductivity (Zamora *et al*., 1995). Introduction of potassium ions as a result of artificial fertilizer has been reported in Makwaye Reservoir, Zaria (Balarabe, 1989) and Romi stream, Kaduna (Hassan, 1998). Specific water conductance in bicarbonate-dominated water bodies has been closely

proportional to the concentration of major cations; Calcium, Magnesium, and Sodium (Hassan, 1998).

2.5.15 Heavy metals

The effects of metals range from beneficial through troublesome to dangerously toxic. Some metals are essential; others adversely affect water consumers depending on their concentrations (APHA, 1995). Metals, including heavy metals/trace metals are required by living organisms for metabolic processes. At high concentration, however, these heavy metals are toxic to plants and animals. Chia (2007) explained that the release of these heavy metals from the sediments poses serious hazards to aquatic organisms, including algae. Many trace metals are regarded as serious pollutants of aquatic ecosystems because of their environment persistence, toxicity and ability to be incorporated into food chain phenomenon of bioaccumulation and biomagnifications. Various metals from industrial, agricultural, domestic and urban wastes may enter river or stream waters through leaching, run-off, effluents and dry deposition (Okoye *et al.*, 1991).

2.5.16 Biological monitoring

Chemical analyses alone, such as pH and concentrations of nutrients, metals, and toxic compounds, often underestimate and misdiagnose the sources of impairment, leading to costly and misdirected remediation efforts (Karr and Chu, 1999). Water chemistry analyses only determine levels of pollutants at the moment of sampling, and they neglect patterns of biodiversity and how interacting and temporally dynamic physico-chemical variables impact the structure and function of ecological communities. The biological components of stream ecosystems are valued attributes deemed important because they

are responsible for aforementioned ecosystem services, and they integrate the effects of multiple stressors, such as chemical pollutants, degradation of habitat, and nutrient loading (Barbour *et al*., 2000, Yuan and Norton, 2004).

Since toxic materials can directly and indirectly affect individuals, communities and ecosystems biological monitoring is better than other types of monitoring. It has a very valuable and interesting role to play in the monitoring of pollution and information obtained indicate the water quality status. Biological communities reflect the overall ecological integrity and thus provide a broad measure of the stressors aggregate impact and an ecological measure of fluctuating environmental conditions.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

River Galma is one of the largest river in Zaria used mostly for irrigation, fishing and domestic purposes in some surrounding villages like Kakeyi, Jushi, Dakachi in Sabon Gari Local Government Areas of Kaduna state. The River originates from Shere in the western edge of Jos Plateau state and flows into Shika dam joining Kubani river close to old Jos brigde Zaria and together pass through Magami into Kaduna plain. Zaria town is located on latitude 11^0 7.97^1N and longitude 7^0 45.59^1E (Figure 3.1). Land use is farming.

3.2 Study Design

Six sampling stations were established along River Galma (Figure 3.2). At each sampling station, three locations 200 m apart were selected to collect water samples and diatoms from available substrate. The rational for choosing the sampling sites was to obtain a pollution gradient due to land use pattern. The number and location of sampling sites were selected to provide representative samples, preferable where marked changes in water quality are likely to occur and also area with important rivers uses such as confluence and discharge points. Sampling station one was at the overflow upstream of the dam characterized by fishing, bathing and washing activities, station two was an area of intense agricultural activity and an outlet containing domestic waste and effluents from surrounding villages and Zaria water treatment plant, station three was characterized by

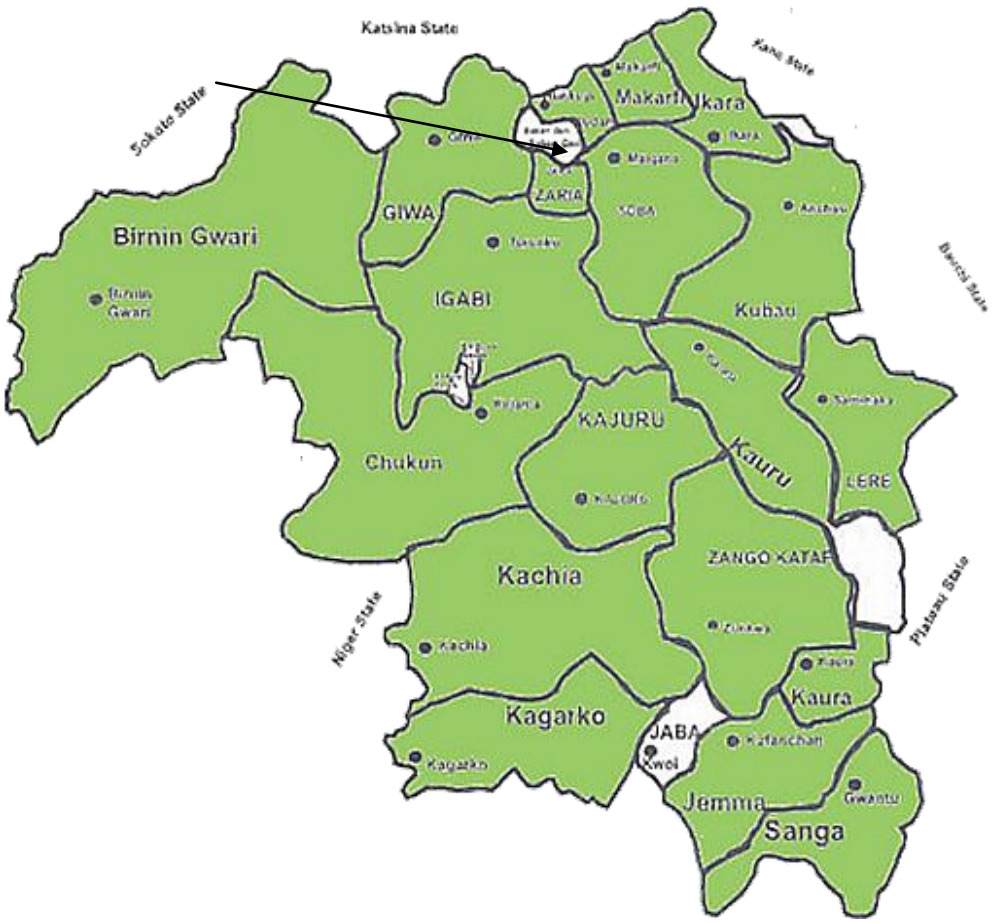


Figure 3.1: Location of the study area River Galma Sabon Gari Zaria Kaduna State

Source: Modified from Administrative Map of Kaduna State 2006.

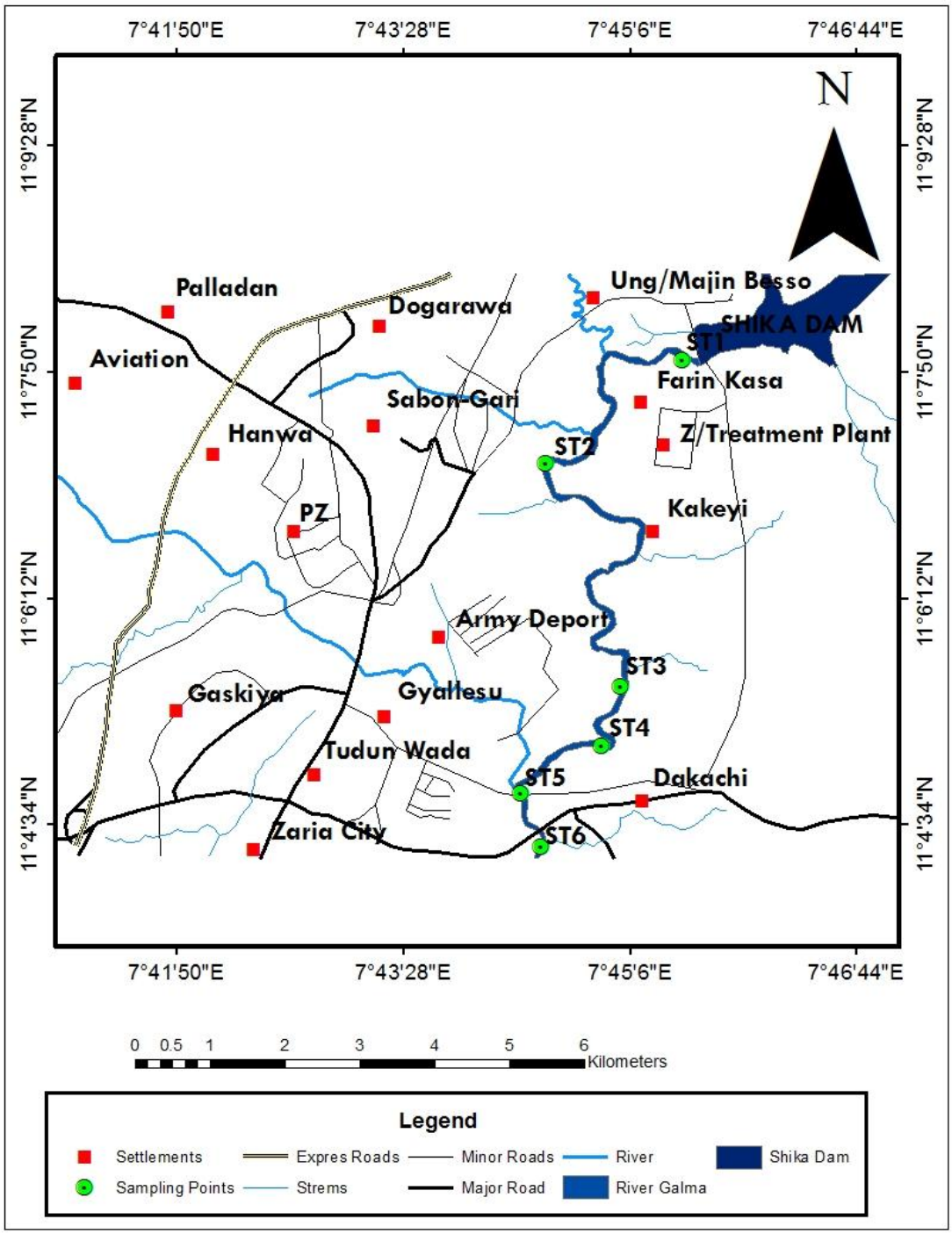


Figure 3.2: Location of sampling sites on a segment of River Galma

Source: Modified Zaria Map (2013).

constant disturbance of the water body because of the behive of anthropogenic activity such as buying, selling and washing of perishable vegetables such as tomatoes, carrots, onions,, paddling of canoe to cross people to and from their farms and workers of sunseed company, station four was another area characterized by high dry season farming, station five was the confluence between River Galma and Kubani near old Jos road and station six was the downstream characterized by sand mining near ungwan malami. Sampling was extended for an approximate distance of 12 Km to assess the quality of the water (CEN, 2003; Taylor *et al*., 2005). Sampling was done during the dry season (November 2012 to April 2013) to avoid variable effects of the rainy season like great variations in water level and velocity, flood and inundations, which affect periphytic diatom development, especially growth rate and relative abundance of species by washing them away thus decreased in abundance (Duong *et al*., 2006; Taurai and Tundisi, 2010).

3.3 Sampling Methods

Sampling was undertaken on a monthly interval following standard procedure of APHA (1998) from 6.00 am to 4.00 pm and this involved six sampling stations (with each sampling station having triplicate sampling points 200 m apart) from November 2012 to April 2013. 80 ml Plastic bottles were used to collect algal (diatom) samples for analysis. Samples for other physicochemical analysis were collected and stored in acid cleaned polyethylene bottles (1.5 L). 300 ml capacity bottles were used to collect water samples for BOD determination and fixed with 2 ml of manganous sulphate. Water samples were collected by dipping the plastic bottles to the sampling depth, then opening them up and

allowing them to be filled with water. They were then covered before removing from the depth of sampling. All samples for physicochemical analysis were either analyzed immediately or stored at room temperature until time for analysis. Samples for diatoms analysis were collected in 80-ml plastic bottles and fixed immediately with 2-3 drops of Lugol Iodine solution to precipitate and preserve diatoms (APHA, 1998). In the Laboratory, the treatment and cleaning of diatom samples followed (Biggs and Kilroy, 2000), APHA (1998) and standard protocol (Karthick *et al*., 2010) and identified following standard diatom literature.

3.4 Determination of Physicochemical Parameters

3.4.1 Temperature

Both air and water temperatures were determined with a calibrated mercury thermometer in degree Celsius (^{o}C) and Hannah portable meter model H1991300. Air temperature at each station was taken by holding the thermometer above the water for 5 minutes until it stabilized followed by lowering the thermometer into the water in an inclined position at a depth of 10 cm for 5 minutes to allow for equilibrium before recording. Water temperature was determined using Hannah multiparameter meter in degree Celsius in Hydrobiology Laboratory Department of Biological Sciences (DBS), A.B.U. Zaria.

3.4.2 pH determination

The portable HANNAH Multi parameter pH EC, TDS and temperature meter model H1991300 instrument was used to measure the pH in Hydrobiology Laboratory (DBS) by turning it on and inserting the probe first into distilled water as the standard and then into the water sample and reading taking when timer disappears.

3.4.3 Electrical conductivity

The electrical conductivity was determined using portable Hannah meter model H1991300 in microsiemens/centimeter (μS/cm) by placing the probe into the sample water and values recorded as the timer disappears in Hydrobiology Laboratory (DBS).

3.4.4 Total dissolved solids (T.D.S)

The total dissolved solids in water was determined using Hannan portable instrument by placing the probe into the sample water and values recorded in parts per million as the timer disappears in Hydrobiology Laboratory (DBS).

3.4.5 Water hardness

25 ml of water sample was diluted to 50 ml using distilled water. 2 ml of NH_4OH (Buffer), 2 drops of Eriochrome-black T were added and titrated against 0.01M Ethylenediaminetetraacetic acid (EDTA) till light blue coloration was observed.

3.4.6 Chloride

Chloride was determined by adding 2 drops of K_2crO_7 to 100 ml of the sample and titrated with silver nitrate ($AgNO_3$).

3.4.7 Nitrate-nitrogen

Nitrate-Nitrogen was determined using Phenoldisulphonic acid method described by Mackereth (1963). 100 ml of sample water was evaporated to dryness and cooled in a crucible. 2 ml of Phenol-disulphonic acid was added to the residue, followed by stirring the entire volume occupied by the sample to remove residue of nitrates on the walls of the crucible, followed by the addition of 15 ml of distilled water and 5 ml of strong ammonia

solution. The resultant yellow mixture was stirred timed for 10 minutes to cool. The spectrophotometer was set at the wavelength of 430 nm; absorbance of the treated sample was obtained from the scale against distilled water (used as a blank). Nitrate-nitrogen concentration was obtained from a calibration curve in mg/L (APHA, 1998).

3.4.8 Phosphate-phosphorus

Phosphate-phosphorus was determined using Deniges method (Mackereth, 1963; Lind, 1979). To 100 ml of water sample, 1 ml of ammonium molybdate (Deniges reagent) and 2 drops of stannous chloride solution were added. Absorbance was taken at 690 nm using spectrophotometer. Thus, PO_4-P concentration was obtained from a calibration curve in mg/L (APHA, 1998).

3.4.9 Sulphate

Sulphate was determined by adding 1 g of Barium chloride to 25 ml of the sample water in a conical flask and stirred with a magnetic stirrer for 1 minute. The stirrer was removed and the suspension was allowed to stand for 3 minutes followed by reading the absorbance on the spectrophotometer at a wavelength of 420 nm using distilled water as a blank. Sulphate concentration was obtained from the calibration curve in mg/L (APHA, 1998).

3.4.10 Dissolved oxygen (DO)

Dissolved oxygen was determined by Modified Winkler's Azide method (Lind, 1979; APHA, 1998). Water sample was collected from the sampling station in 300 ml Amber BODsampling bottles, filled to the neck and fixed immediately with 2 ml standard manganous sulphate solution followed by addition of 2 ml alkaline iodide-azide solution

and the content was stoppered to exclude air burbles and mixed by inverting the bottle for 10 seconds. 2 ml concentrated tetraoxosulphate (VI) acid was added to the sample and the stopper replaced immediately, to avoid air being trapped. The bottle was inverted again till the precipitate dissolved completely. 100 ml of the sample was transferred into 250 ml conical flask then titrated against standard (0.0124N) Sodium thiosulphate. As the color changed to pale yellow, 2 ml starch solution (indicator) was added and further titrated to end point (indicated by appearance of colorless solution from initial blue color). The volume of the thiosulphate used is equivalent to the milligram of the dissolved oxygen per liter.

3.4.11 Biological oxygen demand (BOD)

After the initial dissolved oxygen (DO_1) of water sample was determined by the modified Winkler's Azide method, water sample was incubated in 300 ml BOD bottles at 20 ^{o}C or in the dark for five days. Determination of DO_5 was carried out on the 5^{th} day on the incubated water sample following the procedure of dissolved oxygen determination. BOD (mg/L) was calculated as DO_1- DO_5 (mg/L).

Where,

DO_1 == Dissolved oxygen concentration prior to incubation

DO_5 = Dissolved oxygen concentration after 5 days incubation (APHA, 1998).

3.4.12 Calcium

Calcium was determined by measuring 50 ml of the sample water in a conical flask, 1-2 ml of NaOH was added to produce a pH of 13-14 followed by the addition of few drops of 0.2 g of Murexide. The solution was shaken and titrated with EDTA.

3.4.13 Magnesium

Magnesium concentration was calculated from the concentrations of both calcium and hardness (Rain and Thatcher, 1960). Milliequivalents of hardness per liter was calculated from milligrams of hardness per liter. The milliequivalents of calcium per liter was subtracted from this and the difference multiplied by the equivalent weight of magnesium. This give the magnesium in milligrams per liter as thus,

MEq hardness per liter = mg hardness per liter x 0.01998

MEq calcium ion per liter = Mg Ca^{2+} per liter x 0.0499

Mg $^{2+}$ per liter = 12.16 x (MEq hardness per liter – Meq Ca^{2+} per liter).

3.4.14 Metal analysis

Metals (Cadmium, Lead, Zinc, Cobalt and Copper) composition and concentration of the water samples collected from the river were determined using flame atomic absorption spectrophotometer (AAS) as thus, the ground state atoms in vapour state were first produced by spraying solution containing metallic elements into a flame of specific characteristics. The ground state atoms in the flame were excited by passing resonance radiation from an external light source through the flame. The instrument then measures the amount of light (resonance radiation) absorbed at a specific wavelength at the Multi user Chemistry Laboratory, Ahmadu Bello University, Zaria. The concentration of sodium, ammonium and potassium were determined as thus, solution containing some amount of metallic elements were sprayed into a flame of specific characteristics. The solution was transformed into vapour containing free excited atoms (in high energy state). The instrument then measures the photons emitted by the excited atoms as the fall

back to the ground state (lowest energy level) in Institute of Agricultural Research (IAR) Soil Science Laboratory A.B.U, Zaria by flame photometry.

3.4.15 Biological parameters

The biological parameters sampled were diatoms from stones (Epilithic), plants (Epiphytic), sand (Epipsamic) and mud or silt (Epipelic). Epilithic diatoms were collected by shaken the stones gently in the water to remove other sediments attached followed by brushing the stones with a toothbrush using distilled water to loose them. The whole content was transferred into a labeled 80 ml plastic bottle (Taurai and Tundisi, 2010).

Epiphytic diatoms were collected by cutting the leaves, roots or stem of submerged or emergent plant. Diatom samples was removed by brushing with a toothbrush or scrapping with a spoon using distilled water and the content transferred into a labeled 80 ml plastic bottle.

Epipsamic and Epipelic diatoms were collected by pressing a petri-dish lid into the top layer of sand, silt or clay to a depth of 5-7 mm, followed by sliding a spatula blade under the petri-dish to isolate the content in the petri-dish that was brought to the surface. Using spoon or straw, the diatoms were scrapped/scooped from the substrate and the content emptied into a labeled 80 ml plastic bottle. (Taurai and Tundisi, 2010)

3.4.16 Preservation of diatom sample

Diatom samples collected from the field was preserved using 2-3 drops of Lugol's Iodine solution for short term and Ethanol for long term duration respectively. Diatom sample to be processed within a few hours, do not necessary require preservative provided steps

are taken to minimize cell division by storing in cool, dark place. For short- term storage, the sample can be stored in refrigerator, or Lugol's iodine solution may be added. Lugol's iodine sublimes, and therefore unsuitable for long- term storage of diatom samples, for which ethanol is recommended. Ethanol should be added to reach a final concentration of 20 $^{0}/_{0}$ by volume. Formalin is a common preservative used for algal samples, it should be avoided as it is carcinogenic and it damages fine structure of diatoms (Krammer *et al.,* 2000). Reimann (1960) demonstrated that formalin even in extremely low concentration causes silicic acid to be released from diatom valves.

3.4.17 Cleaning of diatom samples

Diatom samples were cleaned using the bleach method. 15 ml of diatom samples were put into the centrifuge tubes and centrifuged for 30 minutes at 2500 rpm. Each diatom sample was decanted of the supernatant ensuring that no diatom cell was lost and filled with distilled water. The centrifuge process was repeated twice. The final centrifuged sample was decanted of the supernatant. 7 ml each of diatom sample and bleach were transferred into 50 ml conical flask and covered with foiled paper for 24 hours. After 24 hours, the mixture from each conical flask was transferred into the centrifuge tube, centrifuged for 15 minutes at 3000 rpm and decanted of supernatant to remove bleach and other organic matter. The process was repeated 4 times to obtain the desired final volume. The final (milky) cleaned diatom sample was transferred into a labeled sample bottle. Few drops of the cleaned diatom sample were introduced onto glass cover slips cleaned with alcohol and allowed to dry in a dust free environment. Dried cover slips were placed on a labeled glass slide and placed on a hot plate at 350 ^{0} C for 1 minute to do away with excess moisture. After the dried cover slips have cooled, 1-2 drops of zrax mountant was

placed onto each by means of a dropper. A previously cleaned labeled glass slide was lowered onto the cover slip, inverted, and then heated at 90-120 ^{0} C on a hot plate for 2-5 minutes (depending on the temperature and quality of the mountant) until the medium 'boils' and all the solvent evaporates. When the slide is cooled, surplus medium that has exuded and set round the edge of the cover-slip was removed with scalpel and wiped with a cleaned soft rag soaked in the mounting medium' s solvent (Toluene or xylene). The slides were labeled with sample details following Biggs and Kilroy (2000).

3.4.18 Counting and identification of diatom

Diatom biomass (number of cells per ml) was determined using the drop count technique as described by Bartram & Rees (2000). Frustules per slide were counted and identified to species level with the aid of reference texts such as Patrick and Reimer, 1966; Welhr and Shear. 2003; APHA (1998) under Zeiss phase contrast microscopic lens (x1000) and authors cited following Gell *et al*., (1999) and Mark (2012).

Conventional norms of frustules size, shape, and ornamentation were used to identify diatoms. The togetherness or separateness of the frustules determined the counts. Algae were enumerated and identified using the keys and illustrations according to Prescott (1977). The diversity of phytoplankton was expressed both as the number of species and the number of individuals (cells.m-3). The abundance of species was estimated by number of individuals and diversity was calculated using Shannon and Simpson's diversity indices (Margalef, 1978).

3.5 Statistical Analysis of Data

Descriptive statistics was used to calculate mean, Mean± Standard Error (SE) Standard deviation. One way analysis of variance (ANOVA) was used to compare means amongst the sampling sites over the study period. Significantly different means was separated using the Tukey's HSD post HOC Test. Pearson Coefficient correlation was used to determine relationship between biological and physicochemical parameters. Percentage was used to calculate periphyton abundance.

Canonical Correspondence analysis [CCA] (Ter Braak, 1986) was used to investigate the relationships between water quality variables and Periphyton assemblages. Simpson and Shannon diversity indices were used to determine diversity of periphyton. All statistical analysis was carried out using Microsoft office Excell version 21 at $95^0/_0$ confidence limit.

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-Chemical Parameters

Twenty two (22) different physicochemical parameters were measured and analysed based on one way analysis of variance (ANOVA), Duncan's Multiple Range Test (DMRT) using Statistical application for sciences(SAS) and Rank correlation analysis, Principal component Analysis (PCA), Canonical correspondence analysis (CCA) and graphic representations. Results of analyses revealed a wide range of variations in the Biophysicochemical parameters. Mean values of physicochemical parameters were each compared with World health organization standards for drinking water to know if they are within or above the permissible limit. The periphytic diatom species composition and diversity is related to water quality status.

4.1.1 Biochemical oxygen demand

The mean monthly Biochemical oxygen demand (BOD) varied between months ranging from 0.23±0.02 to 5.32±1.15mg/L with the lowest 0.23±0.02mg/L in December and highest 5.32±1.15mg/L in January. Analysis of variance (ANOVA) showed that BOD values were highly significantly ($p<0.01$) between months (Table 4.1). Among Stations, it varied slightly from 1.64±0.41to 3.84±1.42mg/L with lowest in Station 1 and highest in Station 5 respectively. ANOVA (Table 4.2) indicated no significant difference between stations. Figure 4.1 showed the trend between Months and stations.

4.1.2 Dissolved oxygen

Dissolved oxygen showed a mean monthly variation between months with the lowest of 3.60±0.12 mg/L in February and the highest of 8.49±0.59mg/L in January. ANOVA showed a highly significant difference between months (Table 4.1). It ranged from 5.45±0.60 to 6.55±0.99mg/L respectively among Stations with the lowest in station 1 and highest in Station 5. ANOVA (Table 4.2) showed no significant difference ($p>0.05$) between stations. Figure 4.2 showed the trend between Months and stations.

4.1.3 Electrical conductivity

The mean monthly electrical conductivity varied from 94.88±7.30 to 258±60.56 µS/cm with the lowest (94.88±7.30 µS/cm) in November and the highest (258±60.56µS/cm) in March with a mean of 175.34 ± 16.04µS/cm. ANOVA (Table 4.1) indicated a highly significant difference in months. It also ranged from 105.72 to 244.55µS/cm among Stations with the highest (244.55µS/cm) in Station 5 and lowest (105.72µS/cm) in Station 1 and mean ± standard error of 175.34 ± 16.04µS/cm (Table 4.2). ANOVA revealed no significant difference between stations. Figure 4.3 showed the trend between Months and stations.

4.1.4 Water pH

The values for pH varied from 6.95±0.09 to 7.53±0.06 with the lowest 6.95±0.09 in January and the highest 7.53±0.06 in the month of April with mean of 7.24 ± 0.09. ANOVA (Table 4.1) showed a highly significant difference within months. Among Stations, pH varied from 7.11±0.08 to 7.45±0.13 with the lowest 7.11±0.08 in Station 6 and highest (7.45±0.13) in Station 1.

Table 4.1: Mean Monthly Variation of Physico-chemical Parameters of River Galma from November, 2012 – April, 2013

Physicochemical Parameters	Months						Total	P value	WHO STD
	November	December	January	February	March	April			
BOD (mg/L)	3.13±0.59^{b}	0.23±0.02^{c}	5.32±1.15^{a}	1.60±0.19^{bc}	3.23±0.72^{b}	3.19±0.38^{b}	2.78±0.36	0.000**	5
DO (mg/L)	6.94±0.32^{b}	6.44±0.39^{b}	8.49±0.59^{a}	3.60±0.12^{c}	5.75±0.61^{b}	5.78±0.14^{b}	6.17±0.29	0.000**	5
EC (µS/cm)	94.88±7.30^{c}	106.83±4.36^{c}	236.00±34.46^{ab}	194.00±34.67^{ab}	258.00±60.56^{a}	162.33±15.19^{bc}	175.34±16.04	0.005**	300
pH	7.34±0.11^{a}	7.33±0.06^{a}	6.95±0.09^{b}	6.98±0.09^{b}	7.32±0.10^{a}	7.53±0.06^{a}	7.24±0.04	0.000**	6.5-8.5
TDS (mg/L)	48.54±2.26^{d}	53.28±2.14^{d}	122.17±23.75^{ab}	97.17±17.62^{bc}	145.00±23.92^{a}	81.63±7.63^{cd}	91.30±8.40	0.001**	200
Temperature Laboratory.(ºC)	23.68±1.15^{a}	27.17±0.44^{a}	26.79±0.04^{a}	27.22±0.15^{a}	30.67±0.07^{a}	29.33±0.08^{a}	27.40±0.42	0.000**	23-35
Temperature Field(ºC)	25.12±0.36^{abc}	24.93±0.47^{bc}	25.88±1.07^{abc}	23.50±0.56^{c}	26.67±1.23^{ab}	27.60±0.93^{a}	25.62±0.39	0.028*	23-35
Hardness (mg/L)	37.54±0.54^{c}	45.33±2.82^{bc}	46.87±5.68^{bc}	57.53±4.81^{b}	52.67±5.31^{b}	80.67±3.33^{a}	53.43±2.79	0.000**	300

Means with same superscript on the same row are not significantly different**.**
Key: BOD = Biochemical Oxygen Demand, DO = Dissolved Oxygen, EC = Electrical Conductivity, pH = Hydrogen ion Concentration, TDS =Total Dissolved Solids. WHO STD = World Health Organization Standard. ** = Highly significant ($p<0.01$), * = significant ($p<0.05$).

Table 4.2: Mean Station Variation of Physico-chemical Parameter of a segment of River Galma from November, 2012 - April 2013

Physicochemical Parameters	Stations						Total	P value	WHO STD
	1	2	3	4	5	6			
BOD (mg/L)	1.64±0.41^{b}	2.31±0.58^{ab}	2.50±0.71^{ab}	2.93±0.93^{ab}	3.83±1.42^{a}	3.49±0.90^{ab}	**2.78±0.36**	0.541ns	5
DO (mg/L)	6.25±7.89^{a}	6.25±0.62^{a}	5.45±0.60^{a}	6.04±0.78^{a}	6.55±0.99^{a}	6.47±0.72^{a}	**6.17±0.29**	0.923ns	5
EC (µS/cm)	105.72±8.78^{b}	109.55±4.59^{b}	186.28±29.43^{a}	206.83±39.94^{a}	244.55±64.79^{a}	199.12±30.24^{a}	**175.34±16.04**	0.057ns	300
pH	7.45±0.13^{a}	7.25±0.14^{abc}	7.18±0.10^{bc}	7.11±0.08^{c}	7.35±0.09^{ab}	7.12±0.14^{bc}	**7.24±0.05**	0.269ns	6.5-8.5
TDS (mg/L)	56.72±8.16^{c}	61.45±8.48^{c}	92.45±14.76^{bc}	103.67±20.18^{ab}	134.17±33.82^{a}	99.33±15.02^{ab}	**91.30±8.40**	0.067ns	200
Temperature Lab. (ºC)	28.19±0.63^{a}	28.18±0.66^{a}	27.06±1.24^{a}	26.92±1.41^{a}	26.76±1.28^{a}	67.75±0.98^{a}	**27.40±0.42**	0.864ns	23-35
Temperature Field (ºC)	26.00±1.13^{a}	25.30±1.06^{a}	24.43±0.74^{a}	24.97±0.50^{a}	26.00±1.04^{a}	27.00±1.07^{a}	**25.62±0.39**	0.485ns	23-35
Hardness (mg/L)	44.65±7.65^{a}	47.31±5.32^{a}	52.67±5.41^{a}	60.00±6.37^{a}	58.40±6.91^{a}	57.58±9.08^{a}	**53.43±2.79**	0.534ns	300

Means with same superscript on the same row are not significantly different

Key: BOD = Biochemical Oxygen Demand, DO = Dissolved Oxygen, EC = Electrical Conductivity, pH = Hydrogen ion Concentration, TDS = Total Dissolved Solids, Temperature Lab = Temperature Laboratory, WHO STD = World Health Organization Standard. Ns = Not significant ($p > 0.05$), ** = highly significant ($p<0.01$), * = significant ($p< 0.05$).

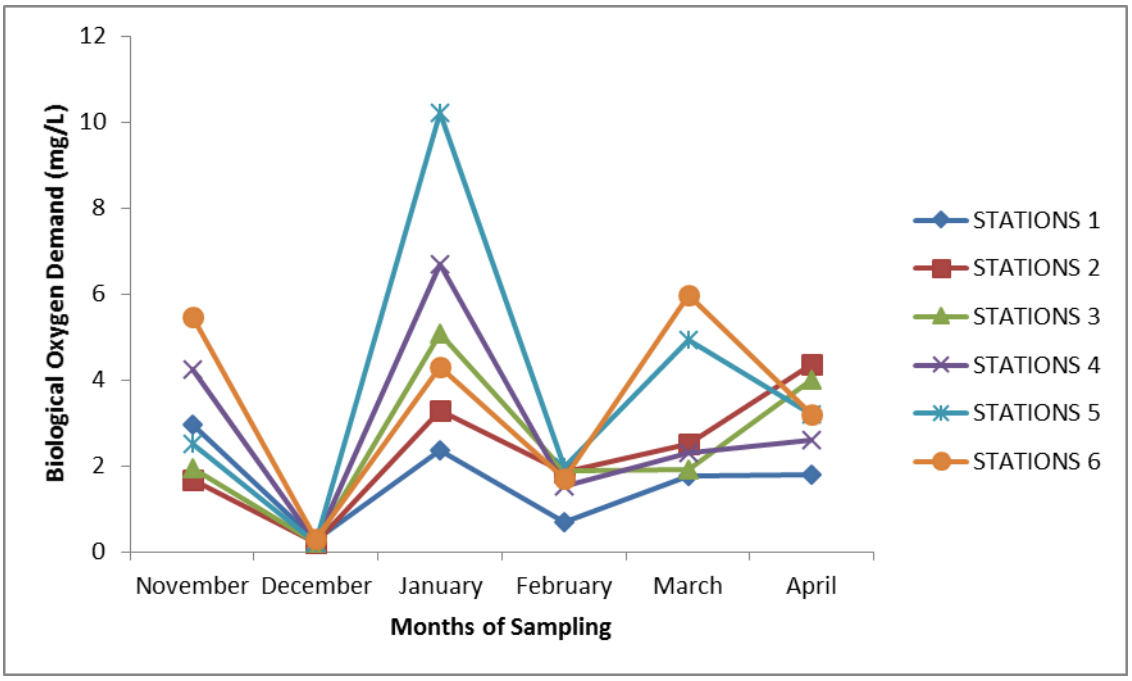


Figure 4.1: Monthly Stations Variations of Biological Oxygen Demand

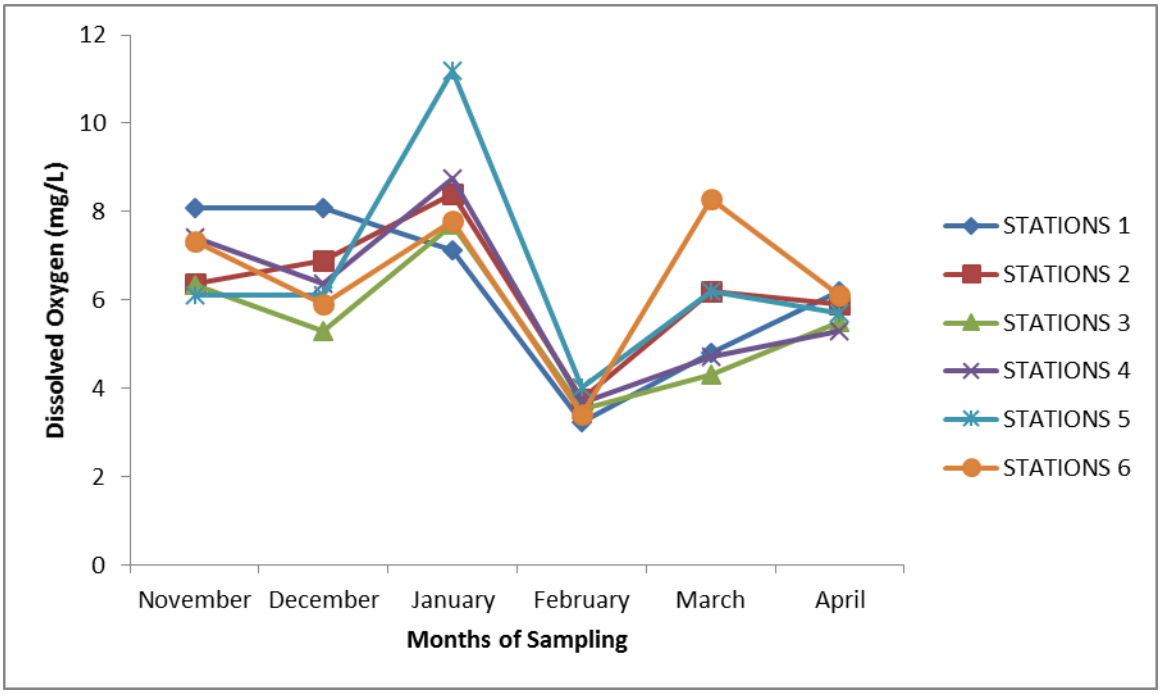


Figure 4.2: Monthly Stations Variations of Dissolved Oxygen

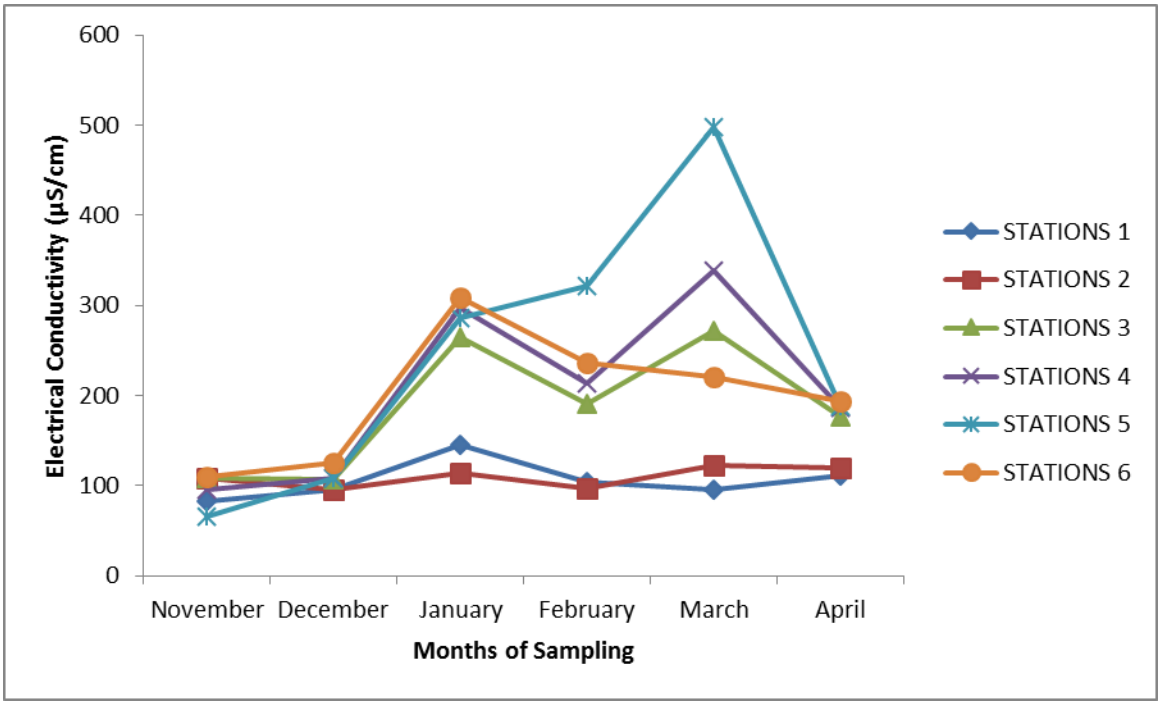


Figure 4.3: Monthly Stations Variations of Electrical Conductivity

Analysis of variance (Table 4.2) showed no significant difference in stations. Figure 4.4 showed the trend between Months and stations.

4.1.5 Total dissolved solids

Mean monthly values of total dissolved solids varied from 48.54±2.26 to 145.00±23.92mg/L with the lowest 48.54±2.26 in November and highest 145.00 ±23.92 in March and a mean of 91.30±8.40mg/L. ANOVA (Table 4.1) indicated a highly significant difference ($p<0.01$) between months. It ranged from 56.72± to 134.17±mg/L among Stations respectively with the lowest in Station 1 and highest in Station 5 ANOVA (Table 4.2) showed no significant difference stations ($p>0.05$). Figure 4.5 showed the trend between Months and stations.

4.1.6 Water temperature

Mean monthly temperature varied from 23.68±1.15 to 30.67±0.07^{0}C with the lowest 23.68±1.15^{0}C in November and highest 30.67±0.07 ^{0}C in March and a mean of 34.14±6.69ºC. ANOVA (Table 4.1) showed a highly significant difference ($p<0.01$) within months. Among Stations, it ranged from 26.76±1.28 to27.75±0.98ºC with the lowest in station 4 and highest in station 6 respectively. ANOVA (Table 4.2) revealed no significant difference between stations. Figure4.6 showed the trend between Months and stations.

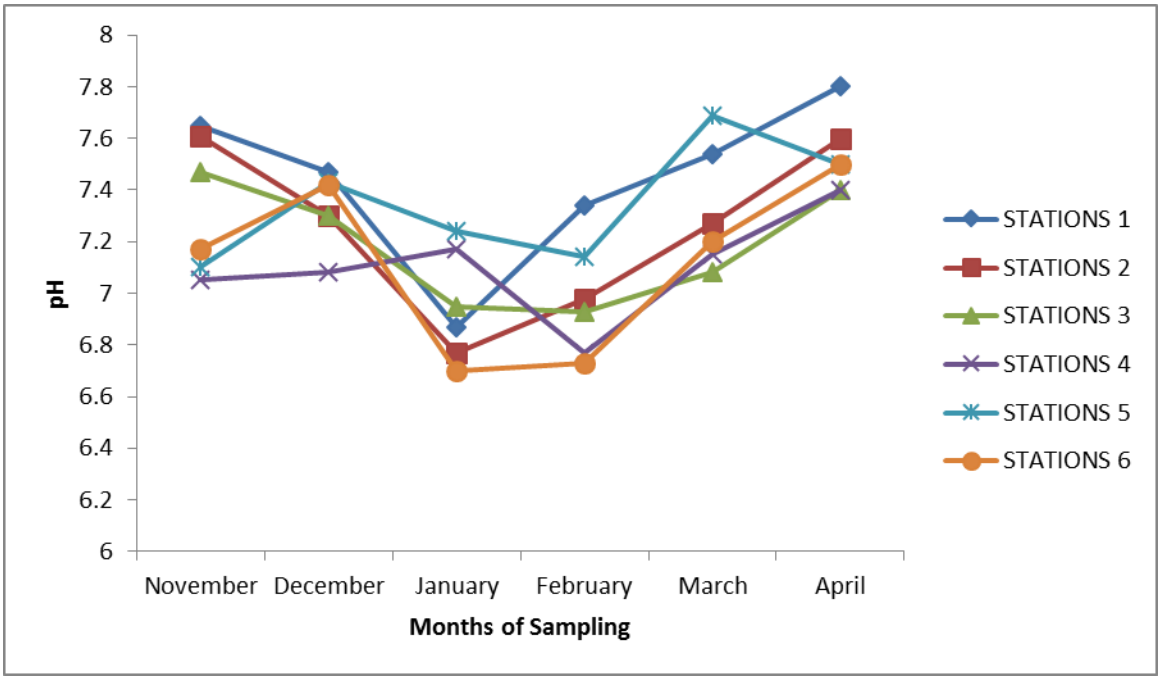


Figure 4.4 Monthly Stations Variations of pH

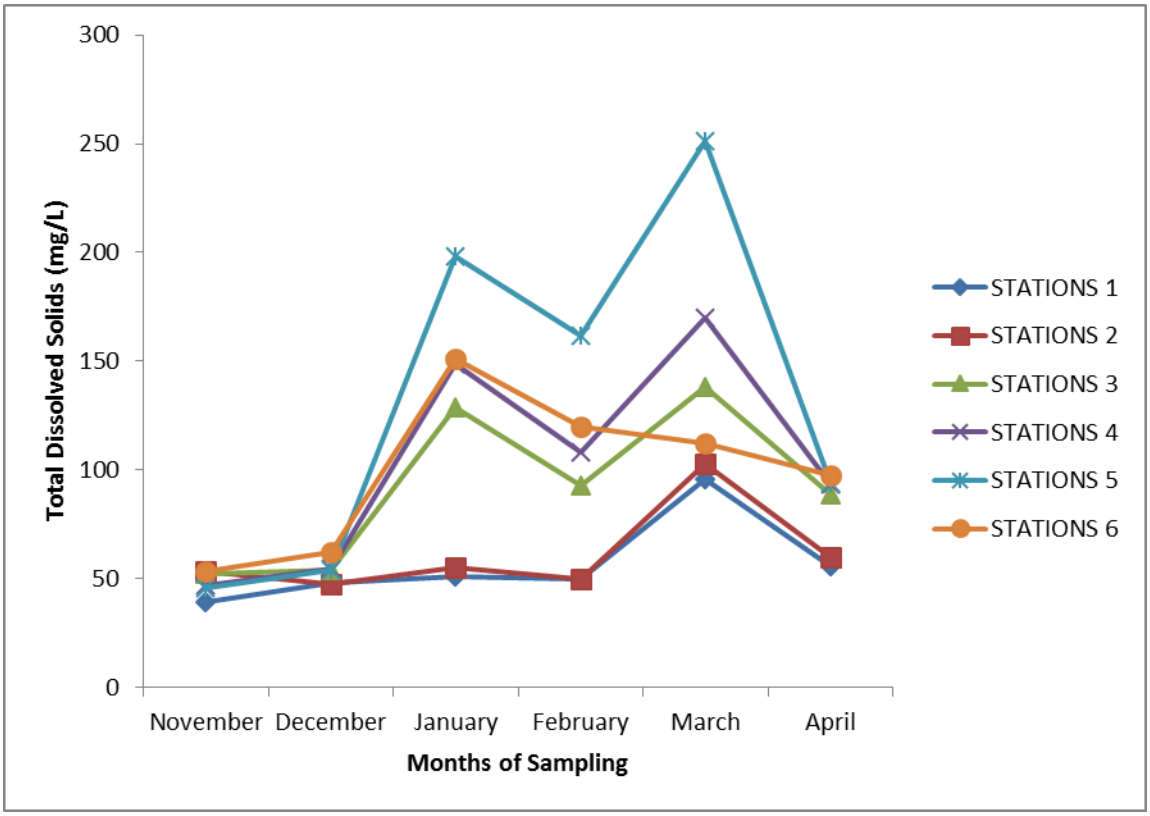


Figure 4.5: Monthly Stations Variations of Total Dissolved Solids

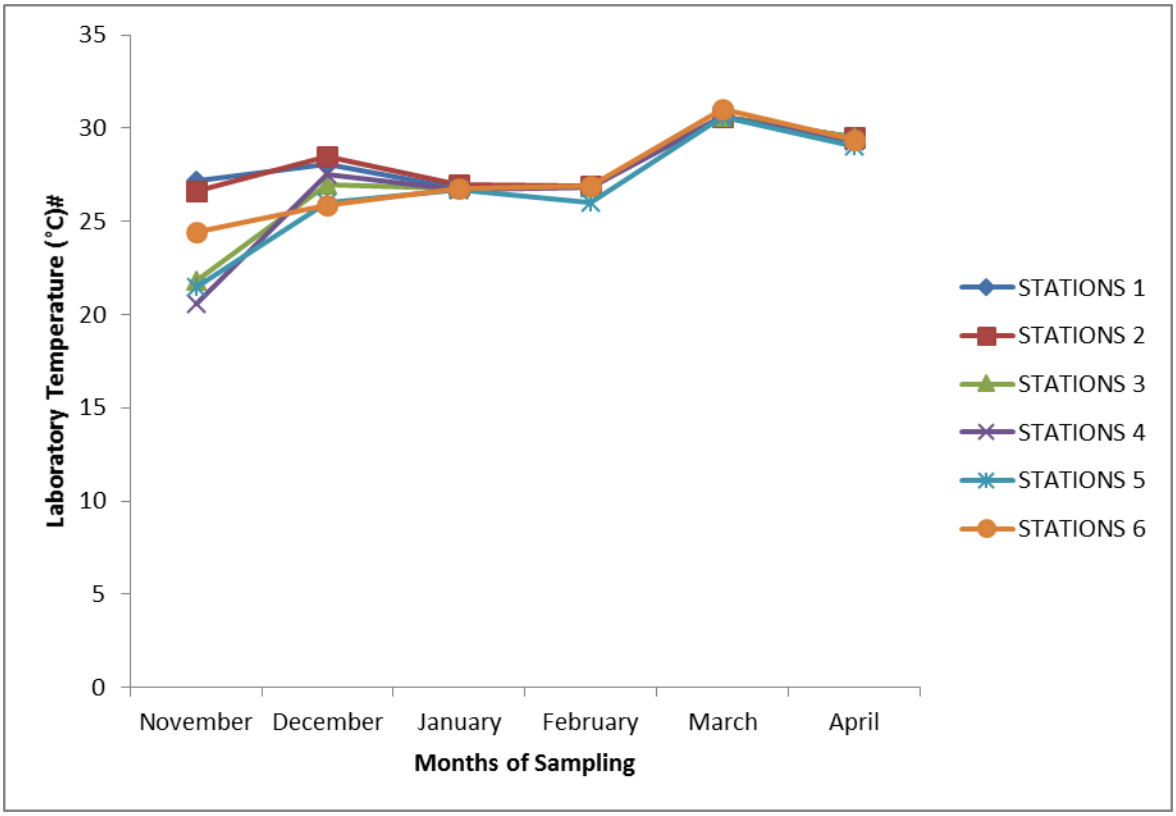


Figure 4.6: Monthly Stations Variations of Water Temperature

4.1.7 Air temperature

The mean monthly air temperature varied from 23.5±0.56 to 27.6±0.93ºC with the lowest 23.5±0.56 in January and highest 27.6±0.93ºC in April and a mean of 25.62 ± 0.39ºC. ANOVA (Table 4.1) indicated a highly significant difference among months whereas in stations, it ranged from 24.43±0.74 to 27±1.07ºC with the lowest in station 2 and highest in station 1 respectively. ANOVA (Table 4.2) showed no significant difference between stations. Figure 4.7 showed the trend between Months and stations.

4.1.8 Hardness

The mean monthly values varied from 37.54±0.54 to 80.67±3.33mg/L with the lowest 37.54±0.54 in November and highest 80.67±3.33mg/L in April and mean of 53.42 ± 2.79mg/L. ANOVA (Table 4.1) showed a highly significant difference ($p<0.01$) between months. Among Stations, it varied from 44.65±07.65 to 60.00±6,37mg/L with lowest in Station 1 and highest in station 4 respectively. ANOVA (Table 4.2) showed no significant difference between stations. Figure 4.8 showed the trend between Months and stations.

4.2 Alkali and Alkaline Earth Metals (Cations)

4.2.1 Calcium, magnesium, potassium and sodium

Calcium showed a mean monthly concentration of 0.99±0.10 to 1.98±0.19mg/L with the lowest of 0.99±0.10mg/L in November and highest 1.98±0.19mg/L in December and a mean of 1.84 ± 0.33mg/L. ANOVA (Table 4.1) indicated no significant difference

between months. It ranged from 1.07±2.00 to 2.01±0.31mg/L among stations with the lowest in station 1 and highest in station 5 respectively.

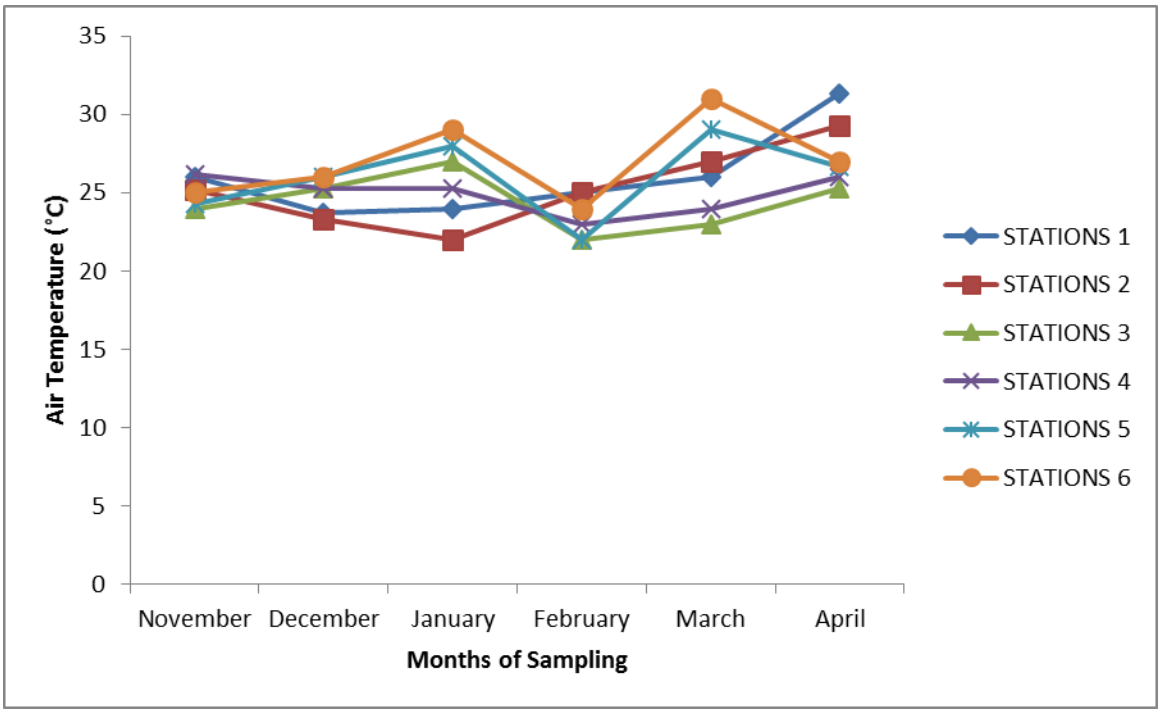


Figure 4.7: Monthly Stations Variations of Air Temperature

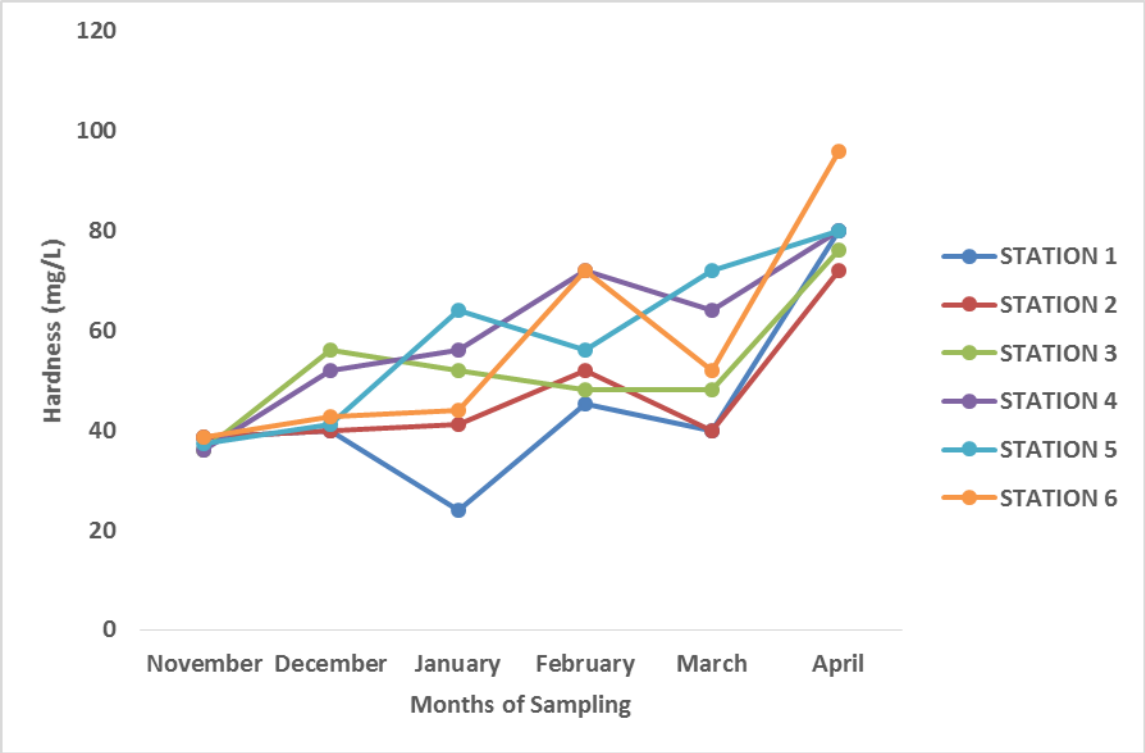


Figure 4.8: Monthly Stations Variations of Hardness

Analysis of variance (Table 4.2) showed no significant difference between stations. Figure 4.9 showed the trend between Months and stations.

Magnesium showed a mean monthly variation of 86.41±1.38 to 186.41±7.86 mg/L with the lowest 86.41±1.38mg/L in November and highest 186.41±7.86mg/L in April and a mean of 120.93±6.86 mg/L. ANOVA (Table 4.3) showed a highly significant difference within month. The concentration varied from 93.85±21.74 to 138.21±14.58 mg/L among stations with the lowest concentration in station 1 and highest in station 4 respectively. ANOVA (Table 4.4) showed no significant difference between stations. Figure 4.10 showed the trend between Months and stations.

Potassium concentration varied from 3.38±0.14 to 6.35±1.83mg/L with the lowest 3.38±0.14mg/L in January and highest 3.38±0.14 in March and a mean of 4.40 ± 0.35mg/L (Table 4.3.). In stations, it varied from 3.27±0.13 to 6.19±0.37mg/L with the lowest in station 2 and highest in station 5 respectively. ANOVA (Table 4.4) indicated no significant difference between stations. Figure 4.11 showed the trend between Months and stations.

Sodium indicated a mean monthly variation of 8.34±0.39 to 46.58±10.92mg/L with the lowest 8.34±0.39 in January and highest 46.58±10.92mg/L in March and a mean of 20.51 ± 2.94mg/L. ANOVA (Table 4.3) showed a highly significant difference between months. It varied from 12.61±2.34 to 28.63±12.48mg/L among stations with lowest in station 2 and highest in station 5 respectively. ANOVA (Table 4.4) showed no significant difference between stations. Figure 4.12 showed the trend between Months and stations.

Table 4.3: Mean Monthly Variation of Physico-chemical Parameters of River Galma from November 2012- April 2013

Physicochemical Parameters	Months						Total	P value	WHO STD
	November	December	January	February	March	April			
Calcium (mg/L)	0.99±0.10^{c}	1.48±1.92^{abc}	1.26±0.23^{bc}	1.64±0.19^{ab}	1.72±0.30^{ab}	1.98±0.19^{a}	1.84±0.33	0.364ns	75
Magnesium (mg/L)	86.41±1.38^{d}	93.49±13.46^{cd}	107.78±12.95^{bcd}	131.83±11.35^{b}	119.65±11.47^{bc}	186.41±7.86^{a}	120.93±6.86	0.000**	50
Potassium (mg/L)	3.44±0.14^{b}	3.45±0.11^{b}	3.38±0.14^{b}	5.24±0.43^{ab}	6.35±1.83^{a}	4.58±0.38^{ab}	4.40±0.35	0.062ns	12
Sodium (mg/L)	8.78±0.47^{c}	8.53±0.0.33^{c}	8.34±0.0.39^{c}	24.00±0.2.28^{b}	46.58±10.92^{a}	26.83±2.57^{b}	20.51±2.94	0.000**	50
Ammonium-N (mg/L)	18.67±2.58^{ab}	25.20±4.57^{a}	25.25±4.56^{a}	9.46±1.43^{c}	15.50±1.28^{bc}	11.13±1.29^{bc}	17.53±1.54	0.002**	NA
Chloride (mg/L)	29.83±1.10^{b}	28.55±1.07^{b}	58.05±11.74^{a}	54.28±10.52^{a}	64.50±11.94^{a}	33.67±3.27^{b}	40.45±3.59	0.104ns	250
Phosphate-Phosphorus(mg/L)	4.84±3.09^{a}	1.37±0.11^{ab}	0.88±0.20^{b}	1.06±0.19^{ab}	0.89±0.45^{b}	1.67±0.22^{ab}	1.78±0.54	0.248ns	≤75
Sulphate(mg/L)	152.12±26.41^{ab}	124.78±9.68^{bc}	79.70±17.61^{c}	198.62±12.55^{a}	133.28±23.62^{bc}	161.65±17.84^{ab}	141.69±9.42	0.004**	200
Nitrate-Nitrogen(mg/L)	12.34±1.42^{c}	8.88±0.87^{c}	10.05±0.61^{c}	30.21±3.40^{a}	33.72±3.50^{a}	21.94±2.64^{b}	19.52±1.88	0.000**	45
Cadmium(mg/L)	0.01±0.00^{b}	0.02±0.00^{a}	0.00±0.01^{e}	0.01±0.01^{d}	0.01±0.00^{d}	0.01±0.00^{c}	4.05±4.03	0.435ns	0.003
Cobalt(mg/L)	0.00±0.00^{c}	0.00±0.01^{c}	0.06±0.01^{a}	0.06±0.01^{a}	0.04±0.01^{b}	0.02±0.12^{b}	0.04±0.01	0.000**	NA
Copper(mg/L)	0.03±0.01^{b}	0.04±0.07^{a}	0.01±0.00^{c}	0.02±0.01^{c}	0.02±0.00^{c}	0.01±0.02^{c}	0.03±0.01	0.135ns	2
Lead(mg/L)	0.13±0.01^{b}	0.19±0.01^{a}	0.10±0.01^{c}	0.12±0.00^{b}	0.14±0.05^{b}	0.13±0.01^{b}	0.14±0.01	0.024*	0.01
Zinc(mg/L)	0.04±0.02^{a}	001±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.01^{b}	0.00±0.00^{b}	0.01±0.00	0.002**	3

Means with the same superscript on the same row are not significantly different.
Key: WHO STD = World Health Organization Standard. NA = Not Available, ns = Not significant (p> 0.05), 0.00 = Not detected, ** = Highly significant (p<0.01), * = significant (p< 0.05).

Table 4.4: Mean Station Variation of Physico-chemical Parameter of a Segment of River Galma from November 2012- April 2013

Physicochemical Parameters	Stations						Total	P value	WHO STD
	1	2	3	4	5	6			
Ammonium-N (mg/L)	18.83±4.25^{ab}	16.04±2.80^{ab}	13.83±1.43^{b}	17.67±3.53^{ab}	24.54±6.49^{a}	14.29±1.31^{b}	**17.53±1.54**	0.381ns	NA
Cadmium (mg/L)	0.01±0.01^{c}	0.01±0.01^{bc}	0.01±0.01^{abc}	0.01±0.01^{abc}	0.01±0.01^{abc}	0.01±0.01^{a}	**4.05±4.03**	0.435ns	0.003
Calcium (mg/L)	1.07±2.00^{c}	1.32±0.10^{bc}	1.61±0.17^{ab}	1.55±0.23^{abc}	2.01±0.31^{a}	1.52±0.26^{abc}	**1.84±0.33**	0.741ns	75
Chloride (mg/L)	25.78±0.82^{c}	25.41±1.07^{c}	44.10±6.15^{bc}	50.38±9.66^{ab}	50.87±14.69^{a}	46.23±7.22^{ab}	**40.45±3.59**	0.095ns	250
Cobalt (mg/L)	0.05±0.01^{a}	0.06±0.01^{a}	0.03±0.01^{ab}	0.04±0.01^{ab}	0.02±0.01^{ab}	0.03±0.01^{ab}	**0.04±0.00**	0.491ns	NA
Copper (mg/L)	0.02±0.00^{a}	0.02±0.00^{a}	0.02±0.01^{a}	0.02±0.01^{a}	0.02±0.07^{a}	0.02±0.01^{a}	**0.03±0.01**	0.561ns	2
Lead (mg/L)	0.13±0.01^{a}	0.12±0.01^{a}	0.14±0.02^{a}	0.14±0.01^{a}	0.14±0.02^{a}	0.14±0.06^{a}	**0.14±0.01**	0.523ns	0.01
Magnesium (mg/L)	93.85±21.74^{a}	108.60±12.78^{a}	120.18±12.40^{a}	138.21±14.58^{a}	132.18±15.51^{a}	132.54±21.11^{a}	**120.93±6.86**	**0.419ns**	50
Nitrate (mg/L)	21.12±3.97^{a}	16.86±3.48^{a}	17.72±4.06^{a}	19.45±6.00^{a}	19.59±5.16^{a}	22.12±6.17^{a}	**19.52±1.88**	0.971ns	45
Phosphate-Phosphorus (mg/L)	5.10±3.05^{a}	1.46±0.12^{b}	1.03±0.22^{b}	1.06±0.26^{b}	1.02±0.25^{b}	1.02±0.29^{b}	**1.78±0.54**	0.172ns	675
Potassium (mg/L)	3.41±0.15^{b}	3.27±0.13^{b}	4.43±0.63^{ab}	4.64±1.81^{ab}	6.19±0.37^{a}	4.49±0.37^{ab}	**4.40±0.35**	0.185ns	12
Sodium (mg/L)	12.61±2.34^{b}	13.05±2.32^{b}	21.32±6.70^{ab}	25.06±8.70^{ab}	28.63±12.48^{a}	22.40±5.88^{ab}	**20.51±2.94**	0.573ns	50
Sulphate (mg/L)	141.38±25.51^{a}	171.38±31.00^{a}	112.77±19.57^{a}	129.72±24.09^{a}	143.13±20.86^{a}	151.77±17.93^{a}	**141.69±9.42**	0.622ns	200
Zinc (mg/L)	0.01±0.01^{a}	0.01±0.01^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.01^{a}	0.02±0.02^{a}	**0.01±0.00**	0.734ns	3

Means with the same superscipt on the same row are not significantly different.

Key:WHO STD = World Health Organization Standard, ns = Not significant.

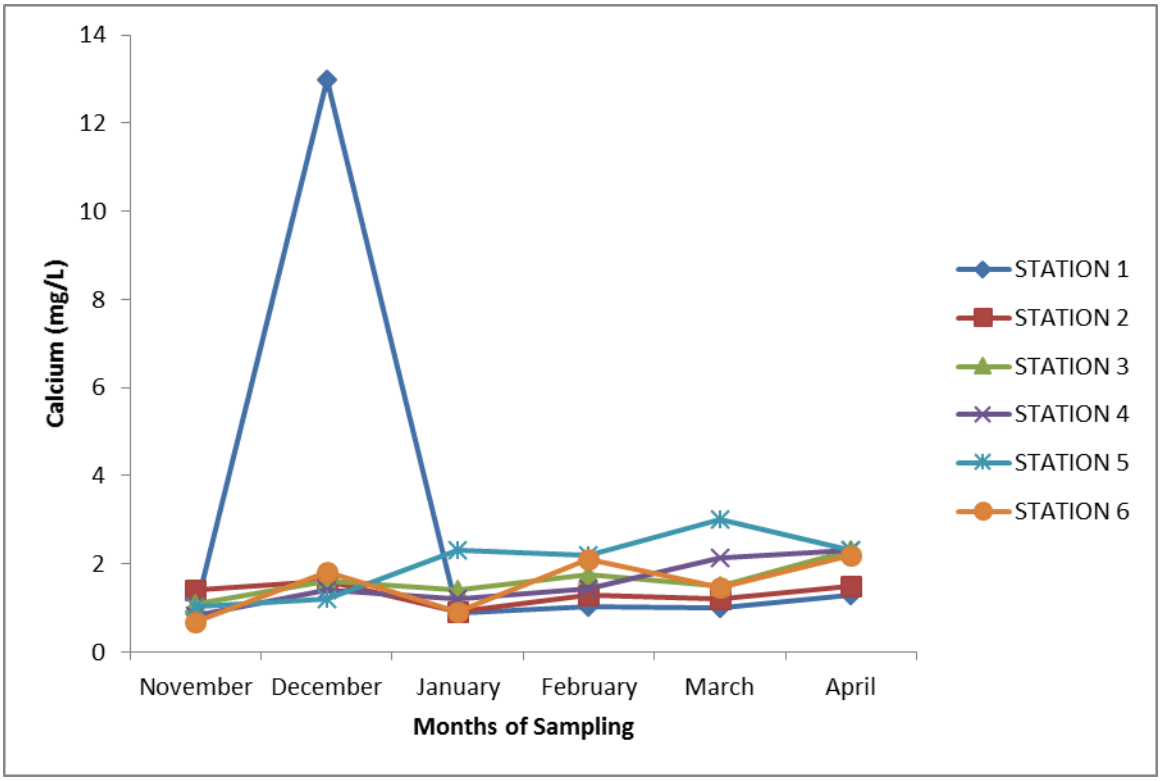


Figure 4.9: Monthly Stations Variations of Calcium

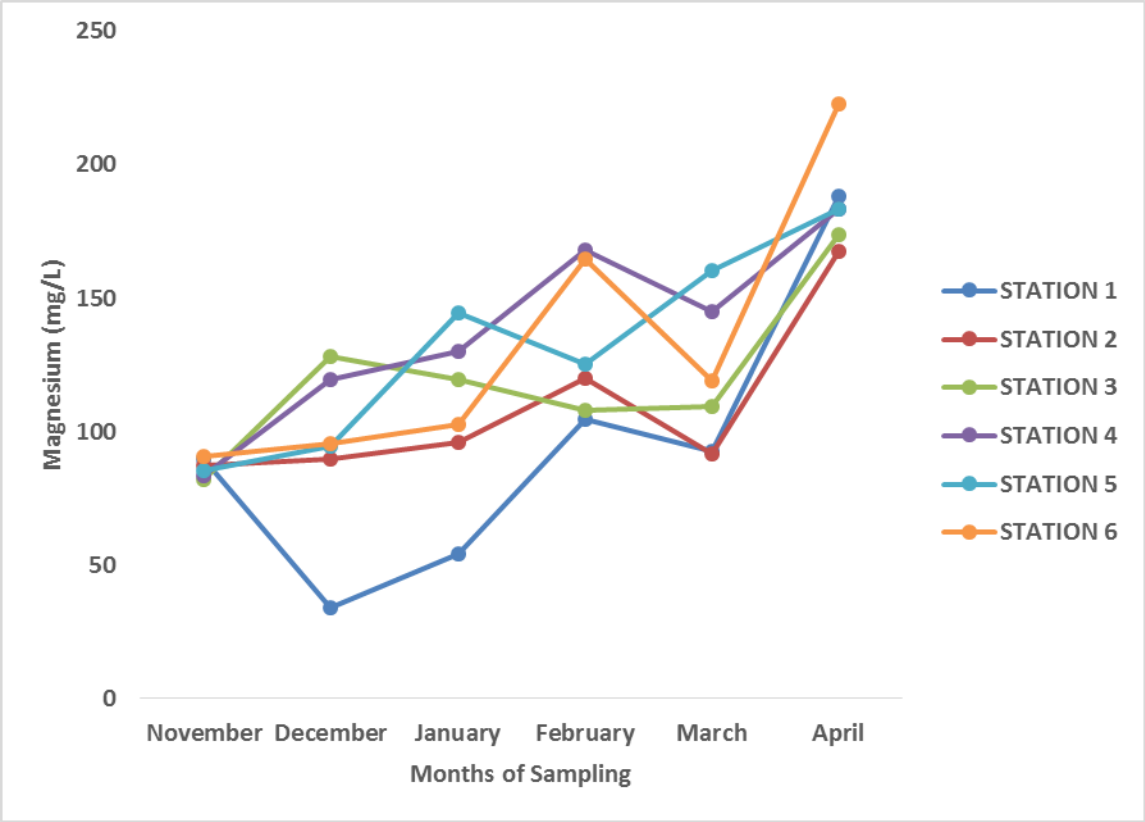


Figure 4.10: Monthly Stations Variations of Magnesium

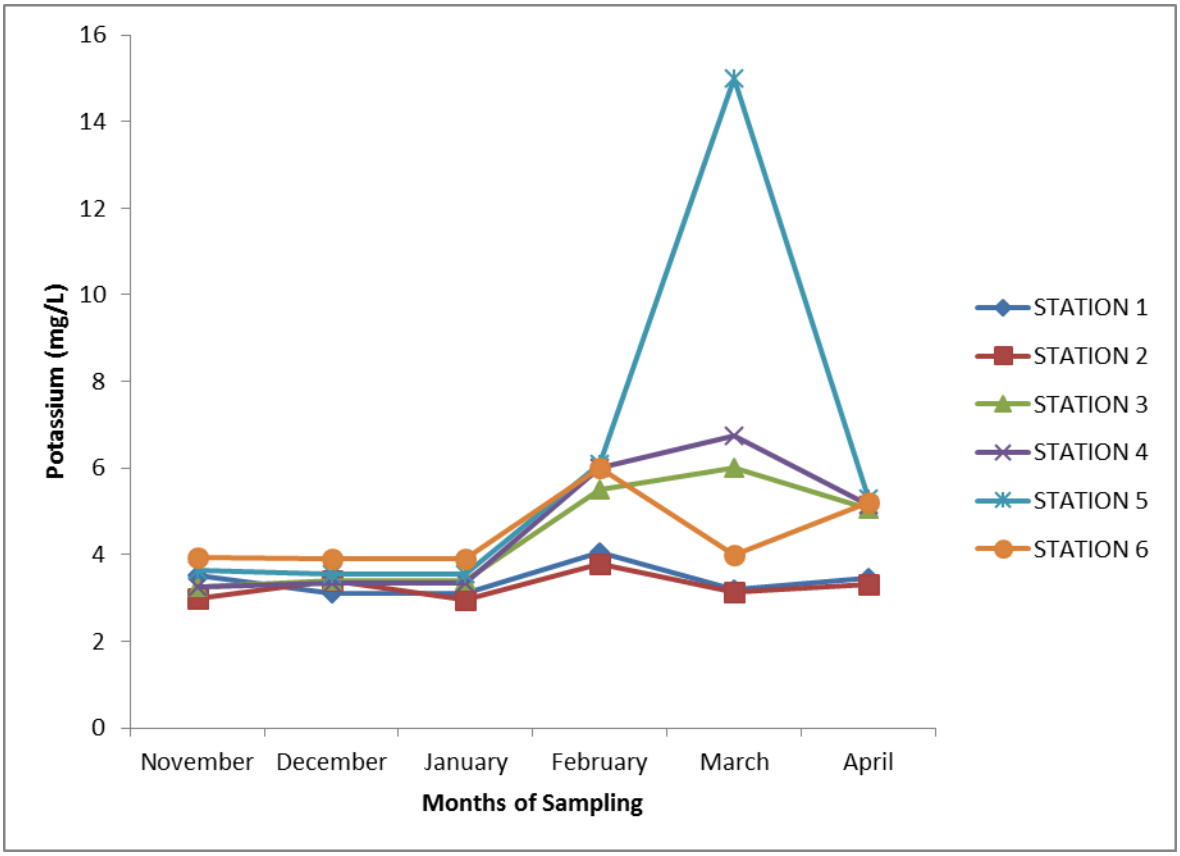


Figure 4.11: Monthly Stations Variations of Potassium

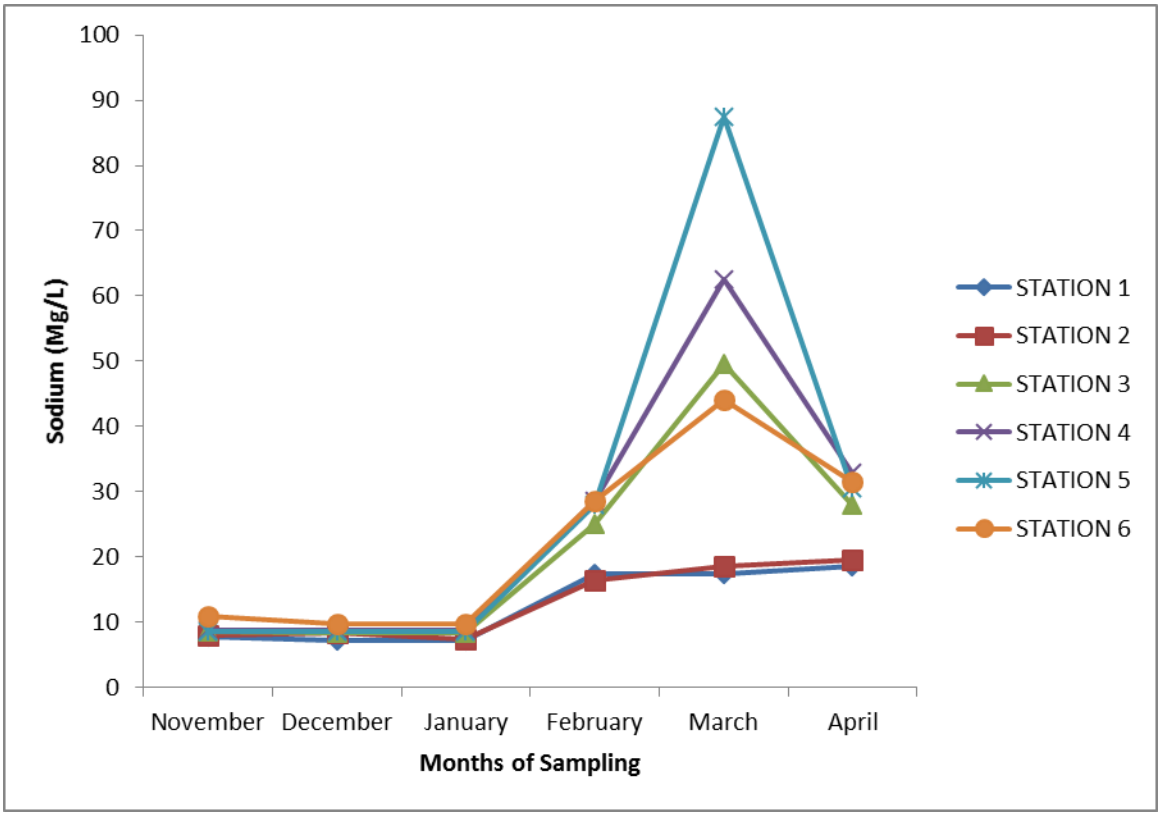


Figure 4.12: Monthly Stations Variations of Sodium

4.3 Anions

The mean concentrations of anions between months and stations revealed the following trends SO_4 > Cl > NO_3 > PO_4-P (Table 4.3 and 4.4).

4.3.1 Sulphate

The concentrations of sulphate ranged from 79.9±17.61 to 198.62±12.55mg/L between months with the lowest 79.9±17.61mg/L in January and highest 198.62±12.55mg/L in February and a mean of 141.69±9.42mg/L.There was a highly significant difference between months (Table 4.3). It ranged from 112.77±19.57 to 171.38±31.00mg/L between stations with the lowest in station 3 and highest in station 2 respectively. ANOVA (Table 4.4) showed no significant difference between stations. Figure 4.13 showed the trend between Months and stations.

4.3.2 Chloride

Chloride mean concentration varied from 28.55±1.07 to 64.50±11.94mg/L between months with the lowest 28.55±1.07 in December and highest 64.50±11.94mg/L in March and mean of 44.45± 3.59mg/L. ANOVA (Table 4.3) showed no significant difference in months. It varied from 25.41±1.07 to 50.87±14.69mg/L between stations with the lowest in station 2 and highest in station 5. Chloride showed no significant difference in stations (Table 4.4). Figure 4.14 showed the trend between Months and stations.

4.3.3 Nitrate-nitrogen

Nitrate-Nitrogen showed a concentration range of 8.8±0.87 to33.72±3.50mg/L between months with the lowest 8.8±0.87mg/L in December and highest 33.72±350mg/L) in March and mean of 19.52 ± 1.88±mg/L. ANOVA (Table 4.3) showed a highly significant

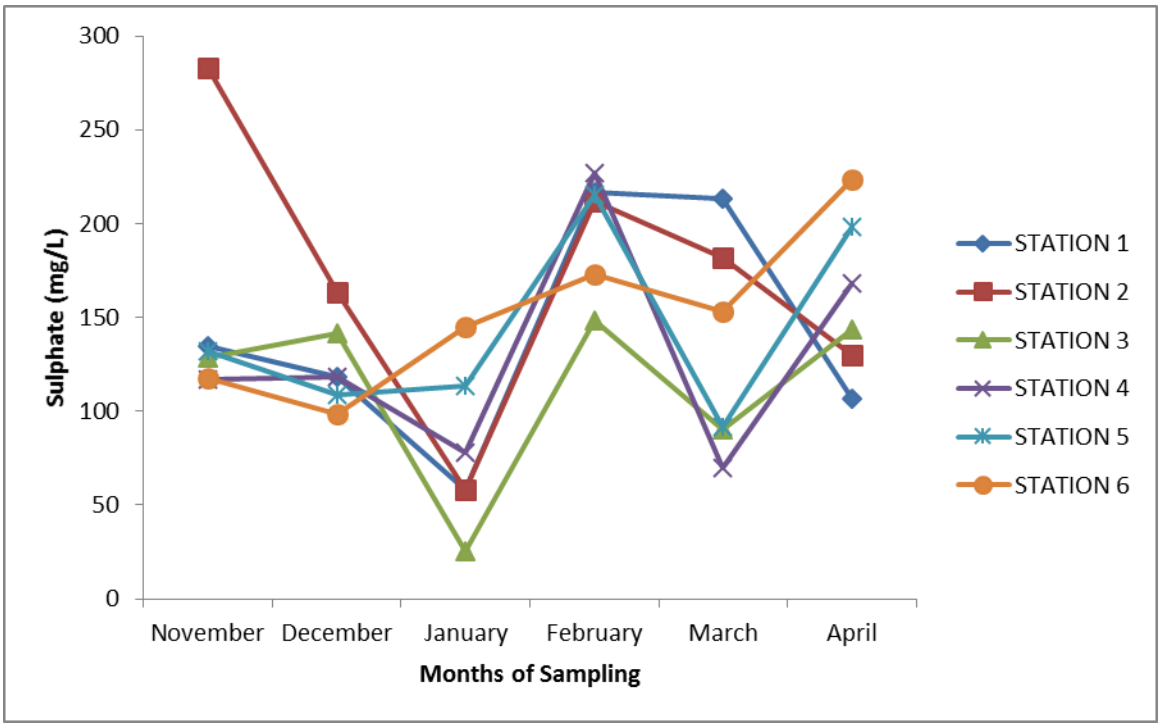


Figure 4.13: Monthly Stations Variations of Sulphate

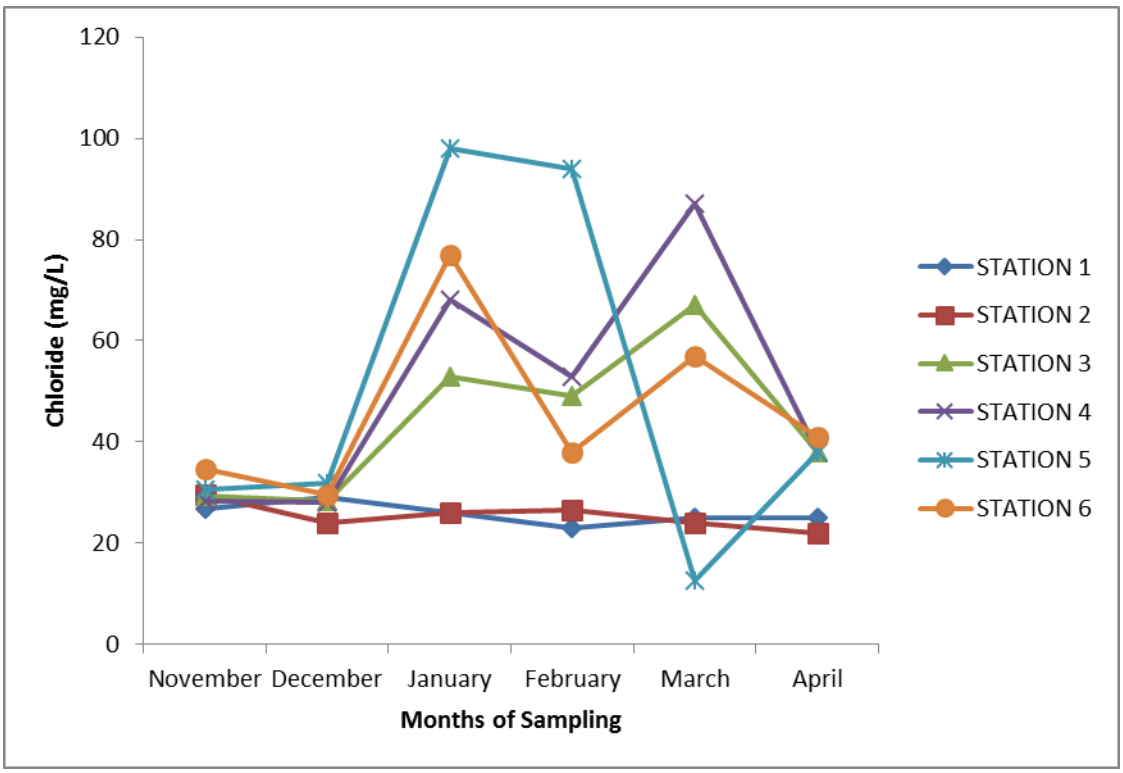


Figure 4.14: Monthly Stations Variations of Chloride

difference($p<0.01$) between months. It ranged from 16 86±3.48 to 22.12±6.17mg/L between stations with the lowest in station 2 and highest in station 6. ANOVA (Table 4.4) showed no significant difference ($p>0.05$) between stations. Figure 4.15 showed the trend between Months and stations.

4.3.4 Ammonium-N

Ammonium concentration ranged from 9.46±1.43 to 25.25±4.56mg/L between months with the lowest 9.46±1.43 in April and highest 25.25±4.56mg/L in January and a mean of 17.53 ± 1.54. ANOVA (Table 4.3) revealed a highly significant difference ($p<0.01$) in months. It ranged from 13.83±1.43 to 24.54±6.49mg/L between stations with the lowest in station 3 and highest in station 5. ANOVA (Table 4.4) showed no significant difference ($p>0.05$) between stations. Figure 4.16 showed the trend between Months and stations.

4.3.5 Phosphate-phosphorus

Phosphate-Phosphorus concentrations ranged from 0.88±0.20 to 4.84±3.09mg/L between months with the lowest 0.88±0.20mg/L in March and the highest 4.84±3.09mg/L in November and mean of 1.78 ± 0.54mg/L. ANOVA (Table 4.3) showed no significant difference ($p>0.05$) between months. It also ranged from 1.02±0.25 to 5.1±3.05mg/L with the lowest in stations 5 and 6 respectively and highest in station 1. ANOVA (Table 4.4) indicated no significant difference between stations. Figure 4.17 showed the trend between Months and stations.

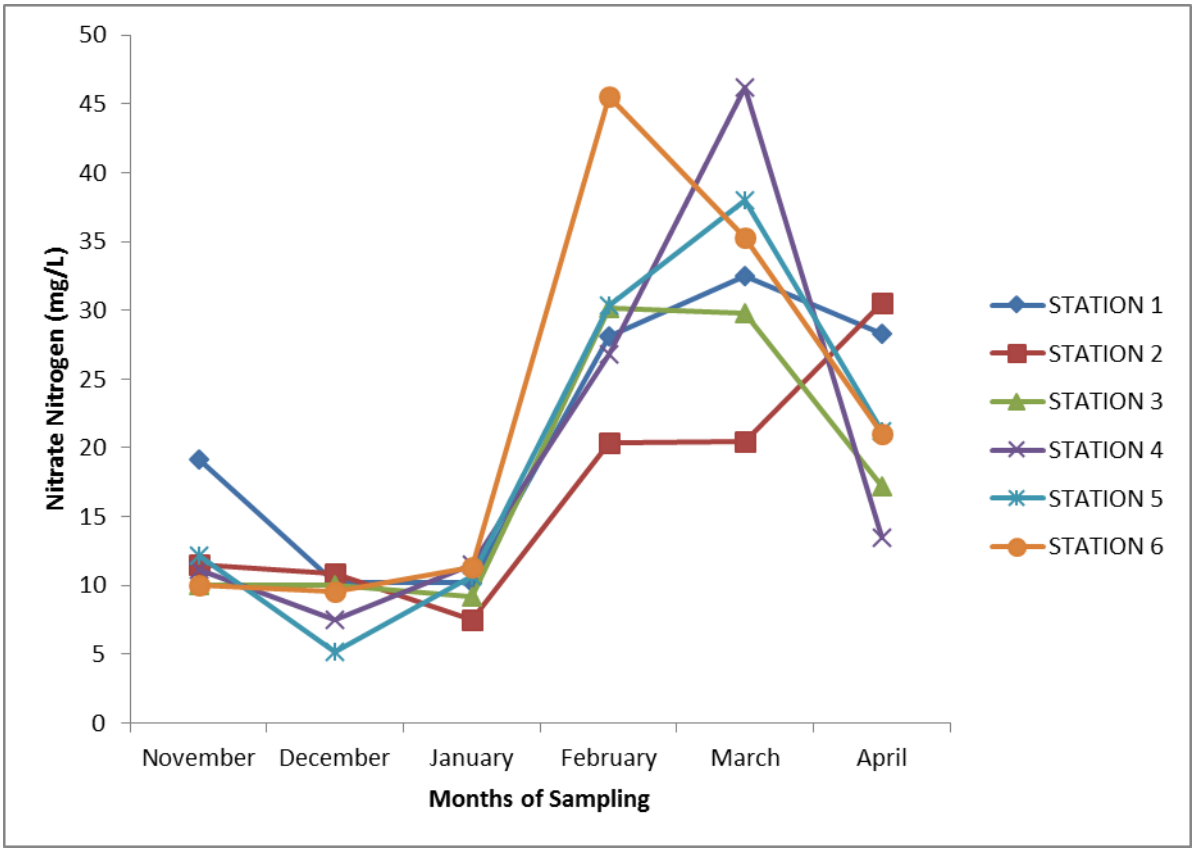


Figure 4.15: Monthly Stations Variations of Nitrate- Nitrogen

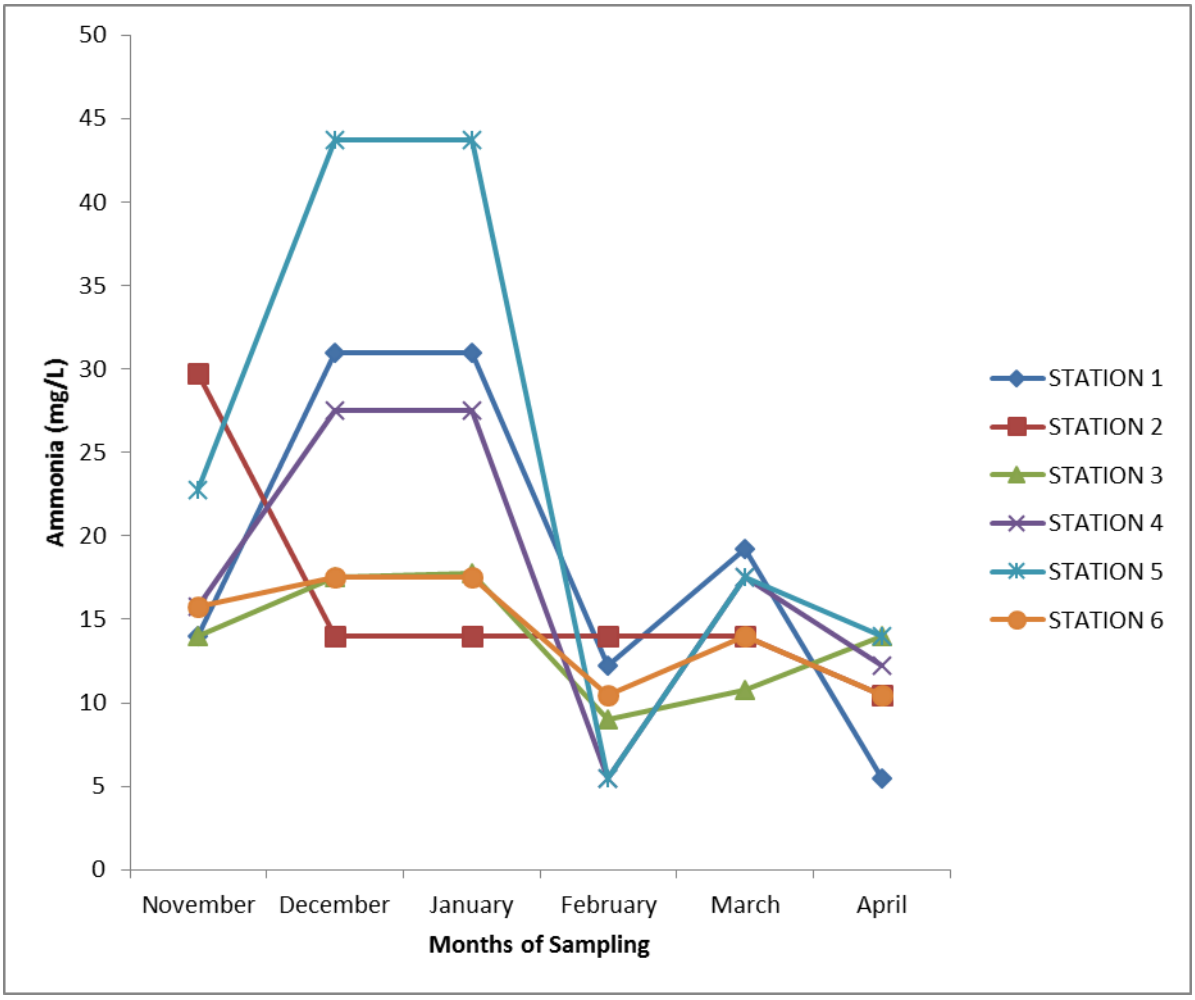


Figure 4.16: Monthly Stations Variations of Ammonium

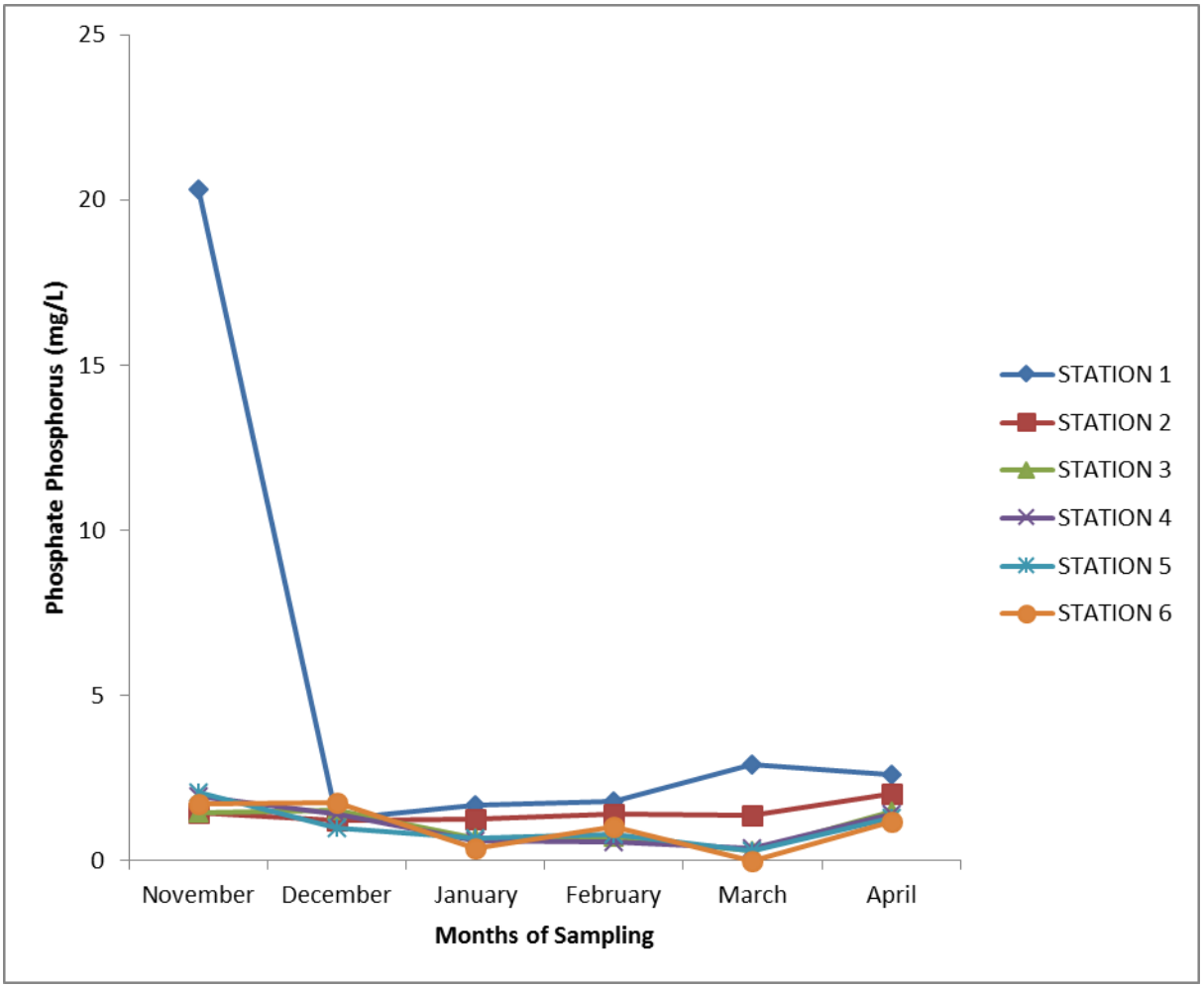


Figure 4.17: Monthly Stations Variations of Phosphate- Phosphorus

4.4 Heavy Metals

4.4.1 Cadmium

The mean monthly concentration varied from 0±0.01 to 0.02±0.00mg/L with the lowest 0±0.01mg/L in December and the highest 0.02±0.00mg/L in November and mean of 4.05 ± 4.03mg/L. However, it was not detected in January. ANOVA (Table 4.3) showed no significant difference ($p>0.05$) in months. Among stations, the values showed no variation. ANOVA (Table 4.4) showed no significant difference between stations. Figure 4.18 showed the trend between Months and stations.

4.4.2 Cobalt

Cobalt concentration varied from 0.02±0.12 to 0.06±0.01mg/L with the lowest 0.02±0.12 in April and December and highest 0.06±0.01mg/L in January and February and mean of 0.04 ± 0.01. However, it was beyond detection limit in November and December. ANOVA (Table 4.3) indicated a highly significant difference ($p<0.01$) in months. Between stations, it varied from 0.02±0.01 to 0.06±0.01mg/L with lowest in station 5 and the highest in station 2 respectively. Statistics (Table 4.4) showed no significant difference between stations. Figure 4.19 showed the trend between Months and stations.

4.4.3 Copper

The mean monthly concentration varied from 0.01±0.00 to 0.04±0.07mg/L with the lowest 0.01±0.00mg/L in November and highest 0.04±0.07mg/L in December and mean of 0.03 ± 0.01mg/L. ANOVA (Table 4.3) showed no significant difference in months. The values showed no variations among stations.

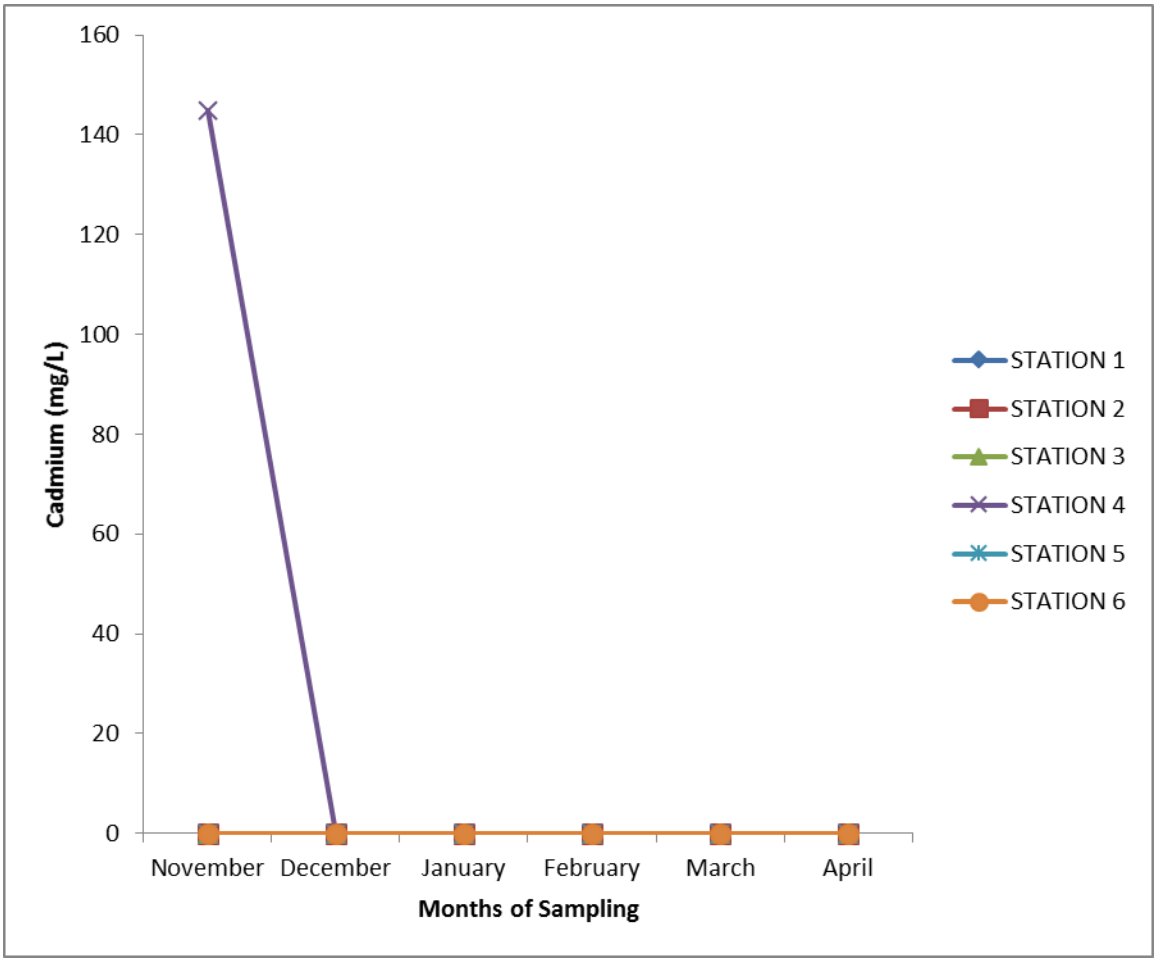


Figure 4.18: Monthly Stations Variations of Cadmium

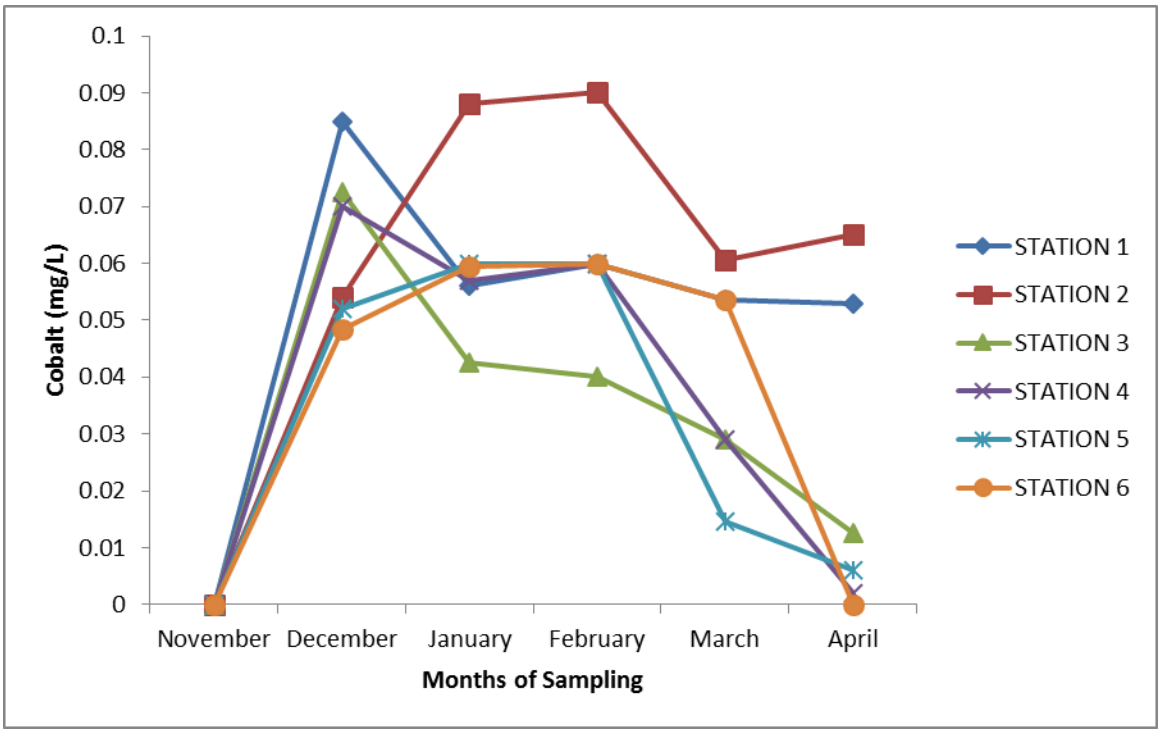


Figure 4.19: Monthly Stations Variations of Cobalt

ANOVA (Table 4.4) showed no significant difference ($p>0.05$) between stations. Figure 4.20 showed the trend between Months and stations.

4.4.4 Lead

The mean monthly variation of Lead ranged from 0.10±0.01 to 0.19±0.01mg/L with the lowest 0.10±0.01 in January and highest 0.19±0.01mg/L in March and mean of 0.14 ± 0.01mg/L. ANOVA (Table 4.3) showed a significant difference ($p<0.05$) in months. Variation among stations ranged from 0.12±0.01 to 0.14±0.06mg/L with lowest in station 2 and the highest in station 6. Statistics (Table 4.4) showed no significant difference between stations. Figure 4.21 showed the trend between Months and stations.

4.4.5 Zinc

Zinc concentration varied from 0.01±0.00 to 0.04 ±0.02 with the lowest 0.01±0.00 in December and the highest 0.04±0.02 in November. It was beyond detectable limit from January to April. ANOVA (Table 4.3) showed a highly significant difference ($p<0.01$) in months. Among stations, it ranged from 0.01± to 0.02±mg/L with the lowest in station 1-5 and highest in station 6. ANOVA (Table 4.4) indicated no significant difference ($p >0.05$) between stations. Figure 4.22 showed the trend between Months and stations.

4.5 Biological Parameters (Diatom Species Composition and Diversity

The periphyton diatom structure during the period of study revealed 8532 individuals spread across 9 families of diatoms, 8 families belong to the pennate and 1 to the centric diatoms. The pennate diatoms family had a total of 7739 individuals and 793 centric

diatoms. Naviculaceae (2798) 33.62 %, Fragilariaceae (3015) 36.23 %, Coscinodiceae (793) 9.53 %, Cymbellaceae (719) 8.64 %, Gomphonemaceae (489) 5.88 %,

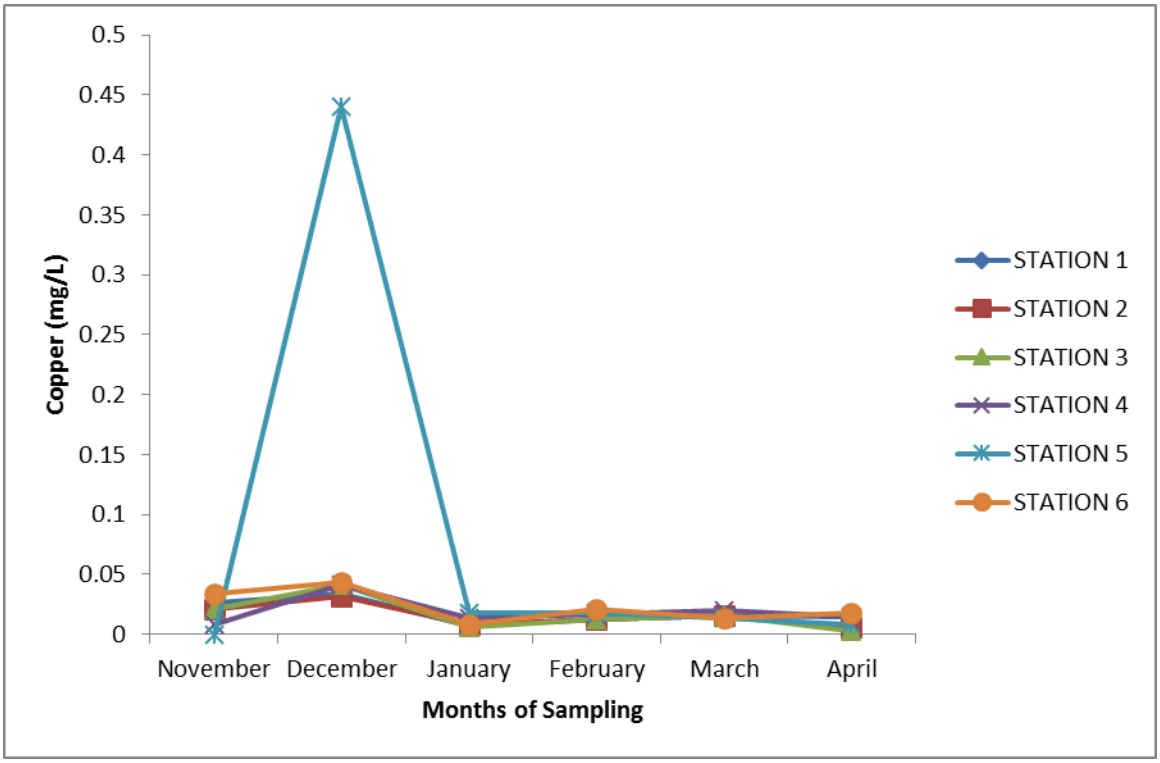


Figure 4.20: Monthly Stations Variations of Copper

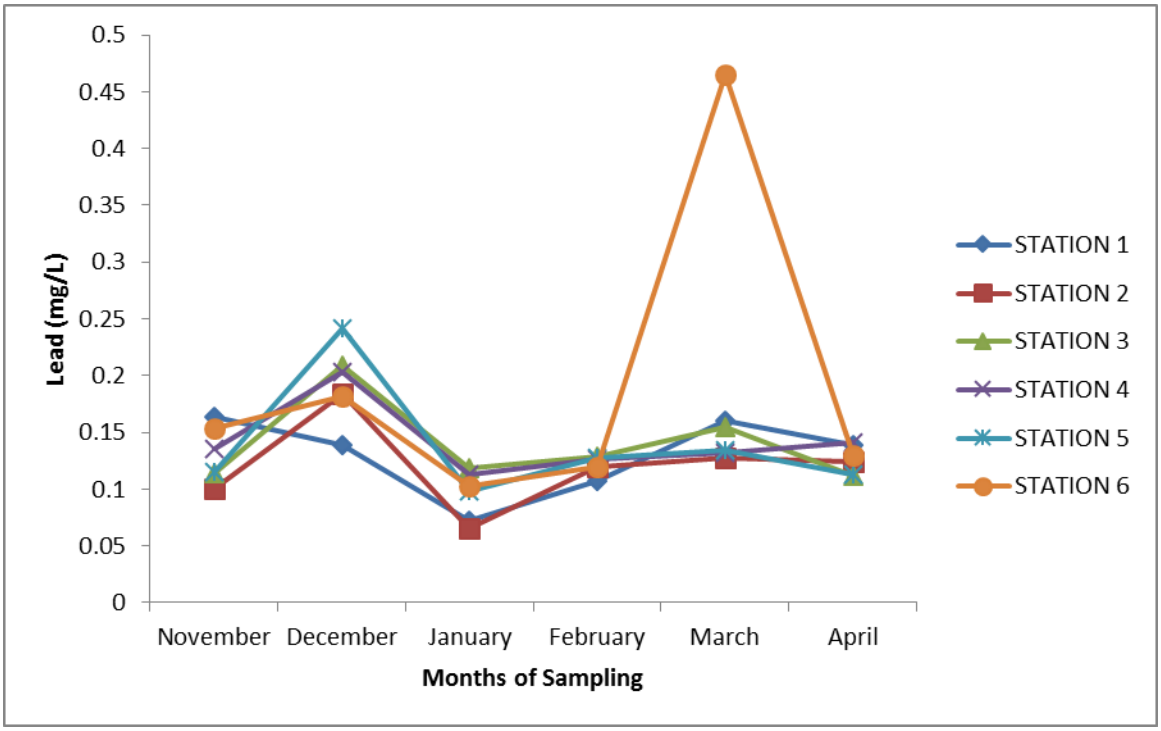


Figure 4.21: Monthly station variation of Lead

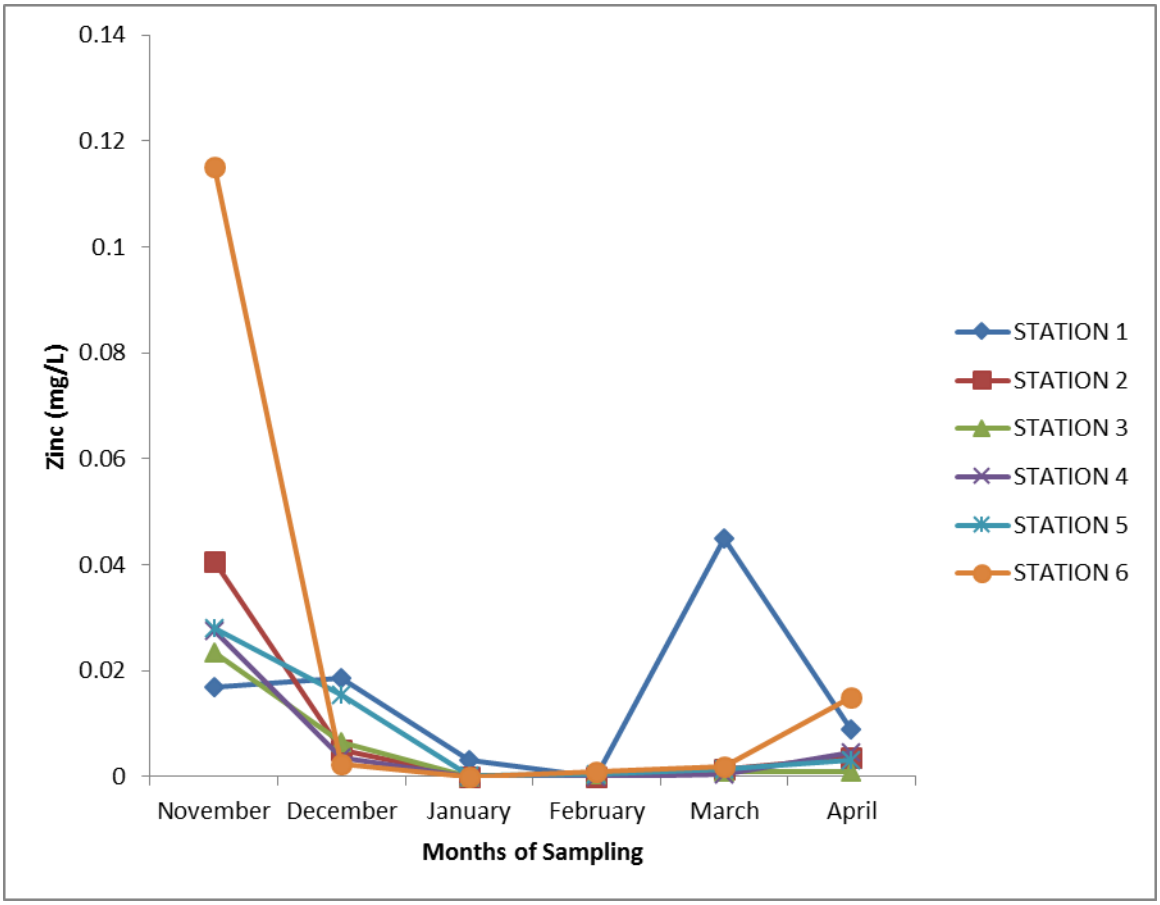


Figure 4.22: Monthly station variation of Zinc

Achnanthaceae (215) 2.58 $^{o}/_{o}$ .Eunotiaceae (181) 2.17 $^{o}/_{o}$, Plagiotropidaceae (66) 0.79 $^{o}/_{o}$, and Epithemiaceae (46) 0.55$^{o}/_{o..}$ The month of January (Table 4.5) recorded the highest (3213) individuals with the lowest (691) in November. Family Fragilariaceae had the highest number of individuals 3015 and the family Eunotiaceae with 46 individuals as the lowest among families (Table 4.6). Among stations, station six (Table 4.7) recorded the highest (1824) number of individuals and the lowest in station three (936). The family Fragilariaceae was the highest with Epithemiaceae recording the lowest in stations (Table 4.8). Table 4.9 to 4.14 shows the monthly and station relative abundance of all the species.

4.5.1 Correlations between physicochemical and biological parameters

Achnanthaceae (Table 4.15) showed a positive correlation(r=0.9) with Fragilariaceae. Naviculaceae showed a positive correlation with Fragilariacea (r=0.8) and Achnanthaceae (r=0.9). Gomphonemaceae showed a negative correlation with Coscinodiceae (r= -0.5) and positive correlation with Naviculaceae (r=0.5). Eunotiaceae showed a positive correlation with Fragilariaceae and Achnanthaceae (r = 0.6) and a negative correlation (r = -0.5) with Epithemiaceae. Plagiotropidiceae showed a negative correlations (r = -0.6) with Fragilariaceae, Achnanthaceae, Gomphonemacea and Naviculaceae(r = -0.8). Cymbellaceae showed a positive correlations (r= 0.7, 0.6 and 0.5) with Fragilariaceae, Achnanthaceae, Gomphonemaceae and Naviculaceae respectively. Biochemical oxygen demand showed a positive correlation with Epithemiaceae (r= 0.5), Gomphonemaceae (r =0.6) and negative correlation with Plagitropidiceae (r =-0.7) and Eunotiaceae(r = -0.8). Dissolved oxygen showed a negative correlation with Cymbellaceae (r =-0.7),

Table: 4.5: Monthly Cell Density Variation of Periphytic Diatom Composition and Diversity in a Segment of River Galma During The Months of November 2012 To April 2013

Family	November	December	January	February	March	April
Achnanthaceae	21 (3.04)	11 (1.30)	101 (3.14)	20 (1.45)	19 (1.67)	43 (4.08)
Coscinodiaceae	134 (19.39)	134 (15.86)	137 (4.26)	138 (9.98)	108 (9.52)	142 (13.46)
Cymbeliaceae	36 (5.21)	192 (22.72)	256 (7.97)	74 (5.35)	67 (5.90)	94 (8.91)
Epithemiaceae	1 (0.14)	3 (0.36)	0 (0.00)	6 (0.43)	2 (0.18)	34 (3.22)
Eunotiaceae	58 (8.39)	26 (3.08)	75 (2.33)	14 (1.01)	4 (0.35)	4 (0.38)
Fragilariceae	175 (25.33)	167 (19.76)	1617 (50.33)	635 (45.91)	252 (22.20)	169 (16.02)
Gomphonemaceae	28 (4.05)	100 (11.83)	108 (3.36)	56 (4.05)	122 (10.75)	75 (7.11)
Naviculaceae	208 (30.10)	193 (22.84)	919 (28.60)	433 (31.31)	554 (48.81)	491 (46.54)
Plagiotropidiceae	30 (4.34)	19 (2.25)	0 (0.00)	7 (0.51)	7 (0.62)	3 (0.28)
Total	**691 (8.30)**	**845 (10.15)**	**3213 (38.61)**	**1383 (16.62)**	**1135 (13.64)**	**1055 (12.68)**

Table: 4.6: Family Cell Density Variation of Periphytic Diatom Composition and Diversity In A Segment of River Galma from the Months of November 2012 to April 2013

Family	November	December	January	February	March	April	Totals
Achnanthaceae	21 (9.77)	11 (5.12)	101 (46.98)	20 (9.30)	19 (8.84)	43 (20.00)	**215 (2.58)**
Coscinodiaceae	134 (16.90)	134 (16.90)	137 (17.28)	138 (17.40)	108 (13.62)	142 (17.91)	**793 (9.53)**
Cymbeliaceae	36 (5.01)	192 (26.70)	256 (35.61)	74 (10.29)	67 (9.32)	94 (13.07)	**719 (8.64)**
Epithemiaceae	1 (2.17)	3 (6.52)	0 (0.00)	6 (13.04)	2 (4.35)	34 (73.91)	**46 (0.55)**
Eunotiaceae	58 (32.04)	26 (14.36)	75 (41.44)	14 (7.73)	4 (2.21)	4 (2.21)	**181 (2.17)**
Fragilariceae	175 (5.80)	167 (5.54)	1617 (53.63)	635 (21.06)	252 (8.36)	169 (5.61)	**3015 (36.23)**
Gomphonemaceae	28 (5.73)	100 (20.45)	108 (22.09)	56 (11.45)	122 (24.95)	75 (15.34)	**489 (5.88)**
Naviculaceae	208 (7.43)	193 (6.90)	919 (32.84)	433 (15.48)	554 (19.80)	491 (17.55)	**2798 (33.62)**
Plagiotropidiceae	30 (45.45)	19 (28.79)	0 (0.00)	7 (10.61)	7 (10.61)	3 (4.55)	**66 (0.79)**

Table: 4.7: Station Average Cell Density Variation of Periphytic Diatom Composition and Diversity of a Segment of River Galma From Months of November 2012- April 2013

Family	Station One	Station Two	Station Three	Station Four	Station Five	Station Six
Achnanthaceae	31 (2.23)	71 (4.26)	20 (2.14)	66 (6.23)	27 (1.86)	0 (0.00)
Coscinodiaceae	140 (10.09)	155 (9.30)	139 (14.85)	65 (6.13)	113 (7.80)	181 (9.92)
Cymbeliaceae	63 (4.54)	85 (5.10)	55 (5.88)	75 (7.08)	203 (14.02)	238 (13.05)
Epithemiaceae	2 (0.14)	6 (0.36)	7 (0.75)	5 (0.47)	13 (0.90)	13 (0.71)
Eunotiaceae	68 (4.90)	14 (0.84)	6 (0.64)	61 (5.75)	25 (1.73)	7 (0.38)
Fragilariceae	914 (65.85)	706 (42.38)	381 (40.71)	222 (20.94)	276 (19.06)	516 (28.29)
Gomphonemaceae	55 (3.96)	79 (4.74)	54 (5.77)	86 (8.11)	160 (11.05)	55 (3.02)
Naviculaceae	106 (7.64)	542 (32.53)	270 (28.85)	458 (43.21)	614 (42.40)	808 (44.30)
Plagiotropidiceae	9 (0.65)	8 (0.48)	4 (0.43)	22 (2.08)	17 (1.17)	6 (0.33)
Total	**1388 (16.68)**	**1666 (20.02)**	**936 (11.25)**	**1060 (12.74)**	**1448 (17.40)**	**1824 (21.92)**

Table: 4.8: Family Density Variation of Periphytic Diatom Composition and Diversity of A Segment of River Galma in Stations 1-6 from November 2012- April 2013

Family	Station One	Station Two	Station Three	Station Four	Station Five	Station Six	Totals
Achnanthaceae	31 (14.42)	71 (33.02)	20 (9.30)	66 (30.70)	27 (12.56)	0 (0.00)	**215 (2.58)**
Coscinodiaceae	140 (17.65)	155 (19.55)	139 (17.53)	65 (8.20)	113 (14.25)	181 (22.82)	**793 (9.53)**
Cymbeliaceae	63 (8.76)	85 (11.82)	55 (7.65)	75 (10.43)	203 (28.23)	238 (33.10)	**719 (8.64)**
Epithemiaceae	2 (4.35)	6 (13.04)	7 (15.22)	5 (10.87)	13 (28.26)	13 (28.26)	**46 (0.55)**
Eunotiaceae	68 (37.57)	14 (7.73)	6 (3.31)	61 (33.70)	25 (13.81)	7 (3.87)	**181 (2.17)**
Fragilariceae	914 (30.32)	706 (23.42)	381 (12.64)	222 (7.36)	276 (9.15)	516 (17.11)	**3015 (36.23)**
Gomphonemaceae	55 (11.25)	79 (16.16)	54 (11.04)	86 (17.59)	160 (32.72)	55 (11.25)	**489 (5.88)**
Naviculaceae	106 (3.79)	542 (19.37)	270 (9.65)	458 (16.37)	614 (21.94)	808 (28.88)	**2798 (33.62)**
Plagiotropidiceae	9 (13.64)	8 (12.12)	4 (6.06)	22 (33.33)	17 (25.76)	6 (9.09)	**66 (0.79)**

Table 4.9: Station Relative Abundance of Periphytic Diatoms in November

Family	Genus/species	1	2	3	4	5	6	Total
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	+	+	6
	Cyclotella sp (Kutz.)	-	-	+	+	+	-	3
Fragilariaceae	*Fragilaria capucina(*Desm*)*	+	-	-	-	+	-	2
	*Fragilaria virescens (*Ralfs*)*	-	-	-	-	-	-	0
	*Frustulia rhomboids (*A. Mayer*)* Patr.	-	-	-	-	-	-	0
	Opephora swartzii (Grun.)	-	-	-	-	-	-	0
	Synedra famlica (Kutz.)	-	-	-	-	-	-	0
	Synedra fasciculate (Kutz.)	-	+	+	-	+	+	4
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	+	-	-	-	1
	Synedra robusta (Ralfs.)	-	-	-	-	-	-	0
	Synedra tenera (W.Sm.)	-	-	-	-	-	-	0
	Synedra ulna (Nitz.) Her.	+	+	-	-	-	-	2
	Synedra ulna (Her.) Grun.	-	-	-	+	+	-	2
	Synedra ulna (Her.) Grun.	-	-	+	+	-	-	2
	Tabellaria fenestrate (Lyngb.) Kutz.	+	+	+	+	-	+	5
Achnanthaceae								
	Achnanthes deflexa (Reim.)	-	-	+	-	-	-	1
	Achnanthes lanceolata (Breb ex kutz.)	+	-	-	-	-	-	1
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	-	-	-	-	-	-	0
	Rhoicosphaenia curtala (Grun.)	-	+	-	-	-	-	1
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.	-	-	+	-	-	-	1
	Diatomelia balfouria (Ehr.)	-	-	-	+	+	+	3
	Gyrosigma acuminatum (Kutz.) Ralbh.	-	-	-	-	-	-	0
	Gyrosigma exilis (NA)	-	-	+	-	-	-	1
	Gyrosigma hummi (NA)	+	-	-	-	-	-	1
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	+	-	-	-	-	1
	Navicula arvensis (Hust.)	-	-	-	-	-	+	1
	Navicula circumtexta (Meist. Ex. Hust.)	-	-	-	-	-	-	0
	Navicula costulata (NA)	-	-	-	+	-	-	1
	Navicula cuspida (Kutz.) Kutz.	-	-	+	-	-	-	1
	Navicula elegans (NA)	-	-	-	-	+	-	1
	Navicula explanata (NA)	-	-	-	-	=	+	1
	Navicula falaisenses (Grun.)	-	-	-	-	-	-	0
	Navicula gysingensis (Fogged.)	-	-	-	-	-	-	0
	Navicula ilopangensis (Hust.)	-	-	-	-	+	-	1
	Navicula imcomposita (NA)	-	-	-	+	-	-	1
	Navicula keelyi (NA)	-	-	-	-	-	-	0
	Navicula latelongitudinalis (NA)	-	-	-	-	-	-	0
	Navicula laterostrata (Hust.)	-	-	-	-	-	-	0
	Navicula mutica (Hilse.) Grun.	-	-	-	-	-	+	1
	Navicula notha (Wall.)	-	-	-	-	-	-	0
	Navicula paucivisitata (Patr.)	-	-	-	-	-	-	0

	Navicula placenta (Her.) Kutz.	-	-	-	-	-	-	0
	Navicula protracta (Grun.)	-	-	-	-	-	-	0
	Navicula simula (Grun.)	-	-	-	-	-	-	0
	Navicula specula (NA)	+	+	-	-	-	-	2
	Navicula subtillisima (Marg.)	-	-	-	-	-	-	0
	Navicula tenelloides (Hust.)	-	-	-	-	-	-	0
	Navicula variostrata (Kras.)	-	-	-	-	+	+	2
	Navicula wardii (Patr.)	-	-	-	-	-	-	0
	Neidum affine (Ehr.)	-	-	-	-	+	-	1
	Neidum hercyanicum (Wall.)	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia divergens (W.Sm.)	-	+	-	-	-	-	1
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	-	-	-	-	0
	Pinnularia termitina (Ehr.) Patr.	-	-	-	-	-	+	1
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	-	-	-	-	-	0
	Pleurosigma delicatulum (W.Sm.)	-	-	-	-	-	-	0
	Pleurosigma salinarum (Grun.)	-	-	-	-	-	-	0
Gomphonemaceae								
	Gomphonema affine (Kutz.)	-	-	-	-	-	-	0
	Gomphonema affine (Greg.) Andr.	-	-	-	-	-	-	0
	Gomphonema angustatum (Kutz.) Rabh.	-	-	-	-	-	-	0
	Gomphonema brasiliense (Grun.)	-	-	-	-	-	-	0
	Gomphonema eriense (Grun.)	-	-	-	-	-	-	0
	Gomphonema gronuwii (Patr.)	-	-	-	-	+	-	1
	Gomphonema montanum (Patr.)	-	-	-	-	-	-	0
	Gomphonema olicaceum (Lyng.)	-	-	-	+	+	-	2
	Gomphonema olivacoides (Hust.)	-	-	+	+	-	-	2
	Gomphonema olivacoides (Hust.)	-	-	-	-	-	+	1
	Gomphonema parvulum (Kutz.) Kutz.	+	-	-	-	+	-	2
	Gomphonema tenellum (Kutz.)	-	-	+	-	-	-	1
Epithemiaceae								
	Denticula tenuis (Kutz.)	+	+	-	-	-	-	0
	Epithemia adnata (Kutz.) Patr.	+	+	-	-	+	-	3
	Epithemia turgid (NA)	-	-	-	-	-	+	1
Eunotiaceae								
	Eunotia vauheurkii (NA)	-	-	-	+	+	+	3
	Peronia intermedia (Breb.)	-	-	-	-	-	-	0
	Semiorbis hemicyclus (Ehr.)	-	-	-	-	-	-	0
Plagiotropidiceae								
	Plagiotropis Lepidoptera (CL.) Reim.	-	-	-	+	+	+	3

Cymbellaceae								
	Amphora submontana (Hust.)	-	-	-	-	-	-	0
	Amphora veneta (Kutz.)	-	-	-	-	-	-	0
	Cymbella angustata (W.Sm.) CL.	-	-	-	-	-	-	0
	Cymbella cistula (Ehr.) Kirchn.	+	+	-	-	-	-	2
	Cymbella minuta (Hilse ex. Rab.	-	+	-	+	+	-	3
	Cymbella minuta (Bleisch ex. Rab.) Reim.	-	-	-	-	+	-	1

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.10: Station Relative Abundance of Periphytic Diatoms in December

Family	Genus/ species	1	2	3	4	5	6	Total
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	+	+	6
	Cyclotella sp (Kutz.)	-	+	+	+	+	+	5
Fragilariaceae	*Fragilaria capucina(*Desm*)*	+	+	+	-	-	-	3
	*Fragilaria virescens (*Ralfs*)*	+	-	-	-	-	-	1
	*Frustulia rhomboids (*A. Mayer*)* Patr.	-	-	-	-	-	-	0
	Opephora swartzii (Grun.)	-	-	-	-	+	-	1
	Synedra famlica (Kutz.)	-	-	+	-	-	-	1
	Synedra fasciculate (Kutz.)	-	-	+	+	+	-	3
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	-	-	-	+	1
	Synedra robusta (Ralfs.)	-	-	-	-	-	-	0
	Synedra tenera (W.Sm.)	+	+	+	-	-	-	3
	Synedra ulna (Nitz.) Her.	+	-	+	+	+	-	4
	Synedra ulna (Her.) Grun.	+	-	-	+	-	-	2
	Synedra ulna (Her.) Grun.	+	-	+	-	-	+	2
	Tabellaria fenestrate (Lyngb.) Kutz.	+	-	-	-	+	-	2
Achnanthaceae								
	Achnanthes deflexa (Reim.)	+	+	-	+	-	-	3
	Achnanthes lanceolata (Breb ex kutz.)	-	-	-	-	-	-	0
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	-	-	-	-	-	-	0
	Rhoicosphaenia curtala (Grun.)	-	+	-	+	-	-	2
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.	-	-	-	-	-	-	0
	Diatomelia balfouria (Ehr.)	-	-	-	-	-	+	1
	Gyrosigma acuminatum (Kutz.) Ralbh.	-	-	-	-	+	+	2
	Gyrosigma exilis (NA)	-	+	-	+	-	-	2
	Gyrosigma hummi (NA)	-	-	-	+	-	-	1
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	-	-	-	-	-	0
	Navicula arvensis (Hust.)	-	-	+	+	+	+	4
	Navicula circumtexta (Meist. Ex. Hust.)	-	-	+	-	-	-	1
	Navicula costulata (NA)	+	-	-	-	-	-	1
	Navicula cuspida (Kutz.) Kutz.	-	-	-	-	-	-	0
	Navicula elegans (NA)	-	-	-	-	-	-	0
	Navicula explanata (NA)	+	-	-	-	-	-	1
	Navicula falaisenses (Grun.)	+	-	-	-	-	+	2
	Navicula gysingensis (Fogged.)	-	-	-	-	+	-	1
	Navicula ilopangensis (Hust.)	-	+	-	-	-	-	1
	Navicula imcomposita (NA)	-	-	-	-	-	-	0
	Navicula keelyi (NA)	-	-	-	-	-	-	0
	Navicula latelongitudinalis (NA)	-	-	-	-	-	-	0
	Navicula laterostrata (Hust.)	+	+	-	+	-	-	2

	Navicula mutica (Hilse.) Grun.	-	-	-	-	-	-	0
	Navicula notha (Wall.)	-	-	-	+	-	-	1
	Navicula paucivisitata (Patr.)	-						
	Navicula placenta (Her.) Kutz.	-	-	-	+	+	-	2
	Navicula protracta (Grun.)	-	-	-	-	-	-	0
	Navicula simula (Grun.)	-	-	-	+	+	-	2
	Navicula specula (NA)	-	-	-	-	-	-	0
	Navicula subtillisima (Marg.)	-	-	-	+	-	-	1
	Navicula tenelloides (Hust.)	-	-	-	-	-	+	1
	Navicula variostrata (Kras.)	+	+	-	-	+	-	3
	Navicula wardii (Patr.)	+	+	+	-	-	-	0
	Neidum affine (Ehr.)	-	-	-	-	-	-	0
	Neidum hercyanicum (Wall.)	-	-	-	+	-	-	1
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	+	1
	Pinnularia divergens (W.Sm.)	-	-	-	-	-	+	1
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	-	-	-	-	0
	Pinnularia termitina (Ehr.) Patr.	-	-	-	-	-	-	0
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	-	+	+	+	+	4
	Pleurosigma delicatulum (W.Sm.)	-	-	-	-	-	+	1
	Pleurosigma salinarum (Grun.)	-	-	-	-	-	-	0
Gomphonemaceae								
	Gomphonema affine (Kutz.)	-	-	+	-	-	-	1
	Gomphonema affine (Greg.) Andr.	-	-	-	-	+	-	1
	Gomphonema angustatum (Kutz.) Rabh.	+	-	+	+	-	-	3
	Gomphonema brasiliense (Grun.)	-	-	-	+	-	-	1
	Gomphonema eriense (Grun.)	+	-	-	-	-	-	1
	Gomphonema gronuwii (Patr.)	-	-	-	-	-	-	0
	Gomphonema montanum (Patr.)	-	-	-	+	-	-	1
	Gomphonema olicaceum (Lyng.)	-	-	-	-	+	-	1
	Gomphonema olivacoides (Hust.)	-	-	-	-	-	-	0
	Gomphonema olivacoides (Hust.)	-	-	-	+	-	-	1
	Gomphonema parvulum (Kutz.) Kutz.	+	+	+	-	+	+	5
	Gomphonema tenellum (Kutz.)	-	-	+	-	-	-	1
Epithemiaceae								
	Denticula tenuis (Kutz.)	-	-	-	-	-	-	0
	Epithemia adnata (Kutz.) Patr.	-	-	-	-	-	-	0
	Epithemia turgid (NA)	-	-	+	+	-	+	3
Eunotiaceae								
	Eunotia vauheurkii (NA)	-	-	-	-	-	-	0
	Peronia intermedia (Breb.)	+	+	-	+	+	-	4
	Semiorbis hemicyclus (Ehr.)	+	+	-	+	-	-	3
Plagiotropidiceae								
	Plagiotropis Lepidoptera (CL.) Reim.	+	+	+	+	+	_	5
Cymbellaceae								
	Amphora submontana (Hust.)	-	-	+	-	-	+	2

Amphora veneta (Kutz.)	-	-	-	-	+	-	1
Cymbella angustata (W.Sm.) CL.	-	-	-	-	-	-	0
Cymbella cistula (Ehr.) Kirchn.	-	-	-	-	-	-	0
Cymbella minuta (Hilse ex. Rab.	+	+	+	+	+	+	6
Cymbella minuta (Bleisch ex. Rab.) Reim.	+	-	+	+	+	+	5

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.11: Station Relative Abundance of Periphytic Diatoms in January

Family	Genus/ species							
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	+	+	6
	Cyclotella sp (Kutz.)	-	+	+	+	+	+	5
Fragilariaceae	*Fragilaria capucina(*Desm*)*	+	-	-	-	-	-	1
	*Fragilaria virescens (*Ralfs*)*	-	-	+	+		+	3
	*Frustulia rhomboids (*A. Mayer*)* Patr.	-	-	-	-	-	-	0
	Opephora swartzii (Grun.)	+	-	+	-	+	-	3
	Synedra famlica (Kutz.)	-	-	-	-	-	-	0
	Synedra fasciculate (Kutz.)	-	+	+	+	+	-	4
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	-	-	-	-	0
	Synedra robusta (Ralfs.)	-	+	+	-	-	-	2
	Synedra tenera (W.Sm.)	-	-	+	+	+	-	3
	Synedra ulna (Nitz.) Her.	-	+	-	-	+	+	3
	Synedra ulna (Her.) Grun.	-	+	+	-	-	-	2
	Synedra ulna (Her.) Grun.	+	+	-	-	+	+	3
	Tabellaria fenestrate (Lyngb.) Kutz.	+	+	+	+	-	+	5
Achnanthaceae								
	Achnanthes deflexa (Reim.)	-	+	+	+	-	-	3
	Achnanthes lanceolata (Breb ex kutz.)	+	-	-	+	-	0	2
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	+	+	+	+	+	-	5
	Rhoicosphaenia curtala (Grun.)	_	-	-	-	-	-	0
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.	-	+	-	+	+	+	3
	Diatomelia balfouria (Ehr.)	-	-	+	+	+	+	4
	Gyrosigma acuminatum (Kutz.) Ralbh.	+	+	+	+	+	+	6
	Gyrosigma exilis (NA)	-	-	-	-	-	-	0
	Gyrosigma hummi (NA)	-	-	-	-	-	-	0
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	-	-	+	+	-	2
	Navicula arvensis (Hust.)	+	-	-	+	-	-	2
	Navicula circumtexta (Meist. Ex. Hust.)	-	-	+	-	-	-	1
	Navicula costulata (NA)	-	-	-	-	-	-	0
	Navicula cuspida (Kutz.) Kutz.	-	-	-	-	-	+	1
	Navicula elegans (NA)	-	-	-	-	-	+	1
	Navicula explanata (NA)	-	-	-	-	-	+	1
	Navicula falaisenses (Grun.)	-	-	-	-	-	-	0
	Navicula gysingensis (Fogged.)	-	-	-	-	+	-	1
	Navicula ilopangensis (Hust.)							

	Navicula imcomposita (NA)	-	-	-	-	-	-	0
	Navicula keelyi (NA)	-	-	-	-	-	-	0
	Navicula latelongitudinalis (NA)	-	-	-	-	-	+	1
	Navicula laterostrata (Hust.)	-	-	-	-	-	-	0
	Navicula mutica (Hilse.) Grun.	-	-	-	-	-	-	0
	Navicula notha (Wall.)	-	-	-	+	+	-	2
	Navicula paucivisitata (Patr.)	-	+	-	+	-	-	2
	Navicula placenta (Her.) Kutz.	-	-	-	-	-	+	1
	Navicula protracta (Grun.)	-	-	-	-	-	-	0
	Navicula simula (Grun.)	-	-	-	-	-	-	0
	Navicula specula (NA)	-	-	-	-	-	-	0
	Navicula subtillisima (Marg.)	-	-	-	-	-	-	0
	Navicula tenelloides (Hust.)	-	-	-	-	-	-	0
	Navicula variostrata (Kras.)	-	-	-	-	-	-	0
	Navicula wardii (Patr.)	-	-	-	-	-	-	0
	Neidum affine (Ehr.)	-	-	-	-	-	-	0
	Neidum hercyanicum (Wall.)	-	-	-	-	+	-	1
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia divergens (W.Sm.)	-	-	-	-	-	-	0
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	-	-	-	+	1
	Pinnularia termitina (Ehr.) Patr.	-	-	-	-	+	-	1
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	-	-	-	-	-	0
	Pleurosigma delicatulum (W.Sm.)	-	-	+	+	+	+	4
	Pleurosigma salinarum (Grun.)	-	+	+	-	-	-	2
Gomphonemaceae								
	Gomphonema affine (Kutz.)	-	-	-	-	+	-	1
	Gomphonema affine (Greg.) Andr.	-	-	-	-	-	-	0
	Gomphonema angustatum (Kutz.) Rabh.	-	-	-	-	-	+	1
	Gomphonema brasiliense (Grun.)	-	-	-	+	-	-	1
	Gomphonema eriense (Grun.)	-	-	-	-	+	-	1
	Gomphonema gronuwii (Patr.)	-	-	-	-	-	-	0
	Gomphonema montanum (Patr.)	-	-	-	-	+	-	1
	Gomphonema olicaceum (Lyng.)	-	-	+	-	-	-	1
	Gomphonema olivacoides (Hust.)		-	-	-	-	-	0
	Gomphonema olivacoides (Hust.)	-	-	-	-	+	-	1
	Gomphonema parvulum (Kutz.) Kutz.	-	-	-	+	-	-	1
	Gomphonema tenellum (Kutz.)	-	-	+	-	-	+	2
Epithemiaceae								
	Denticula tenuis (Kutz.)	-	-	-	-	-	-	0
	Epithemia adnata (Kutz.) Patr.	-	-	-	-	-	-	0
	Epithemia turgid (NA)	-	-	-	-	-	-	0

Eunotiaceae								
	Eunotia vauheurkii (NA)	-	-	-	+	+	-	2
	Peronia intermedia (Breb.)	+	-	+	-	-	+	3
	Semiorbis hemicyclus (Ehr.)	-	-	-	-	-	-	0
Plagiotropidiceae								
	Plagiotropis Lepidoptera (CL.) Reim.	-	-	-	-		-	0
Cymbellaceae								
	Amphora submontana (Hust.)	-	-	-	-	-	+	1
	Amphora veneta (Kutz.)	+	-	-	-	-	-	1
	Cymbella angustata (W.Sm.) CL.	-	-	-	-	-	-	0
	Cymbella cistula (Ehr.) Kirchn.	-	-	-	-	-	+	1
	Cymbella minuta (Hilse ex. Rab.	-	-	-	-	+	+	2
	Cymbella minuta (Bleisch ex. Rab.) Reim.	-	-	+	+	+	+	4

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.12: Station Relative Abundance of Periphytic Diatoms in February

Family	Genus/ species	1	2	3	4	5	6	Total
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	+	-	5
	Cyclotella sp (Kutz.)	+	+	+	+	+	+	6
Fragilariaceae	*Fragilaria capucina(*Desm*)*	-	-	-	-	-	-	0
	*Fragilaria virescens (*Ralfs*)*	-	-	-	-	-	+	1
	*Frustulia rhomboids (*A. Mayer*)* Patr.	-	-	-	--	-	-	0
	Opephora swartzii (Grun.)	+	-	+	-	+	+	4
	Synedra famlica (Kutz.)	-	-	-	+	-	-	1
	Synedra fasciculate (Kutz.)	+	-	+	+	+	-	4
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	-	-	-	-	0
	Synedra robusta (Ralfs.)	-	-	-	-	-	-	0
	Synedra tenera (W.Sm.)	-	-	-	-	-	-	0
	Synedra ulna (Nitz.) Her.	+	+	+	+	+	+	6
	Synedra ulna (Her.) Grun.	-	-	-	-	-	-	0
	Synedra ulna (Her.) Grun.	-	-	-	-	-	+	1
	Tabellaria fenestrate (Lyngb.) Kutz.	+	+	+	+	+	+	6
Achnanthaceae								
	Achnanthes deflexa (Reim.)	-	-	-	-	-	+	1
	Achnanthes lanceolata (Breb ex kutz.)	-	-	-	-	-	-	0
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	-	-	-	-	-	-	0
	Rhoicosphaenia curtala (Grun.)	-	-	-	-	-	-	0
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.	-	-	+	-	-	-	1
	Diatomelia balfouria (Ehr.)	-	-	+	-	-	-	1
	Gyrosigma acuminatum (Kutz.) Ralbh.	-	-	+	+	+	+	4
	Gyrosigma exilis (NA)	-	-	-	-	-	-	0
	Gyrosigma hummi (NA)	-	-	-	-	-	-	0
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	-	-	-	-	-	0
	Navicula arvensis (Hust.)	-	-	-	-	+	+	2
	Navicula circumtexta (Meist. Ex. Hust.)	-	+	-	-	-	-	1
	Navicula costulata (NA)	-	-	-	-	-	-	0
	Navicula cuspida (Kutz.) Kutz.	-	-	-	-	+	-	1
	Navicula elegans (NA)	-	-	-	-	-	-	0
	Navicula explanata (NA)	-	-	-	-	+	-	1
	Navicula falaisenses (Grun.)	-	-	-	-	-	-	0
	Navicula gysingensis (Fogged.)	-	-	-	-	+	-	1
	Navicula ilopangensis (Hust.)	-	-	+	+	-	-	2
	Navicula imcomposita (NA)	+	+	-	-	-	-	2

	Navicula keelyi (NA)	-	-	-	+	-	-	1
	Navicula latelongitudinalis (NA)	+	-	-	-	-	-	1
	Navicula laterostrata (Hust.)	-	-	-	-	+	-	1
	Navicula mutica (Hilse.) Grun.	-	-	-	+	-	+	2
	Navicula notha (Wall.)	-	-	-	-	-	-	0
	Navicula paucivisitata (Patr.)	-	-	-	-	-	-	0
	Navicula placenta (Her.) Kutz.	-	-	-	+	-	-	1
	Navicula protracta (Grun.)	-	-	-	-	-	-	0
	Navicula simula (Grun.)	-	-	-	-	-	-	0
	Navicula specula (NA)	+	-	-	-	+	+	3
	Navicula subtillisima (Marg.)	-	-	-	-	-	-	0
	Navicula tenelloides (Hust.)	-	+	-	+	-	-	2
	Navicula variostrata (Kras.)	-	-	-	-	-	-	0
	Navicula wardii (Patr.)	-	-	-	-	-	-	0
	Neidum affine (Ehr.)	-	-	-	-	-	-	0
	Neidum hercyanicum (Wall.)	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	+	-	+	-	-	2
	Pinnularia abaujenensis (Pant.) Roos.	+	-	-	-	-	-	1
	Pinnularia divergens (W.Sm.)	-	-	-	-	+	-	1
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	+	-	-	-	1
	Pinnularia termitina (Ehr.) Patr.	-	-	-	-	-	-	0
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	+	-	-	-	-	1
	Pleurosigma delicatulum (W.Sm.)	-	-	-	-	-	-	0
	Pleurosigma salinarum (Grun.)							
Gomphonemaceae								
	Gomphonema affine (Kutz.)	-	-	-	-	-	+	1
	Gomphonema affine (Greg.) Andr.	-	-	-	-	-	+	1
	Gomphonema angustatum (Kutz.) Rabh.	-	-	-	-	-	-	0
	Gomphonema brasiliense (Grun.)	+	-	-	-	-	-	1
	Gomphonema eriense (Grun.)	-	-	-	-	-	-	0
	Gomphonema gronuwii (Patr.)	-	-	-	-	-	-	0
	Gomphonema montanum (Patr.)	+	-	-	-	-	-	1
	Gomphonema olicaceum (Lyng.)	-	+	-	-	-	-	1
	Gomphonema olivacoides (Hust.)	+	-	-	-	-	+	2
	Gomphonema olivacoides (Hust.)	+	-	-	-	-	-	1
	Gomphonema parvulum (Kutz.) Kutz.	+	+	-	-	+	+	4
	Gomphonema tenellum (Kutz.)	-	-	+	-	-	-	1
Epithemiaceae								
	Denticula tenuis (Kutz.)	-	-	-	-	-	+	1
	Epithemia adnata (Kutz.) Patr.	-	-	-	-	-	-	0
	Epithemia turgid (NA)	-	-	-	-	-	-	0
Eunotiaceae								
	Eunotia vauheurkii (NA)	-	-	-	+	-	-	1
	Peronia intermedia (Breb.)	-	+	+	+	-	+	4

	Semiorbis hemicyclus (Ehr.)	-	-	-	-	-	-	0
Plagiotropidiceae								
	Plagiotropis Lepidoptera (CL.) Reim.	-	-	-	-	-	+	0
Cymbellaceae								
	Amphora submontana (Hust.)	-	-	-	-	-	+	1
	Amphora veneta (Kutz.)	-	-	-	-	-	-	0
	Cymbella angustata (W.Sm.) CL.	-	-	-	-	-	-	0
	Cymbella cistula (Ehr.) Kirchn.	-	-	-	-	-	-	0
	Cymbella minuta (Hilse ex. Rab.	+	+	+	-	+	+	5
	Cymbella minuta (Bleisch ex. Rab.) Reim.	+	+	-	-	-	+	3

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.13: Station Relative abundance of periphytic diatoms in March

Family	Genus/ species	1	2	3	4	5	6	Total
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	+	+	6
	Cyclotella sp (Kutz.)	+	+	+	+	-	-	4
Fragilariaceae	*Fragilaria capucina(*Desm*)*	+	-	-	-	-	-	1
	*Fragilaria virescens (*Ralfs*)*	-	+	-	-	-	+	2
	*Frustulia rhomboids (*A. Mayer*)* Patr.	+	-	+	+	+	-	4
	Opephora swartzii (Grun.)	+	-	-	+	-	-	2
	Synedra famlica (Kutz.)	-	-	-	+	+	+	3
	Synedra fasciculate (Kutz.)	+	-	+	+	+	-	4
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	-	+	-	+	2
	Synedra robusta (Ralfs.)	-	-	-	-	-	-	0
	Synedra tenera (W.Sm.)	-	-	-	-	-	-	0
	Synedra ulna (Nitz.) Her.	-	-	+	-	-	+	2
	Synedra ulna (Her.) Grun.	-	-	-	-	-	-	0
	Synedra ulna (Her.) Grun.	-	-	+	+	-	-	2
	Tabellaria fenestrate (Lyngb.) Kutz.	-	+	+	+	+	+	5
Achnanthaceae								
	Achnanthes deflexa (Reim.)	-	+	-	-	+	-	2
	Achnanthes lanceolata (Breb ex kutz.)	-	-	-	-	-	-	0
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	-	-	-	-	-	-	0
	Rhoicosphaenia curtala (Grun.)	-	-	-	-	-	-	0
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.	-	-	-	-	-	-	0
	Diatomelia balfouria (Ehr.)	-	-	-	-	-	-	0
	Gyrosigma acuminatum (Kutz.) Ralbh.	-	-	-	+	+	+	3
	Gyrosigma exilis (NA)	-	+	-	-	-	-	1
	Gyrosigma hummi (NA)	-	+	-	+	-	-	2
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	-	-	+	+	+	3
	Navicula arvensis (Hust.)	-	-	-	-	-	+	1
	Navicula circumtexta (Meist. Ex. Hust.)	-	-	-	-	-	+	1
	Navicula costulata (NA)	-	-	-	-	+	-	1
	Navicula cuspida (Kutz.) Kutz.	-	+	-	-	-	-	1
	Navicula elegans (NA)	-	-	+	-	-	-	1
	Navicula explanata (NA)	-	-	-	-	-	-	0
	Navicula falaisenses (Grun.)	+	-	+	+	-	+	3
	Navicula gysingensis (Fogged.)	-	-	-	-	-	-	0
	Navicula ilopangensis (Hust.)	-	-	-	-	-	-	0
	Navicula imcomposita (NA)	-	-	-	-	+	-	1
	Navicula keelyi (NA)	-	+	-	-	-	+	2

	Navicula latelongitudinalis (NA)	-	-	-	-	-	-	0
	Navicula laterostrata (Hust.)	+	+	-	-	-	-	2
	Navicula mutica (Hilse.) Grun.	-	-	-	+	-	-	1
	Navicula notha (Wall.)	-	-	-	+	-	-	1
	Navicula paucivisitata (Patr.)	-	-	-	-	-	-	0
	Navicula placenta (Her.) Kutz.	-	-	-	+	+	+	3
	Navicula protracta (Grun.)	-	-	-	-	-	-	0
	Navicula simula (Grun.)	-	-	+	-	-	-	1
	Navicula specula (NA)	+	-	-	+	-	-	2
	Navicula subtillisima (Marg.)	-	+	-	-	-	-	1
	Navicula tenelloides (Hust.)	+	+	+	+	-	-	0
	Navicula variostrata (Kras.)	-	-	-	+	-	-	1
	Navicula wardii (Patr.)	-	-	-	-	-	-	0
	Neidum affine (Ehr.)	-	-	+	-	+	-	2
	Neidum hercyanicum (Wall.)	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	+	-	-	-	1
	Pinnularia divergens (W.Sm.)	-	-	+	+	-	-	2
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	-	-	-	-	0
	Pinnularia termitina (Ehr.) Patr.	+	+	-	+	+	+	4
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	-	-	-	-	+	1
	Pleurosigma delicatulum (W.Sm.) *Pleurosigma salinarum* (Grun.)	-	-	-	-	-	+	1
Gomphonemaceae								
	Gomphonema affine (Kutz.)	+	-	-	+	+	+	4
	Gomphonema affine (Greg.) Andr.	-	+	-	+	-	-	2
	Gomphonema angustatum (Kutz.) Rabh.	-	-	-	-	-	-	0
	Gomphonema brasiliense (Grun.)	+	-	-	-	-	-	1
	Gomphonema eriense (Grun.)	-	-	-	-	+	-	1
	Gomphonema gronuwii (Patr.)	-	-	-	-	-	-	0
	Gomphonema montanum (Patr.)	-	-	-	-	-	-	0
	Gomphonema olicaceum (Lyng.)	-	-	-	-	-	-	0
	Gomphonema olivacoides (Hust.)	+	+	+	-	+	-	4
	Gomphonema olivacoides (Hust.)	-	-	-	-	-	-	0
	Gomphonema parvulum (Kutz.) Kutz.	-	+	+	+	-	-	3
	Gomphonema tenellum (Kutz.)	-	-	-	-	-	-	0
Epithemiaceae								
	Denticula tenuis (Kutz.)	-	-	+	-	-	-	1
	Epithemia adnata (Kutz.) Patr.	-	-	-	-	-	-	0
	Epithemia turgid (NA)	-	-	-	-	-	-	0
Eunotiaceae								
	Eunotia vauheurkii (NA)	-	-	-	-	-	-	0
	Peronia intermedia (Breb.)	-	-	-	+	-	-	1
	Semiorbis hemicyclus (Ehr.)	-	-	-	-	-	-	0
Plagiotropidiceae								

	Plagiotropis Lepidoptera (CL.) Reim.	-	+	-	-	+	+	3
Cymbellaceae								
	Amphora submontana (Hust.)	-	-	-	+	+	-	2
	Amphora veneta (Kutz.)	-	-	+	-	-	-	1
	Cymbella angustata (W.Sm.) CL.	-	+	+	+	-	-	3
	Cymbella cistula (Ehr.) Kirchn.	-	-	-	-	-	-	0
	Cymbella minuta (Hilse ex. Rab.	+	+	+	-	-	-	3
	Cymbella minuta (Bleisch ex. Rab.) Reim.	-	-	-	-	-	-	0

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.14: Station Relative abundance of periphytic diatoms in April

Family	Genus/ Species	1	2	3	4	5	6	Total
Coscinodiceae	*Melosira sp* (Ehr.) Ralfs.	+	+	+	+	-	+	5
	Cyclotella sp (Kutz.)	+	-	-	+	+	+	4
Fragilariaceae	*Fragilaria capucina(*Desm*)*	-	-	-	-	-	-	0
	*Fragilaria virescens (*Ralfs*)*	-	-	+	+	+	-	3
	*Frustulia rhomboids (*A. Mayer*)* Patr.	-	-	+	-	-	-	1
	Opephora swartzii (Grun.)	-	-	-	-	-	-	0
	Synedra famlica (Kutz.)	-	-	-	-	-	-	0
	Synedra fasciculate (Kutz.)	-	-	-	-	-	-	0
	Synedra minusculata (Grun.Sensu. Patr.)	-	-	-	-	-	-	0
	Synedra robusta (Ralfs.)	-	-	-	-	-	-	0
	Synedra tenera (W.Sm.)	+	+	-	-	-	+	3
	Synedra ulna (Nitz.) Her.	-	-	-	-	-	-	0
	Synedra ulna (Her.) Grun.	-	-	+	-	-	+	2
	Synedra ulna (Her.) Grun.	-	+	+	+	+	+	5
	Tabellaria fenestrate (Lyngb.) Kutz.	+	+	+	+	+	+	6
Achnanthaceae								
	Achnanthes deflexa (Reim.)							
	Achnanthes lanceolata (Breb ex kutz.)	-	+	-	+	-	-	2
	Rhoicosphenia curvata (Kutz.) Grun ex Rab.	-	-	-	-	-	-	0
	Rhoicosphaenia curtala (Grun.)	-	-	-	-	-	-	0
		+	+	-	+	-	-	3
Naviculaceae								
	Amphipleura purpusila (Kutz.) Kutz.							
	Diatomelia balfouria (Ehr.)	-	-	+	-	-	-	1
	Gyrosigma acuminatum (Kutz.) Ralbh.	-	-	-	-	-	-	0
	Gyrosigma exilis (NA)	-	-	-	-	+	+	2
	Gyrosigma hummi (NA)	-	-	-	-	-	-	0
	Gyrosigma macrum (W.Sm.) Griff & Henfr.	-	-	-	-	-	-	0
	Navicula arvensis (Hust.)	-	-	-	-	-	-	0
	Navicula circumtexta (Meist. Ex. Hust.)	-	+	-	-	+	+	3
	Navicula costulata (NA)	+	+	+	-	-	-	3
	Navicula cuspida (Kutz.) Kutz.	+	-	-	-	-	-	1
	Navicula elegans (NA)	-	-	-	-	-	-	0
	Navicula explanata (NA)	-	-	-	-	-	-	0
	Navicula falaisenses (Grun.)	-	-	-	-	-	-	0
	Navicula gysingensis (Fogged.)	-	-	-	-	-	-	0
	Navicula ilopangensis (Hust.)	-	-	-	-	-	-	0
	Navicula imcomposita (NA)	-	-	-	-	--	-	0
	Navicula keelyi (NA)	-	-	-	-	-	-	0
	Navicula latelongitudinalis (NA)	-	-	-	-	-	-	0
	Navicula laterostrata (Hust.)	-	-	-	+	-	-	1
	Navicula mutica (Hilse.) Grun.	-	-	-	+	-	-	1

	Navicula notha (Wall.)	+	+	+	+	-	-	4
	Navicula paucivisitata (Patr.)	-	-	-	-	-	-	0
	Navicula placenta (Her.) Kutz.	+	-	-	-	-	-	1
	Navicula protracta (Grun.)	-	-	+	-	-	-	1
	Navicula simula (Grun.)	-	-	-	-	+	-	1
	Navicula specula (NA)	-	+	+	+	+	+	5
	Navicula subtillisima (Marg.)	-	+	-	-	-	-	1
	Navicula tenelloides (Hust.)	-	-	-	-	-	+	1
	Navicula variostrata (Kras.)	-	-	-	-	-	-	0
	Navicula wardii (Patr.)	-	-	-	-	-	-	0
	Neidum affine (Ehr.)	-	-	-	-	-	-	0
	Neidum hercyanicum (Wall.)	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia abaujenensis (Pant.) Roos.	-	-	-	-	-	-	0
	Pinnularia divergens (W.Sm.)	-	-	-	-	-	-	0
	Pinnularia mesolepta (Ehr.) W.Sm.	-	-	-	-	-	-	0
	Pinnularia termitina (Ehr.) Patr.	-	-	-	-	-	-	0
	Pleurosigma angulatum (Quek.) W.M.Sm.	-	-	-	+	-	+	2
	Pleurosigma delicatulum (W.Sm.)	-	-	-	-	-	-	0
	Pleurosigma salinarum (Grun.)	-	-	-	-	-	-	0
Gomphonemaceae								
	Gomphonema affine (Kutz.)							
	Gomphonema affine (Greg.) Andr.	-	-	-	-	-	-	0
	Gomphonema angustatum (Kutz.) Rabh.	-	-	-	-	-	-	0
	Gomphonema brasiliense (Grun.)	+	-	-	+	-	-	2
	Gomphonema eriense (Grun.)	-	-	-	-	-	-	0
	Gomphonema gronuwii (Patr.)	-	-	-	-	--	-	0
	Gomphonema montanum (Patr.)	-	-	-	-	-	-	0
	Gomphonema olicaceum (Lyng.)	-	-	-	-	-	-	0
	Gomphonema olivacoides (Hust.)	-	-	-	-	-	-	0
	Gomphonema olivacoides (Hust.)	-	-	-	-	-	--	0
	Gomphonema parvulum (Kutz.) Kutz.	-	-	-	-	-	-	0
	Gomphonema tenellum (Kutz.)	+	-	-	-	-	+	2
		-	-	-	-	-	-	0
Epithemiaceae								
	Denticula tenuis (Kutz.)							
	Epithemia adnata (Kutz.) Patr.	+	+	+	+	+	+	6
	Epithemia turgid (NA)	+	+	-	-	-	-	2
		-	-	-	-	-	-	0
Eunotiaceae								
	Eunotia vauheurkii (NA)							
	Peronia intermedia (Breb.)	-	-	-	-	-	-	0
	Semiorbis hemicyclus (Ehr.)	+	+	-	-	-	-	2
		+	-	-	-	-	-	1
Plagiotropidiceae								
	Plagiotropis Lepidoptera (CL.) Reim.							
		+	+	-	-	-	-	2
Cymbellaceae								
	Amphora submontana (Hust.)							

Amphora veneta (Kutz.)	-	-	-	+	+	-	2
Cymbella angustata (W.Sm.) CL.	-	-	-	-	-	-	0
Cymbella cistula (Ehr.) Kirchn.	-	-	-	-	-	-	0
Cymbella minuta (Hilse ex. Rab.	-	-	-	-	-	-	0
Cymbella minuta (Bleisch ex. Rab.) Reim.	+	-	-	-	-	+	2

Key:1-6 =Stations, + = Present, - = Absent, NA = No authors of species but authors of genus, Epithemia(Kutz), Eunotia(Ehr), Gomphonema(Ehr), Gyrosigma (Hassal), Pleurosigma(W. Sm), Navicula(Bory de St.Vincent).

Table 4.15: Correlation of the Relationship between Physicochemical and Biological Parameters in a Segment of River Galma

	Cosc	Frag	Achn	Navi	Gomph	Epith	Euno	Plag	Cymb	BOD	DO	EC	PH	TDS	TEMPL	TEMPF
Cosc	1															
Frag	0.2	1														
Achn	0.3	0.9*	1													
Navi	-0.1	0.8*	0.9*	1												
Gomph	-0.5*	0.3	0.3	0.5*	1											
Epith	0.4	-0.3	0	0	-0.1	1										
Euno	0.3	0.6*	0.6*	0.3	-0.2	-0.5*	1									
Plag	0	-0.6*	-0.6*	-0.8*	-0.6*	-0.4	0.2	1								
Cymb	0.3	0.7*	0.7*	0.5*	0.6*	-0.2	0.5*	-0.4	1							
BOD	-0.4	-0.1	0	0.4	0.6*	0.5*	-0.8*	-0.7*	-0.2	1						
DO	-0.4	-0.9*	-0.8*	-0.6*	-0.1	0.4	-0.8*	0.3	-0.7*	0.4	1					
EC	-0.4	0.2	0.2	0.6*	0.5*	0.2	-0.5*	-0.8*	-0.1	0.9*	0.1	1				
PH	-0.5*	-0.4	-0.3	-0.4	-0.2	-0.5*	0.3	0.8*	-0.4	-0.4	0.3	-0.4	1			
TDS	-0.6*	0.1	0.1	0.6*	0.5*	0.2	-0.5*	-0.7*	-0.2	0.9*	0.2	1	-0.3	1		
TEMPL	0.4	-0.3	0.1	0	-0.1	1	-0.4	-0.3	-0.1	0.4	0.4	0.2	-0.4	0.1	1	
TEMPF	-0.1	-0.8*	-0.4	-0.4	-0.2	0.7*	-0.6*	0.2	-0.6*	0.4	0.8*	0.1	0.2	0.1	0.8*	1
NH3	-0.9*	-0.4	-0.6*	-0.2	0.2	-0.4	-0.4	0.2	-0.6*	0.3	0.6*	0.3	0.6*	0.5*	-0.4	0.2
Cd	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ca	-0.6*	0.2	0.2	0.6*	0.8*	0	-0.4	-0.7*	0.1	0.9*	0.1	0.9*	-0.2	1	0	0
Cl	-0.2	0.3	0.3	0.7*	0.4	0.3	-0.4	-0.8*	-0.1	0.8*	0	1	-0.5*	0.9*	0.2	0
Co	0.4	-0.3	-0.4	-0.7*	-0.5*	-0.2	0.2	0.7*	0.1	-0.8*	0	-0.9*	0.2	-0.9*	-0.2	-0.2
Cu	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hard	-0.2	0.1	0.1	0.5*	0.3	0.4	-0.6*	-0.8*	-0.2	0.9*	0.1	0.9*	-0.6*	0.9*	0.3	0.1
Pb	-0.1	0.4	0.5	0.7*	0.1	0.3	-0.2	-0.7*	-0.2	0.6*	-0.1	0.9*	-0.4	0.8*	0.3	0.1
Mg	0.8*	-0.2	-0.1	-0.3	-0.8*	0.6*	-0.1	0.1	-0.3	-0.2	0	-0.2	-0.5*	-0.3	0.6*	0.3
NO3N	0.1	-0.4	-0.2	-0.2	-0.6*	0.6*	-0.3	0.1	-0.8*	0.2	0.5*	0.2	0.1	0.2	0.7*	0.8*
PO4P	0.1	-0.3	-0.3	-0.5*	-0.7*	-0.3	0.5*	0.9*	-0.4	-0.7*	0.1	-0.7	0.8*	-0.7*	-0.2	0.2
K	-0.7*	0.1	0.1	0.5*	0.5*	0.1	-0.5*	-0.6*	-0.2	0.9*	0.2	0.9*	-0.1	1	0	0.1
Na	-0.4	0.2	0.1	0.6*	0.4	0.2	-0.5*	-0.8*	-0.2	0.9*	0.1	1	-0.4	1	0.1	0
SO4	-0.1	-0.8*	-0.7*	-0.8*	0	0.3	-0.5*	0.5*	-0.2	0	0.7*	-0.4	0.2	-0.3	0.3	0.5*
Zn	0.4	-0.3	0.1	0	-0.1	1	-0.4	-0.3	-0.1	0.4	0.4	0.2	-0.4	0.1	1	0.7

Table 4.15 cont'd: Correlation Relationship between Physicochemical and Biological Parameters in a Segment of River Galma

	NH3	Cd	Ca	Cl	Co	Cu	Hard	Pb	Mg	NO3N	PO4P	K	Na	SO4	Zn
Cd	NA	1													
Ca	0.5*	NA	1												
Cl	0.2	NA	0.8*	1											
Co	-0.3	NA	-0.8*	-0.9*	1										
Cu	NA	NA	NA	NA	NA	1									
Hard	0.2	NA	0.8*	1	-0.7*	NA	1								
Pb	0.1	NA	0.6*	0.9*	-0.9*	NA	0.8*	1							
Mg	-0.6*	NA	-0.5*	0	0.3	NA	0.1	0.1	1						
NO3N	0.1	NA	-0.1	0.2	-0.3	NA	0.2	0.4	0.5*	1					
PO4P	0.1	NA	-0.7*	-0.7*	0.5*	NA	-0.7*	-0.4	0.2	0.3	1				
K	0.6*	NA	0.9*	0.9*	-0.9*	NA	0.8*	0.7*	-0.4	0.2	-0.5	1			
Na	0.4	NA	0.9*	1	-0.9*	NA	0.9*	0.8*	-0.2	0.2	-0.7*	0.9*	1		
SO4	0.1	NA	-0.3	-0.5*	0.5*	NA	-0.3	-0.7*	0	0	0.1	-0.3	-0.4	1	
Zn	-0.4	NA	0	0.2	-0.3	NA	0.3	0.3	0.6*	0.7*	-0.2	0	0.1	0.2	1

Key: Cosc = Coscinodiceae, Frag = Fragilariaceae, Achn = Achnanthaceae, Navi = Naviculaceae, Gomph = Gomphonemaceae, Epith = Epithemiaceae, Euno = Eunotiaceae, Plag = Plagiotropidiceae, Cymb = Cymbellaceae BOD = Biochemical Oxygen Demand, DO = Dissolved Oxygen, EC = Electrical Conductivity, TDS – Total Dissolved Solids, T1 – Temperature Laboratory, T2 = Temperature Field, NH_4 = Ammonium, Cd = Cadmium, Ca = Calcium, Cl = Chloride, Co = Cobalt, Cu = Copper, HA = Hardness, Pb = Lead, Mg = Magnesium, N-N = Nitrate – Nitrogen, P –P = Phosphate-Phosphorus, K = Potassium, Na = Sodium, Sulphate, Zn = Zinc, NA & 0 = Not detected, 0.5 -0.9 = positive correlation, - 0.5 – 0.9 = negative correlations respectively.

Achnanthaceae (r =-0.8) and Fragilariaceae (r = -0.9). Electrical conductivity showed a positive correlation with Naviculaceae (r=0.6), Gomphonemaceae (r=0.5), Cymbellaceae (r=0.9) and a negative correlation with Eunotiaceae (r=-0.5) and Plagiotropidiceae (r=-0.8). pH showed a positive correlation with Plagiotropidiceae (r=0.8) and a negative correlation with Coscinodiceae and epithemiaceae (r= -0.5) respectively. Total dissolved solids showed a positive correlation with Naviculaceae (r=0.6), Gomphonemaceae (r=0.5), Biological oxygen demand (r=0.9) and a negative correlation with Coscinodiceae (r=-0.6), Eunotiaceae (r=-0.5) and Plagiotropidiceae (r=-0.7). Temperature field showed positive correlation with Epithemiaceae (r=0.7), Dissolved oxygen (r=0.8), Temperature laboratory (r=0.8) and a negative correlation with Fragilariaceae (r=-0.8), Eunotiaceae and Cymbellaceae (r=-0.6) respectively. Hardness showed a positive correlation with Naviculaceae (r=0.5), Electrical conductivity (r=0.9), Cadmium (r=0.8) and negative correlation with Eunotiaceae and Electrical conductivity (r=-0.6), Plagiotropidiceae(r=-0.8) and Chloride(r =-0.7). Calcium showed a positive correlation with Temperature field (r=0.5), Naviculaceae (r=0.6), Gomphonemaceae (r=0.8), Biological oxygen demand and Electrical conductivity (r=0.9) and negative correlation with Coscinodiceae (r=-0.6) and Plagiotropidiceae (r=-0.7). Magnesium showed a positive correlation with Coscinodiceae (r=0.8), Epithemiaceae and Temperature field (r=0.6) and negative correlation with pH and Cadmium (r=-0.5) and Gomphonemaceae (r=-0.8). Potassium showed a positive correlation with Naviculaceae, Gomphonemaceae (r=0.5), Ammonium (r=0.6), Hardness (r=0.7), Biological oxygen demand, Electrical conductivity, Cadmium and Calcium(r=0.9) and negative correlation with Eunotiaceae, Nitrate-Nitrogen (r=-0.5), Plagiotropidiceae (r=-0.6), Coscinodiceae (r=-0.7) and Chloride (r=-0.9). Sodium showed

a positive correlation with Naviculaceae (r=0.6), Hardness (r=0.8), Biological oxygen demand, Cadmium, Cobalt and Phosphate-Phosphorus (r=0.9) and negative with Eunotiaceae (r=-0.5) and Plagiotropidiceae (r=-0.8). Ammonium showed a positive correlation with Total dissolved solids (r=0.5), Dissolved oxygen, pH (r = 0.6) and a negative correlation with Coscinodiceae (r=-0.9), Achnanthaceae and Cymbellaceae (r=-0.6) respectively. Chloride showed positive correlation with Naviculaceae (r=0.7), Biological oxygen demand and Cadmium(r=0.8) and negative correlation with pH (r=-0.5) and Plagiotropidiceae (r=-0.8). Nitrate showed a positive correlation with Dissolved oxygen, Magnesium (r=0.5), Epithemiaceae (r=0.6), Temperature field (r=0.7), Temperature laboratory (r=0.8) and negative correlation with Gomphonemaceae (r=-0.6) and Cymbellaceae (r=-0.8). Phosphate- Phosphorus showed a positive correlation with Eunotiaceae, Chloride (r=0.5), pH (r=0.8), Plagiotrodiceae (r=0.9) and negative correlation with Naviculaceae (r=-0.5), Gomphonemaceae, Electrical conductivity, Total dissolved solids, Calcium, Cobalt, Copper (r=-0.7) respectively. Sulphate showed a positive correlation with Temperature field, Chloride, Cobalt (r=0.5), Biological oxygen demand (r=0.7) and negative correlation with Eunotiaceae, Calcium (r=-0.5), Achnanthaceae, Hardness (r=-0.7), Fragilariaceae and Naviculaceae (r=-0.8). Cobalt showed a positive correlation with Plagiotropidiceae (r=0.7) and negative correlation with Gomphonemaceae (r=-0.5), Naviculaceae (r=-0.7), Biological oxygen demand, Cadmium (r=-0.8) and Electrical conductivity, Total dissolved solids and Calcium (r=-0.9) respectively. Zinc showed a positive correlation with Hardness (r=0.6), Temperature laboratory, Magnesium (r=0.7).

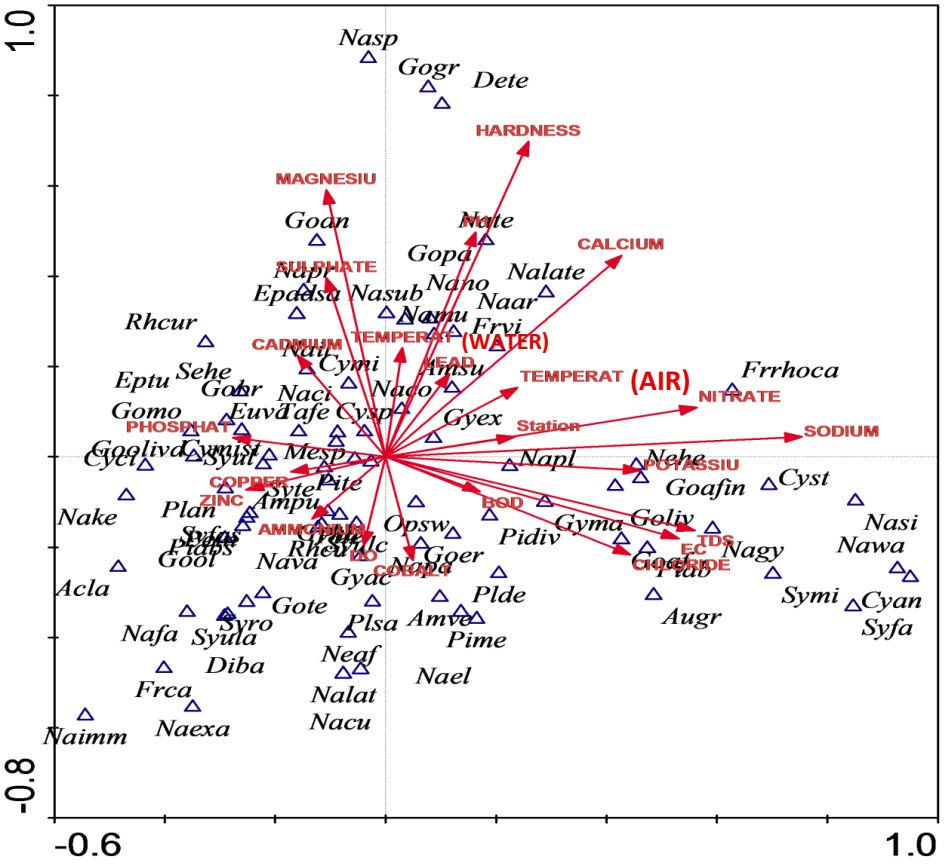


Fig 4.23:

Canonical Correspondence Analysis of the Relationship between Diatoms and Physicochemical Parameters

Key: Napl= *Navicula placenta*, Nehe=*Neidum herrmanii*, Goafin= *Gomphonema affine var insigua*, Cyst= *Cymbella stleriaca*, Nasi= *Navicula sinuata*, Nawa= *Navicula wardii*,Cyan= *Cymbella angustatum*, Syfa= *Synedra falaisensis*, Symi= *Synedra minuta*, Nagy= *Navicula gysingensis*, Goliv= *Gomphonema olivaccoides*,Gyma= *Gyrosigma macrum*, Pidiv= *Pinnularia divergens*, Opsw= *Opephora swartzii*, Goer= *Gomphonema eriense*, Napa= *Navicula parvulum*, Plde= *Pleurosigma delicatulum*, Amve= *Amphora veneta*,Pime= *Pinnularia mesolepta*, Nael= *Navicula elegans*, Nacu=*Navicula curvata*, Nalat= *Navicula laterostrata*, Neaf= *Neidum affine*,Plsa= *Pleurosigma salinarum var boyeri*,Gyac= *Gyrosigma acuminatum*, Nava= *Navicula variostrata*,Rhcu= *Rhoicosphaenia curvata*, Ampu= *Amphipleura purpusila*, Syte= *Synedra tenera*, Pite= *Pinnularia tenelloides*, Mesp= *Melosira sp*, Syul= *Synedra ulna*, Cyci= *Cymbella cistula*, Nake= *Navicula keelyi*, plan= *Pleusigma angustatum*,Syfas= *Synedra fasciculata*, Piabs= *Pinnularia abaujenensis var subundulata*, Gool= *Gomphonema olicaceum*, Acla= *Achnanthes lanceolata*,Nafa= *Navicula falaisensis*, Frca= *fragilaria capucina*,Naexa= *Navicula explanata*,Diba=*Diatomela balfouria*, Naimm= *Navicula immcomposita*, Goolivd= *Gomphonema olivacoides var densestriata*, Cymist= *Cymbella minuta var stleriaca*,Euva= *Eunotia vauhecrkii*, Tafe= *Tabellaria fenestra*, Naci= *Navicula cistula*, Cysp= *Cymbella sp*, Gomo= *Gomphonema montanum*, Eptu= *Epithemia turgid*, Gobr= *Gomphonema brasilensis*, Sehe= *Semiorbis hemicyclus*, Rhcur= *Rhoicosphaenia curtala*, Epadsa= *Epithemia adnata var saxonica*, Napr= *Navicula protracta*,Nasub= *Navicula subtillisima*, Goan= *Gomphonema angustatum*, Nasp= *Navicula spicula*, Gogr= *Gomphonema grunuwii*, Dete= *Denticla tenuis*, Nate= *Navicula tenellum*, Gopa= *Gomphonema parvulum*, Nano= *Navicula notha*, Namu= *Navicula mutica*, Naco= *Navicula costulata*, amsu= *Amphora submontana*, Frvi= *Fragilaria virescens*, Naar= *Navicula arcensis*, Nalate= *Navicula latelongitudinalis*,Gyex= *Gyrosigma exilis*, Frrhoca= *Frustulia rhomboids var capitata*

4.5.2 Relationships between Diatoms and Physico-Chemical Parameters

Canonical correspondence analysis (Figure 23) showed that *Melosira sp, Cymbella minuta var stleriaca, Gomphonema olivacoides var densegensis, Gomphonema montanum,, Eunotia vauheurckii, Tabellaria fenestra, Navicula circumtexta, Gomphonema brasiliensis, Epithemia turgida, Semiorbis hemicyclus, Rhoicosphaenia curvata, Cyclotell sp, Navicula ilopongensis, Epithemia adnata var saxonica, Navicula protracta, Gomphonema affine, Navicula spicula* showed a positive association with Phosphate, Cadmium, Sulphate and Magnesium but are negatively related to Cobalt Chloride Electrical Conductivity, Total Dissolved Solids and Biochemical Oxygen Demand. *Navicula costulata, Amphora submontana, Navicula mutica var undulata Navicula subtilissimum, Navicula notha, Gomphonema parvulum, Navicula tenelloides, Gomphonema granulata, Denticula tenuis, Navicula arcensis, Navicula laterostrata, Frustulia rhomboides var capitata Fragilaria virescence, Gyrosigma exilis* showed a positive relationship with Temperature laboratory and Field, Lead, Calcium, Hardness, Nitrate and Sodium but indicated a negative relationship with Ammonium, Copper, Dissolved Oxygen and Zinc respectively. *Navicula placenta, Neidum hercyanicum, Opephora schwartzii, Navicula parvulum, Gomphonema eriense, Pinnularia divergens, Gyrosigma macrum, Gomphonema olicaceum, Gomphonema affine var insigua, Cymbella stleriaca, Navicula sinuate, Navicula gysingensis, Navicula wardii, Synedra sinuta, Synedra minuta, cymbella angustatum, Synedra falaisensis, Aulocoseira granulata, Plagiotropis Lepidoptera var probiscidea, Amphora veneta, Pinnularia mesolepta and Navicula elegans* showed positive relation to total dissolved solids, Chloride, biochemical oxygen demand, Cobalt, Potassium and electrical conductivity. A

negative relationship was indicated with Cadmium, Phosphate, Sulphate and Magnesium. *Cymbella cistula, Synedra ulna, Pinnularia termitina, Synedra tenera, Amphora perpusila, Pleurotaenium angustatum, Navicula keelyi, Synedra famlica, Pinnularia abaujensis var subundulata, Gomphonema olivacoides,Navicula variostrata,Rhoicosphaenia curtala, Gyrosigma aculeatum, Gomphonema tenellum, Synedra robusta, Synedra ulna var ampula, Diatomella balfouriana, Fragilaria capitata, Navicula imcomposita, Navicula expansa, Navicula curvata, Navicula latelongicep, Neidum affine* showed a positive association with Copper, Ammonium, zinc and Dissolved Oxygen but showed negative relationship with Calcium, Temperature, Nitrate, Sodium, Lead and Hardness.

4.5.3 Diversity indices of diatoms

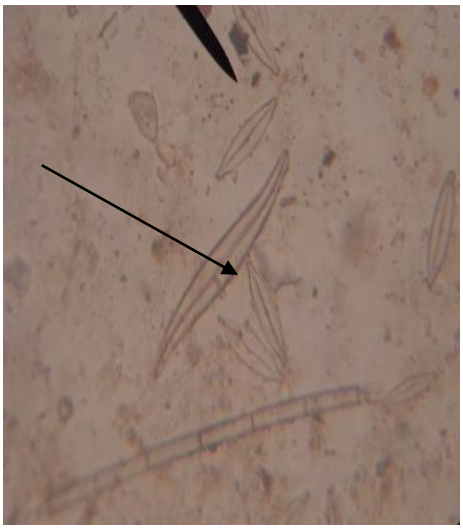
The result of diversity indices (Table 4.16) showed that the month of January had the highest number of taxa (119) as well as individuals (4597) while the month of April and November had the lowest taxa (58) and individuals (1137) respectively. Dominance was higher in February (0.07) and lower in March (0.03). Simpson diversity index was higher in March (0.97) and lower in February (0.93). Shanon-H index was higher in November (3.83) and lower in April (3.22).

Table 4.16: Periphytic diatom community structure analyses results of River Galma

Diatoms diversity indices	Months					
	November	December	January	February	March	April
Taxa_S	116	110	119	88	103	58
Individuals	1137	1276	4597	1742	1497	1186
Dominance_D	0.0355	0.0434	0.04049	0.06956	0.03366	0.05766
Simpson_1-D	0.9645	0.9566	0.9595	0.9304	0.9663	0.9423
Shannon_H	3.83	3.76	3.651	3.345	3.793	3.215



(a): *Cyclotell sp* (coscinodisceae)



(a): *Gyrosigma sp* (Naviculaceae)



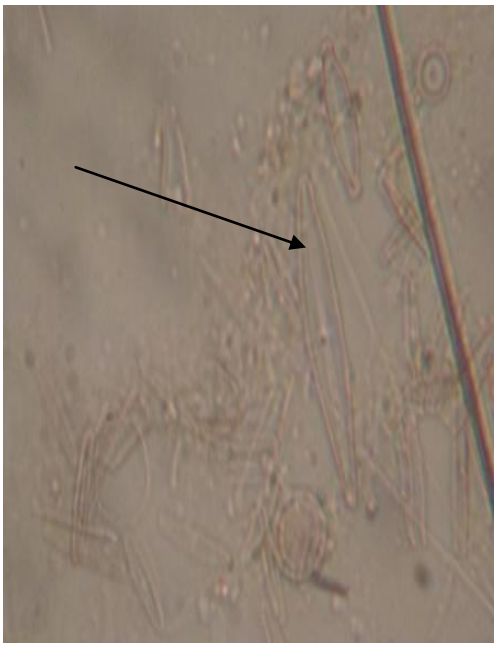
(a) *Synedra sp* (Fragilariaceae)



(d) *Pinnularia sp* (Naviculaceae)

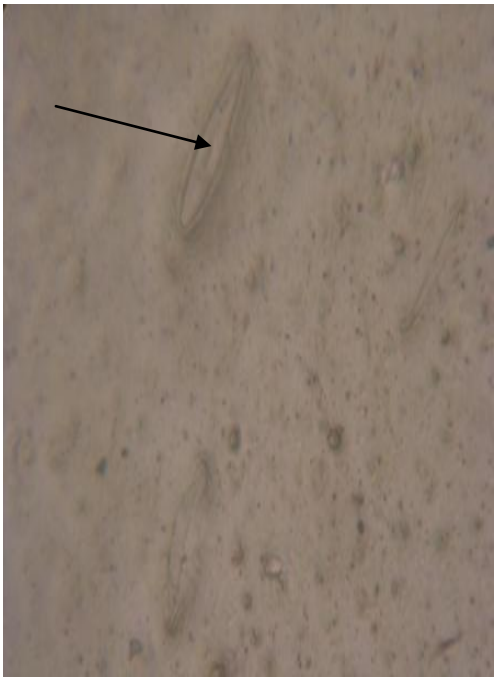
Plates I: Representative species of periphytic Diatom families observed in River Galma





(a) *Cymbella* sp. (Cymbellaceae) (b) *Navicula* sp. (Naviculaceae)





(c)*Achnanthes sp* (Achnanthaceae) (d):*Gomphonema sp* (Gomphonemaceae)

Plate II: Representative species of periphytic diatom families observed in a segment of River Galma.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physico-chemical Parameters

The aim of this study is to determine the physicochemical parameters, Periphytic diatom composition and diversity and data obtained will provide baseline information on the periphytic diatom composition and diversity in a segment of River Galma in relation to the water status. The following parameters Biochemical oxygen demand, dissolved oxygen, electrical conductivity, total dissolved solids, pH, air water temperature field, laboratory water temperature, ammonium, chloride, sulphate, phosphate-phosphorus, nitrate-nitrogen, calcium.sodium, magnesium, potassium,cadmium, cobalt, copper, lead, zinc and periphytic diatom diversity and abundance were studied

The quality of any given water body is influenced by physical and chemical factor which ultimately determines the species composition of the water body. These physicochemical parameters interact with one another and with more than one parameter at a time to greatly influence the water quality characteristic. The variation displayed by the results of most physicochemical parameters between months and stations to be below the permissible limits of World health organization (WHO) standards for drinking water implies that the water is not polluted by these parameters. This agree with the finding of Butu and Bichi, (2013). The low values could be attributed to the natural processes of physical, chemical and biological characteristics of the water such as self purification and utilization of the nutrients for growth, reproduction and restoration to its pristine conditions. Edward and Ugwumba, (2010) made similar observation in Egbe River Ekiti

and reported that the low values of parameters was due to interplay between the physical, chemical and biological processes that self purify the water. The consistency of most physicochemical parameters to be low is an indication of clean water. This result is similar to that of Pongpan and Yuwade, (2010) in ping river, Thailand, where low values were recorded and inferred that the water is clean. Higher Values (8.49 mg/L) of dissolved oxygen above WHO standard could be attributed to the unpolluted nature of the water and rapid photosynthesis from aquatic macrophytes increasing oxygen concentration. DO concentrations of unpolluted water are normally about 8-10 mg/L (DFID, 1999). This agrees with report of Araoye (2008) where he observed that, higher oxygen concentration of 8.2 mg/L in Omi, Kogi during the dry season was due to enhanced photosynthetic activities. Lead concentration was higher than the permissible limits of World health organization standards. Butu and Bichi, (2013) reported higher concentration of lead in river Galma. High concentration of lead and cadmium in the water body could possibly be due to lickage and corrosion of water pipes, organochemicals from irrigated farms and industrial effluent, oils, paints, batteries from pluvial discharge of domestic man made wastes dumped in the river, dust from the combustion of fuels from automobiles constantly washed in river Galma and discharge of corroded galvanized pipes, leachates from landfill and geologic processes respectively contain these metals and can release them. Lead and cadmium at high concentration is dangerous to aquatic organism and algae including man accumulating in soft tissues and bones (Wikipedia, 2013) causing human problems like the nervous system damage, crime and anti-social behavior in children (USGAO, 2000). Chia (2007) made similar

observation. Lead poisoning disease was reported to kill 355 children in six villages of Zamfara (Ibrahim *et al.,* 2010).

The variation of biochemical oxygen demand between months and stations could be implicated to the build up of organic load of fertilizer from irrigated farms, sewage and other biological activities such as decomposition of plants and animals around and in the water. This agrees with the findings of Tanimu (2008) who attributed the BOD variation to decomposition of organic waste by bacteria. The level of organic and inorganic matter in water is related to the amount of biochemical oxygen demand. Increase in organic load lowers amount of dissolved oxygen as decomposer utilize it for oxidation. Gomphonemaceae and Epithemiacea show positive correlation while Plagiotropidiceae showed negative correlation. This could implied that Gomphonemaceae and Epithemiaceae population will increase with correspondence increase in the concentration of BOD while that of Plagiotropidiceae decreases. This agree with Adakole *et al*.(2008) who reported that the correlation that exist between the physicochemical quality of a water body and the population of organisms indicates that the physicochemical quality tends to have regulated the distribution of the organism. Mahar (2003) made similar observation in Lake Manchlar. The value of BOD 5.32 mg/ in January and station 5 indicated nutrient rich water possibly because of runoff from excessive use of fertilizer from irrigated farms and domestic waste and sewages from both Kubani and Galma add organic and inorganic load in the water around the catchment areas and or present of oxygen demanding pollutants (organochemicals) in the water body. Amadi *et al.* (2006), made similar observation.

This higher concentration of DO 8.49 mg/L is an indication of unpolluted water and could be attributed to enhanced photosynthesis from aquatic macrophytes, diffusion from the atmosphere all contribute in oxygenating the water. Araoye (2008) recorded similar high concentration of 8.2 mg/L in Omi, Kogi and attributed it to enhanced photosynthesis, low organic load and decomposers to utilize it for oxidation. According to DFID (1999), DO provides a broad indicator of water quality and that DO concentration of unpolluted waters are normally about 8-10 mg at (25 ^{0}C). The change in temperature, depth, water movement and biological activities may be responsible for the significant variation of dissolved oxygen within months. The highest peak recorded by dissolved oxygen in January coincided with the minimum water temperature because of the cool North-East harmatan. Water loose oxygen at high temperature. This agrees with the observations reported by Balarabe (2001) and chia (2007). The value of 8.4 mg/L is similar to that of Karikari *et al*. (2007) in River Volta and lower than 6.7 mg/L of Salanta River in Kano observed by Mohammed and Saminu, (2012). Emmanuel and Onyeama (2007) reported value of 3.4-4.5 mg/L in polluted water and Nkwoji (2005) reported highest value of 5.2 mg/L in Lagos lagoon.

Variation in concentration of electrical conductivity may be due to runoff from farms and excessive evaporation associated with decreased in depth of water as it flows and used for domestic and agricultural purposes add concentration of ions. High concentration at sampling point five could be as a result of more dissolved salts from Kubani river and also as a result of decreased level of water and evaporation from intense heat. Ahmed (2014) made similar observation in Ajiwa Reservoir Katsina and agrees with the findings of (comin *et al*., 1983) in their limnological study of Gallocanta lake, Aragon, Spain,

observed that high balance of evaporation lead to reduction in water volume with an increase in salt concentration. Atobatele and Ugwumba (2008) suggested that decrease in conductivity during the rainy season may be due to dilution by rainwater and higher values in the dry season may be from chemical fertilizer from irrigated farmlands around the water body coupled with higher rate of evaporation that reduces the level of water during the dry season; thus conductivity of water depends on the concentration of ions and nutrient status.

A pH of 6.95 -7.53 recorded shows that the water of the river was circum neutral, falls within the acceptable limit of WHO (2004) 7.0-8.5. pH of this result was at a range that supports biological activities. Ibrahim *et al*. (2009) reported that pH values of 6.5-8.5 was nearly neutral throughout both season and was within the range for inland water in kontagora reservoir, Niger state Nigeria.which makes it suitable for optimal biological activity. pH Values of 6.98-7.50 was reported by Ali *et al*. (2013) in lower Niger, Kogi, 6.9-7.6 in Tiga Lake Kano. pH is an important indicator of water quality and extend of pollution in the aquatic environment. Low pH values or acidic waters are known to allow toxic elements and compounds such as heavy metals to become mobile thus producing conditions that are inimical to aquatic life (APHA, 1995). The little increase in pH could be due to decaying and decomposition of living organism in the water coupled with reduction in water level of the dry season due to irrigation. Increase in alkalinity values could result from extended dry season period, high evaporation and the nature of the substratum (Chindah and Brailde, 2004**).**

The significant variation could be attributed to photosynthesis, change in the values of carbon (IV) oxide, Carbonate and bicarbonate in the water. Mustapha (2008) reported the

variation in pH to high Carbon (IV) oxide concentration occurring from organic decomposition in Oyun Reservoir, Offa. Wetzel (2001) observed that photosynthesis strongly affect pH causing water to become more alkaline. All biological activities depend on pH, any change in pH affects organism productivity in the ecosystem. Similar observation was reported by Chia (2007).

Total dissolved solids significantly varied possibly because of the gradual entry of substances such as soil particles mixed up with fertilizer from irrigated land, disturbance of the sediments by grazing animals, domestic sewage runoff and effluents from Zaria water treatment plant entering the river from neighboring settlements and farm lands especially sampling point two and five that introduced more substances from river Kubani thereby increasing the concentrations of dissolved substances in water. Carpenter and Waite,(2000) and Akin-Oriola(2003) made similar observations. The fluctuation could also be due to variations in the decomposition of organic matter of plants residue from the farms and low level of water due to evaporation. This agree with the finding of Atobatele and Ugwumba,(2008) who reported that the decaying of vegetation in the dry season lead to rise in the amount of total dissolved solids and low in the rainy season due to dilution factor. Soil beneath water contributes to the level of total dissolved solids in water.

The variation of temperature between months and stations could be as a result of response to seasonal changes in air temperature especially in the northern part of the country from the Northeast trade wind and turbulence of water as it moves thereby losing heat which invariably lowers the temperature. This agrees with the findings of Balarabe (2001), Chia

(2007) and Indabawa (2009). The range in this study compares well with values of 27.6-28.0 ^{0}C in Jebba and contradicts 25.9-32.4 ^{0}C reported by Ansa (2005) in Andoni Rivers, possibly because of its location in the humid equatorial area. In the tropics, water temperature variation is governed by climatic factors (Kadiri 2000a). The low temperature observed in November and February could apart from the cool harmattan be due to the time of the day sampling was conducted (Ovie and Adayi, 2000). The absence of significant difference in temperature between months and stations is a characteristic of the tropical climate (Ezra and Nwankwo, 2001). Tiseer *et al*. (2008) reported similar result. Lack of significant difference between stations is due to the absence of micro climate variation.

The significant variation in Hardness could be implicated to reduced water level through evaporation and irrigation in the dry season and also the increased concentration of Carbonate and bicarbonate ions of Calcium, Magnesium and Potassium from water used for laundry and domestic purposes and other hydroxide forming compounds. This result is similar to that of Ibrahim *et al.* (2009) who opined that hardness is higher in the dry season due to low water levels with its attendant concentration of salts. Most of the values obtained were low classifying the water as soft. The value of 80.64 mg/L in April agrees with that of 80.45 mg/L of hard water reported in Illaje Ondo (Ajibare, 2014). The significant difference between months due to high concentration of carbonates agrees with findings of Balogun *et al*. (2005) in Makwaye Dam.

5.2 Anions

The variation in nutrients could be due to reduced water levels and agricultural drain due to excessive use of fertilizers and organochemicals with varying proportion of nutrient as the major occupation of the study area is farming to improve crop yield by farmers around the river increased their concentrations beside those embedded in sediment. Ahmed (2014) reported that the high concentration of nitrates in the rainy season to be due to excessive influx of nutrients from farmlands and runoff. Land use in the riverine areas in Nigeria is predominantly farming (Adeyemo *et al.,* 2008). Nitrate higher concentration than phosphate could be due to the presence of some blue-green algae like *Anabaena sp* and *Nostoc* s*p* encountered during this study have heterocysts and *Lyngbya sp* and *spirulina sp* that live symbiotically with diatoms all have ability to fix atmospheric nitrogen into nitrates and not phospates for use by algae. Plant decay and animal debris (including fish, wild animals and birds) may be other sources of nitrates in the study area beside man made sources like fertilizers with varying proportion of these elements. Nitrate is the most important nutrient in the ecosystem (Chandaluri *et al*., 2010). It stimulates plankton growth and water weeds that provide food to fish. Phosphates are less soluble and volatile forming salts with calcium and magnesium and fall out of solution to accumulate in the sediment. Phosphate ions in natural water exist in solution in its ionized form, as salts and in organic form and therefore taking rapidly by plants and bacteria (Patra, 2011). This could be implicated for its low concentration. Equally, a bloom of phytoplankton associated with high nutrients concentration increase the population of tolerant species and massive death of intolerant species due to lack of oxygen and space required for the decomposition of the increasing concentration of

organic matter content from the death of these intolerant species. Adakole *et al*. (2008) and Kadiri (2006) made similar observations.

The observed variation in Chloride concentration could be implicated to anthropogenic activities particularly livestock grazing, laundry, agrochemicals, automobiles repairs around the catchment area and deicers from road construction. Kaushal (2005) reported high concentration of chloride to deicer mostly from road construction and has negative effect on aquatic organisms changing water chemistry. In addition, high concentration could be due to large amount of organic matter of both allochthonous and autochthonous origin. Chloride ions are essential for photolysis to release oxygen for A.T.P formation and Phosphorylation reaction. The salts of Sodium, Calcium and Magnesium from fertilizer contribute to concentration of chloride in water. Large contents of chlorides in freshwater is an indication of pollution (Chandra *et al*., 2012). Chlorine kills diatoms growing in water with high levels of organic pollution (person, 1989). Babatunde (2009) made similar observation.

5.3 Cations

Concentration of Cations in this study indicated this trend Mg > Na > K >Ca. This variation could be due to the land use pattern and geology of the study area. The concentration of Sodium in this study could be attributed to precipitation of calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$ and runoff from roads.This agree with finding of Tewodros and Afework, (2014) in Ethopia. Koistic (2010) reported that stream salinity is impacted greatly by addition of dissolved salts such as sodium chloride to prevent ice formation on roads. However, he explained that on the other hand if drainage water

passes over non calcareous rocks such as granite igneous, less Calcium ions will be present in the water. This could account for the low concentration of Calcium as the underlying water rock is granite igneous rock.

The variation in the concentration of Potassium could be implicated to human activities such as use of potassium based inorganic fertilizer. Introduction of potassium ions as a result of artificial fertilizer has been reported in Makwaye Reservoir, Zaria (Balarabe, 1989) and Romi stream, Kaduna (Hassan, 1998). Similar observation was reported by Vaisanen *et al*. (1998). Magnesium concentration was higher than Calcium probably because the underlying granite igneous rocks are biotites, which is a ferromagnesium mineral and rich in soluble magnesium. Magnesium is often associated with calcium in all kinds of water. This findings contradicts that of Babatunde (2009) with this trend Mg >K> Ca>Na in Assessment of Physicochemical parameters of Selected Biota and Fishes of Kuddiffi, Kubani Stream, Hanwa Makera Zaria,Nigeria and that of Arienzo *et al.* (2000) in this order Ca >Na >Mg >K in the work on Sarno River. This could be due to variation in the prevailing environmental factors, different anthropogenic activities and the nature of the sediments in the catchment areas which affect the concentrations of cations. Balarabe (2001) reported similar observation in Dumbi and Kwangila ponds, Zaria, Nigeria.

5.4 Heavy Metals

The presence of heavy metals in aquatic environment in trace concentration is important for normal development of the organism (kori *et al*., 2008). These metals are cofactors of a large number of enzymes and have a range of intake beyond that ranges are toxic and below they are inadequate. Research has shown that aquatic plants are not able to

successfully regulate metal uptake (Connell *et al.*, 1984). In comparism to freshwater fish and invertebrates, aquatic plants are equally less sensitive to Cadmium, Copper, Lead and Zinc. However, no known species of Phytoplankton grow using cadmium or Lead because they are toxic metals.

Cadmium had a mean concentration of 4.05 mg/L and is above the acceptable limit in drinking water of 0.003 mg/L (WHO 2011). Cadmium concentration may be due to pluvial discharge of man made debris such as corroded galvanized pipes, batteries from homes and shops, natural and industrial activities such as volcanic emissions, geologic processes, leachates from landfill, electroplating, metallurgy of zinc and cement production all release cadmium. High concentration could be implicated to the use of phosphatic fertilizer in farms and also the inability of phytoplankton to utilize it. Mason (2002) reported similar findings in Egypt. Julius (2014) and Hanaa *et al*. (2000) reported concentrations of 0.044 mg/L and 0.03 mg/L in Kubani and El.magr. Cadmium is toxic even at low concentration and may induce kidney dysfunction, headache, vomiting, osteomalacia and reproductive deficiency. Ikem (2005) made similar observation.

Cobalt concentration of 0.04 mg/L is lower than 0.3 mg/L reported by Butu and Bichi, (2013) in Galma reservoir. This could be explained by the loading of the reservoir with debris and effluents produced by various human activities within the river catchment area and disturbance of sediments known to contain high concentration of heavy metals. The concentration of cobalt could be due to green leafy vegetables such as spinach, carrots predominantly produced washed in the catchment area of river Galma. Cobalt is important at a low level for enzymes activity but at high concentration, it caused

breakdown of immune system which open gateway for all kind of diseases and decrease fertility in men.

Copper showed a mean concentration of 0 03 mg/L which is below the permissible limit of 3 mg/L WHO (2011). This result contradict that of Hannaa *et al*.(2013) who recorded 1.02 mg/L in patient 3 in El.magr, Egypt. The concentration could be implicated to electronic wires, alloys and antimicrobial products from the dumping of domestic waste into the river. Copper is essential to humans but exposure to high concentrations in drinking water causes cirrhosis, anaemia and diarrhea in children (Ben and Bohm, 1995).

Lead showed a mean concentration of 0.14mg/L between months and stations which is above the acceptable limit of 0.01 WHO (2011). The high concentration could be implicated to discharge of huge amount of industrial effluent from Zaria sunseed company Dakachi, agricultural organochemicals from farms, plumbingmaterials, bullets, gasoline, paints, batteries from the catchment areas and dust that holds large amount of lead from combustion of petrol in automobile cars that find their ways in to the river. This is similar to the result of Butu and Bichi, (2013) in Galma reservoir. Lead poisoning is linked to crime and anti-social behavior in children (USGAO, 2000).

Zinc mean concentration of 0.01mg/L is within the WHO (2011) acceptable limit of 3mg/L. Zinc concentration could be attributed to the considerable amount of leached Zinc from protection plates of active Zinc, zinc based fertilizers from pluvial discharge of rural settlement near the river. Abolude (2007) reported a high concentration of 4.63 mg/L in A.B.U Reservoir. Zinc at low concentration is a cofactor for enzymes and at high concentration induces adverse nutrient interaction with Copper.

The heavy metal in this study exhibited this trend of abundance Cd> Pb > Co > Cu > Zn Samir *et al*. (2008) observed similar trend in Lakes Edku and Borollus Egypt. The variations in the concentrations of heavy metals could be due to natural contact of water with rock and soil containing large deposits, increased urbanization and industrilization. Similar observations was reported by Ibrahim and El-Naggar, (2006) in Egypt.

5.5 Periphytic Diatom Composition and Diversity

The relatively low population of Periphytic diatoms in November could be implicated to low nutrients due to dilution factor because of large volume of water resulting in fast flow of water that washes away periphyton while that of April could be due to disturbance of the sediment by animals and humans especially fishermen that constantly visit the river to drink water, graze as most sources of water are dried up and catch fish. This activities bury them deep under the sediment or are removed from their substrates, moved and fed upon by zooplankton and subsequently reducing their population. High population of periphytic diatoms in January could be attributed to the stability of flow favouring diatom growth and development, availability of nutrients in January from farms and the North east wind that lowers level of water bodies concentrating nutrients such as nitrates and phosphates which lead to a corresponding surge in diversity and density of diatoms. Low population of periphytic diatoms in station three could be due to human and animal disturbance of the substrate and low nutrients due to reduced agricultural activity. High species composition in Station six could be due to concentration of nutrients at the lower course of the river because of low flow rate as a result of Zaria water board reservoirs that regulate the quantity of water released via its spillway and reduced water volume in the dry season due to evaporation and abstraction

of water for irrigation and intense solar radiation thereby increasing concentration of nutrients with a correspondent surge in diatom density. High decay of leaves and grasses from canopy cover and sewage and domestic waste water from kubani and ungwan malami could be responsible for nutrients enrichment promoting sudden population rise of diatoms. Diatoms grow abundantly in rivers rich in nutrients. Opute (2000) reported that high algae productivity results from sufficient nutrients enrichment of water in conjunction with adequate radiation. Walker *et al.* (2001) explained that the input of nutritive substance is the main factor that determines periphytic diatom composition and diversity in any place. The observed population trend in this study could be implicated to the prevailing environmental conditions that determine their nourishment and consequently biomass. Changes in water chemistry will inhibit the multiplication of some species while supporting that of others, thus the percentage composition of certain species within a community will be changed (Harding *et al*. 2005). The relative importance of nutrients varies considerably among different taxa. Taxonomic composition and species diversity change with increasing nutrients and periphyton vary in their nutrient uptake, storage, growth, lose rate and substrates preference. Change in composition and diversity of periphytic diatom community structure in different locations at a time in this study is a direct and profound response to the nutrient status or environmental conditions of the water body. This agrees with the observations of Townsend *et al*. (2000), Peerapornpisal *et al*. (2004) and Rabiu *et al.* (2014) who explained that the composition and abundance of phytoplankton (diatom) in any water body clearly indicates the health status of the water body. In addition, the variation in the population of diatom composition and diversity in this study could be due to the

physicochemical properties of water like temperature, light, pH, nutrients and predator level of the river which influence the distribution and richness of biota. Unanam and Akpan, (2006), made similar observation. Human activities along the river such as washing, bathing, sewage discharge, agricultural runoff, industrial waste from sunseed company Dakachi may alter the physicochemical variable causing variation in composition and diversity. Variations in physicochemical and biological composition depend mainly on the type and nature of the water as well as on the man made additions or runoff of minerals and chemicals from agriculture soils (Fathi and Flower, 2005). Tanimu, (2008) reported the dominance of bacillariophyta in saminaka and Zaria reservoirs and attributed it to more organic load from fertilizer and untreated sewage due to human activity because of dense population. Similarly, Benjamin (2013) reported the dominance of Cyanophyta in river ogun and attributed it to pollution as a result of human activities around the river.

On the biodiversity of periphytic diatoms, a total of nine families were recorded in this study. The occurrence of an algal species depends on whether it can tolerate the water and flourish in the system. The relatively low population of the various classes of periphytic diatoms encountered in this study between months and stations could be attributed to the low nutrient status of the water which may be an indication that the water is relatively clean and tallied with the works of Edward and Ugwumba, (2010) and Pongpan and Yuwade, (2013) in Rivers Egbe, Ekiti and Ping, Thailand respectively. Diatoms grow abundantly in rivers rich in nutrients colonizing almost suitable habitats (Celtin and Yildirin, 2000). Clean water have low nutrients thereby supporting only few different groups as in this study compared to polluted water with high nutrient content

encouraging the proliferation of more diverse and more tolerant diatoms. The dominance of the two families (Fragilariaceae and Naviculaceae) could be implicated to them as most adaptable, tolerant, bioindicators and better competitors under the prevailing environmental conditions. Person (1989) reported that clean water has relatively low population of the various group of diatoms and as pollution increases, the population of the less tolerant group decreases while that of high tolerant one increases. The dominance of Naviculaceae and Fragilariaceae by *Navicula* and *synedra* genera respectively in this study is an index of organic pollution. Polge (2010) made similar observation. Taylor *et al*. (2007 b) reported Navicula species as indicators of agricultural disturbances. Several authors have reported the dominance of *Navicula sp* and *Synedra sp* as indicators of clean to moderately polluted water such as Reichard, 1999; Pruentiworonan and peerapornpisal, (2008) and Monteiro *et al.,* (1995) and Taurai and Tundisi (2010) respectively. Palmer (1970), listed 20 algal genera as pollution index organisms of which the genera *Navicula* and *synedra* the most dominant genera of this study belong indicates organic pollution of the water possibly due to organic manure from animal droppings and untreated sewage. *Synedra ulna* was the most dominant species with the highest number of 17 individuals, *Navicula sp* was the most diverse with 22 species and *Melosira sp* the most abundant found in almost all the sampling stations (appendix 10) The family naviculaceae and *Navicula sp* with the highest number of 24 species and 2344 individuals was the most diverse possibly because of their motility and tallied with the work of (Opute, 2002).

The continuous flowing of water and activities of biological components such as aquatic macrophytes and bacteria is a self-regulating mechanism that has transformed inorganic

and organic matter (pollutants) in the water into useable forms (nutrients) used by the aquatic organisms for their growth and reproduction accounts for low values of most physicochemical parameters and the absence of algal blooms observed unlike lakes and reservoir where the nutrients accumulate enhancing excessive proliferation of algae. River water are characterized by low nutrient status, high turn up rate resulting in rapid utilization of these nutrients as fast as they are released by decomposition, therefore very little remain in the water (Chessman, 1995). The pennate diatoms accounted for 90.21 $^{0}/_{0}$ and centric diatoms 9.79 $^{0}/_{0.}$ This is similar to the 97 $^{0}/_{0}$ pennate and 3 $^{0}/_{0}$ centric reported by Pongpan and Yuwade (2010) in ping river. The dominance of the pennates diatom is due to their high tolerances to environmental changes (Shams, 2012). Egborge and Kadiri (2001) claim the dominance of the pennate diatoms than centric diatoms in fresh water to be a peculiar phenomenon or characteristics sequence of fresh water habitat. The centric diatoms are more abundant in marine ecosystem (peerapornpisal, 2006).

The shanon-weaner diversity index was high in November (3.8) and low in April (3.2) which could be an indication of a stable ecosystem that can support diverse biota. Magurran, (1991) reported that higher diversity value greater than 3.5 and rarely exceeds 4.5(Margalef, 1987; Kadiri, 2006) indicates more diversity and uniformity of the various diatom groups and suggest unstressed system (Magurran, 1991). Based on shanon diversity index, the water is clean. Water bodies with Shanon diversity index of > 3 are classified as clean, 1-3 moderately polluted and < 1 as polluted respectively (Wihms and Dorris, 2007; Islam, 2008; Tanimu *et al*., 2011).

5.6 Relationship of Periphytic Diatom Composition and Diversity to Physicochemical Parameter

Hardness, calcium, nitrate, sodium, electrical conductivity, total dissolved solids, chloride and magnesium are significantly related to diatom assemblages. This strong correlation implies that they determine the diatom composition and diversity. As the concentration of these variable increased, the population density and diversity of diatom increases and decreases with reduce concentration. *Opephora swardii, Navicula placenta, Pinnularia divergenses* showed strong association with electrical conductivity, total dissolved solids and chloride. The strong association of this diatom species to these physicochemical parameter could be implicated to them as an index of pollution, while those that showed negative association as indicators of clean water. *Gomphonema montanum* and *Gyrosigma olivaccoides* showed strong association to ammonium and phosphate which could be an indication of relationship with eutrophication. Gomez and Licursi (2001), made similar observation. The physicochemical parameters of water in this study is directly related to the population (composition and diversity) of organism (diatoms) in water body Adakole and Enuola (2010) made similar observation. Fathi and Flower 2005 also explained that Changes in physico-chemical characteristics of any water mass lead to concomitant qualitative and quantitative changes in phytoplanktonic organisms. The observed correlation of some diatom species in this study with physicochemical parameter such as *Navicula tenelloides, Gomphonema parvulum* to hardness, *Navicu laterostrata, Fragilaria viridis* to calcium, *Gomphonema angustatum* to magnesium and *Frustulia rhomboides var capitata* to nitrates agree with those reported by (Lacerda *et al*. (2004), Tanimu, 2008 and Chia *et al*.(2011). Chia (2007) explained that physicochemical

parameters that showed positive correlation with algal species clearly indicated that as the level of these parameters increase or decrease, the occurrence and biomass of algae species increase or decrease respectively.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

Water is life and needed every day for various domestic, irrigation, industrial and drinking purposes. Water sources are continously polluted by unplanned urbanization, domestic and industrial wastes from rural and urban areas and unjustifiable use of chemical fertilizers and pesticides. The physical, chemical and biological quality of water is a vital concern for mankind because it is deeply linked to human health. BOD, DO, EC, pH, TDS, $T_{2,}$ Hardness, Ca, Na, Mg, Cl, NO_3-N, $SO_{4,}$ and NH_4 varied significantly between months. All measured values of physicochemical parameters except lead and Cadmium were below their permissible limits. The pennates diatoms dominated the centrales diatoms. The family Fragilariaceae was the most dominant with the month of January recording the highest and lowest in November and family Epithemiaceae the least. Among stations, station six recorded more species density with the least in station three. The differences in the number of Taxa and number of individuals may be due to environmental factors such as water chemistry (nutrients), differences in temperatures and pH. Significant relationship was observed between biological parameters (diatom composition and diversity) and physicochemical parameters. Hardness, Calcium, Nitrate, Sodium and magnesium showed significant positive association with *Denticula tenuis, Navicula laterostrata, Fragilaria rhomboids var capitata* and *Gomphonema angustatum* thus determined their composition and diversity in this study. The significant association

of *Rhoicosphaenia curvata* and *Gomphonema montanum* with Ammonium and Phosphorus indicates relationship with eutrophication.

6.2 Conclusion

The physicochemical parameters showed significant variations between months and stations. The null hypothesis one that states that there is no significant difference in the physicochemical parameters in River Galma is rejected.

There was a significant relationship between diatom composition and diversity and physicochemical parameters. Therefore the second null hypothesis which states that there is no significant relationship between diatom diversity and abundance and physicochemical parameters in River Galma is not accepted.

There was a significant relationship between diatom composition and diversity between months and stations in a segment of River Galma. The third hypothesis that states that there is no significant relationship between diatom composition and diversity over time and space in a segment of River Galma is rejected.

6.3 Recommendations

Both anthropogenic and industrial wastes observed from this study has adverse effects on the periphytic diatom and physicochemical parameters of the river indicated by the high concentration of Lead and Cadmium posing health risk to aquatic organisms and rural communities that rely on the receiving water primarily as their source of domestic water. There is need for the intervention of regulatory agencies and other non-governmental organisations to ensure the production of high quality treated final waste devoid of Lead and Cadmium by water treatment facilities. Communities in the

catchments area should be enlightened on the best practices and justifiable use of selective agro-chemicals that are consistent with state nutrient criteria devoid of toxic metals such as Lead and cadmium that are biodegradable and or have no or less effect on their health and that of the aquatic environment. Farmers and industries within the catchment areas should be mandated to construct soakaway on their farms and treatment plants near their sites to avoid direct contact of their wastes with river water. Rivers Galma which is the major source of water to Zaria metropolis should be monitored regularly against eventual pollution and deterioration because of its low nutrients signifying relatively good quality water. Relevant laws should be made on the best practices that will regulate anthropogenic and industrial activities around the river to ensure its conservation. Monitoring team should be inaugurated to provide empirical information to policy makers routinely on the water status of river Galma and ensure safe use of agrochemical to safe guard the aquatic ecosystem. Calcium and magnesium salts should be artificially introduced into River Galma as chelating agents to removed toxic metals like lead and cadmium. Silica is an important element (nutrient) for diatom growth, hence its content in water should be studied. The unhealthy practices such as discharging of oil of all kinds, petrol, used batteries, grease, used bulbs/fluorescent tubes, electrical and electronic appliances and salon effluent into public drains which finally end up into rivers/reserviours should be discouraged. Government should rather organize collection system of waste lubricants which can be recycled.

REFERENCES

Abolude, D.S. (2007).Water Quality and metal concentrations in sediments and Fish from Ahmadu Bello University Reservoir, Zaria using neutron Activation analysis and AtomicAbsorbtion Spectrophotometry. Ph.D Thesis, A.B.U., Zaria.

Adakole, J.A., Abulode, D.S. and Balarabe, M.L. (2008). Assessment of Water Quality of A Man-Made Lake in Zaria, Nigeria. *Proceedings of Taal*: The 12th World Lake Conference: 1373-1382.

Adekunle, A.S. and Eniola, I. T. K. (2008) Impact of Industrial Effluents on Quality of Segment of Asa River within an industrial Estate in Ilorin,Nigeria. *New York Science Journal,***1(1):**18-29.

Adeyemo, O.K, Adedokun, O.A, R.K. Yusuf, R.K and Adeleye, E.A (2008). Seasonal changes in Physico-chemical parameters and nutrient load of sediments in Ibadan city, Nigeria. *Global NEST Journal*, **10(3):** 326-336

AFNOR (2000) Norme Francaise NF T 90–354. De´termination de l'Indice Biologique Diatom's (IBD). Association Franc¸aise de Normalisation, 63 pp.

Ahmed, I. (2014). Studies on the Physico-chemical Parameters and Plankton composition of Ajiwa Reservoir Katsina State, Nigeria. An Msc Thesis submitted to the Department of Biological Sciences, Ahmadu Bello University, Zaria.

Ajibare, A.O. (2014). Assessment of Physico-chemical Characteristics of Waters in Illaje Local Government Area of Ondo state, Nigeria

Akin-Oriola, G.A (2003). On the phytoplankton of Awba Reservoir, Ibadan Nigeria. *Rev. Bio. trop*. **5I (1):** 99-106. .

Akomeah, P.A., Ekhator, O. and Udoka, C. (2010). Dry Season Phytoplankton Composition Of Ibiekuma Dam, Ekpoma, Edo State. *Ethiopian Journal of Environmental Studies and Management* **3(3):** 36-40

Ali, M.Z., Michael, A.A. and Yahuza, T. (2013). Physico-chemical Characteristics And Phytoplankton Abundance of the Lower Niger River, Kogi State, Nigeria. *Journal of Environmental Science Toxicology and Food Technology*, **2(4):** 31-37

Al-Jizani, H.R.G. (2005). Organic pollution and its impact on the diversity and abundance of plankton in the Shatt Al-Arab, Al-Ashaar and Al-Robat Channel. M.Sc. Thesis, College of Education, University of Basrah. 82 pp. (In Arabic)

Almeida, S. F. P. DE and Gill, M. C. P (2001). Ecology of freshwater diatoms from the central region ofPortuga1. *Cryptogamie Algologie,* **22 (1**): 12 – 16.

Amadi B.A., Chikezie, P.C. and Okeoma, H.C. (2006). Physico-chemical characteristics of Nworie River and its effect on liver function of rats. *Journal of Nigerian Environmental Society* **3:** 183-187.

Anawara, H.M., Akaib, J., Mostofac, K.M.G., Safiullahd, S & Tareqd, S.M. (2002). Arsenic poisoning in groundwater- health risk and geochemical sources in Bangladesh. *Environ. Int.*, **27**:597-604.

Ansa, E.J. (2005). Studies of the benthic macrofauna of the Andoni flats in the Niger Delta Area of Nigeria. Ph.D Thesis University of Port Harcourt, Port Harcourt, Nigeria; 242pp.

APHA (1995). Standard methods for the examination of water and wastewater. 19th edition. American Public Health Association, Washington DC. 1467.

APHA (1998). *Standard methods for the examination of water and wastewater*. 20th edition. Published by American Public Health Authority, *Water Environmental Federation. Washington* DC. 1287pp.

APHA (2002*). Standard Methods for the Examination of Water and Wastewater*. 21st Published by American Public Health Authority, Water Environmental Federation, Washington D.C. 1287pp.

APHA., AWWA., WEF(2005). (21st ed.), Standard Methods for the examination of water and wastewater, American Public Health Association Washington, DC

Araoye, P.A. (2008). Physical factors and their Influence on Fish Species Composition in Asa Lake, Ilorin, Nigeria. *International Journal of Tropical Biology* **57 (1-2):** 167 175.

Archibald, G.G.M, Harding, R.W and Taylor, J.C (2005). relevance of diatoms for water quality assessment in South Africa: *A Position Paper* Vol.**31(1)**: 41-46.

Arienzo, M., Adamo, P., Bianco, M.R. and Violant, P. (2000). Impact of Land Use and Urban Run-offs on the contamination of the Sarno River Basin in South-Western Italy. *Water, Air & Soil Pollution*, **131**: 349-366.

Armbrust, E.V. (2009). The life of diatoms in the world's oceans. *Nature,* 459: 185- 192.

Asonye, C. C., Okolie, N. P., Okenwa, E. E. and Iwuayanwu, U. G. (2007). "Some Physico- Available online at http://www.academicjournals.org/AjB.

Atalay, A., Pao, S., James, M., Whitehead, B and Allen, A. (2008). Drinking water assessment at underserved farms in Virginia's coastal plain. *Journal of Environmental Monitoring and Restoration*, **4:** 53-64.

Atobatele, O.E. and Ugwumba, O.A (2008). Seasonal Variation in the Physico-chemistry of a Small Tropical Reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology Vol.* **7 (12):** 62-171.

Ayoade, B.B (2000). Effect of treated sewage on agricultural practice in the tropics. *Nigerian Journal of ecology*. **2:** 33-37.

Babatunde, M.M. (2009). Assessment of the physicochemical parameters, selected biota and fishes of Kuddiffi-Kubani stream, Hanwa-Makera, Zaria, Nigeria. Ph.D Thesis, A.B.U., Zaria.

Badmus, B.S. (2008). Leachate contamination effect on groundwater exploration. *African Journal of Environmental Studies*, **(8):**38-41.

Beadle, L.C. (1974).The inland waters of Tropical Africa. An introduction to tropical limnology. Longman-London 356Pp.

Balarabe, M.L. (2001). Effect of limnological characteristics of zooplankton composition and distribution in Dumbi and Kwangila ponds, Zaria, Nigeria. Unpublished Ph.D. Thesis, Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria. 7-12Pp.

Balarabe, M.L. (1989).Limnology and Zooplankton Distribution of Makwaye (Ahmadu Bello University Farm) Lake, Samaru, Zaria-Nigeria. Unpublished M.Sc.Thesis of Department of Biology Sciences, Ahmadu Bello University, Zaria, Nigeria.Pp 1-50.

Ball, F. and Glucksman, J. (1978). Limnological survey of lakes Dakatana, Large Caldera lakes on West New Britain, Guinea, with comparism to Lake Wisdom, a younger nearby Caldera Lake. *Fresh Water Biology,* **10**:73-84.

Balogun, J.K., Balarabe, M.L. and. Igberaese, P.M (2005) Some Aspects of the Limnology of Makwaye (Ahmadu Bello University Farm) Lake, Samaru, Zaria. *Academic Journal,* **23(12)**: 850-860

Barbour, M.T., Swietlik, W.F., Jackson, S.K., Courtemanch, D.L., Davies, S.P., and Yoder, C.O. 2000. Measuring the attainment of biological integrity in the USA: a critical element of ecological integrity. *Hydrobiologia* 422/423: 453-464

Bartram, J. and Rees G. (2000). Monitoring Bathing Waters - A practical guide to the design and implementation of assessments and monitoring programmes. World Health Organisation.

Bate, G.C., Adams, J.B. and van der Molen, J.S. (2002). Diatoms as Indicators of Water Quality in South African River Systems. Water Research Commission Report No 814/1/02.

Benjamin, (2013). The Phytoplankton Species Composition and Abundance of Ogun River, Abeokuta, Southwestern Nigeria, *International Journal of Aquaculture*, **3**(2): 4-7.

Bhaven, N., Tandel, J.E.M. and Soni, C.K (1998). Assessment of water quality index of small lake in Gujurat region, India.

Biggs, B.J.F. (1995). The contribution of flood disturbances, catchment geology and land use to the habitat template of periphyton in stream ecosystems. *Fresh. Biologia*, **33**: 419-438.

Biggs, B. J. F. and C. Kilroy, (2000). Stream periphyton monitoring manual. NIWA, Christ Church, New Zealand.

Bijaya, K.P., Jnanendra, R. and Pratap, K.P. (2010). Diatoms for assessing the ecological condition of inland freshwater bodies. *World Review of Science, Technology and Sustainable Development*, **7(4):** 352 DOI: 10.1504/WRSTSD.2010.032743

Bishnoi, M and Arora, S. (2007). Potable ground water quality in some villages of Haryana India: focus on fluoride. *Journal of Environmental Biology*, **28(2)**: 291-294.

Blanco, S. and Becares, E. (2010). Are biotic indices sensitive to river toxicants? A comparison of metrics based on diatoms and macro-invertebrates. *Chemosphere* **79**: 18-25.

Blazs, R.L., Walter, D.M. Coffey, T.E., White, D.K. and Boyle, D.L. (1991). ‘’Water recourse data for Oklahoma’’, *united State of Geological Survey Rep. No.USGS/WRD/HD*-91/303.517pp.

Bott, T.L. (1996). *Algae in microscopic food webs*. In: Algal Ecology: Freshwater Benthic Ecosystems (Eds Stevenson, R.J., Bothwell, M.L. and Lowe , R.L.), pp. 574–608. Academic Press, San Diego, CA.

Brown, G.W. and Krygler, J.T. (1970) Effect of clear cutting on stream temperature. *Water Resource*, **6:** 1133-1139.

Burkholder, J. M. (1996). Interactions of benthic algae with their substrata. In Stevenson, R.J., Bothwell, M.L. and R.L. Lowe (edn.). Algal Ecology: Freshwater Benthic Ecosysterns. Academic Press, San Diego. pp. 253-297.

Butu, A.W and Bichi, A.A (2013). Assesment of some heavy elements in Galma dam, Zaria, Nigeria. *International Journal of Development and Sustainability* **2(2):** 686-696.

Butzler, J.M. (2002).The Role of Nutrient Variability in Aquatic Ecosystems. M.Sc. Thesis, University of Pittsburgh.1pp Chemical Characteristics and Heavy Metal Profiles of Nigeria Rivers", **6(5):** 617-24.

Buzzi, F. (2000). Phytoplankton assemblages in two sub-basins of Lake Como. *Journal of Limonology*, **61**:117-128.

C.C., Klein Jr, R.L, and Gibbs, C.R. (1990). *Introduction to Biochemical oxygen demand*. Technical information series-booklet No7. Hach Technical center for Applied Analytical Chemistry.Hachcoy; Loreland. Colorado, USA. 27pp.

Carpenter, K. D. & I. R. Waite, (2000). Relations of habitat specific algal assemblages to land-use and water chemistry in the Willamette Basin, Oregon. *Environmetal Monitoring and Assesment*, **64**: 247–257.

Carpenter, S.R., Caraco, N.F., Corrrell, D.L., Howarth, R.W., Sharpley, A.N., and Smith, H.V (1998).Non Point Pollution of Surface waters with Phosphorus and Nitrogen. *Ecological Applications*, **8**: 559-568.

Cattaneo A., Kerimian T., Roberge M. and Marty, J. (1997). Periphyton distribution and abundance on substrata of different size along a gradient of stream trophy. *Hydrobiologia*, **354**: 101-110.

Catteneo A, Couillard Y, Wunsam S and Courcelle M (2004), " Diatom Taxonomic and Morphological Changes as indicators of Metal Pollution and Recovery in Lac Dufault (Quebec, Canada)' Journal of Paleolimnology, **32(2**): 163-175.

Celtin, A.K.and Yildirin,v. (2000). Species composition and Seasonal Variation on the Phytoplankton in Surgu Reservoir (Malaysia, Turkey). *Acta Hydrobiology*, **42**: 21-28.

CEN (Comit'e Europ'een de Normalisation) (2003). Water quality – guidance standard for the routine sampling and pretreatment of Benthjc Diatom, p.14, Geneva.

Chandaluri, S.R., Sreenivasa, R.A., Hariharann, V.L.N. and Manjula, R. (2010). Determination of water quality index of some areas in Guntur district Andhra Pradesh. *IJABPT*, **1:** 79-86.

Chandra, S; Singh, A and Tomar, P. K (2012). Assessment of Water Quality Values in Porur Lake Chennai, Hussain Sagar Hyderabad and Vihar Lake Mumbai, India. *Chemical Science Transactions*, **1(3),** 508-515.

Charles DF (1996) Use of algae for monitoring rivers in the United States. Some examples. In: Whitton BA and Rott E (eds.) *Use of Algae for Monitoring Rivers*, **1:** 109-118.

Charles, D.F., Smol, I.P. and D.R. Engstrom (1994). *Paleolimnological approaches to biological monitoring*. In Loeb, S.L. and A. Spacie (eds.). Biological Monitoring of Aquatic Systems. CRC Press, Boca Raton, Florida. pp. 233-293.

Chen, G., Dalton, C., Leira, M., Taylor, D., (2008). Diatom-based total phosphorus (TP) and pH transfer functions for the Irish Ecoregion. *J Paleolimnol*., **40 (1):** 143-163.

Chessman IC, In: Hart, B. T. (Ed.), (1995). Water Quality Management Monitoring Programme and Diffuse Run Off. 39 – 66Pp.

Chessman, B., I. Growns, J. Curry, and N. Plunkett- Cole. (1999). Predicting diatom communities at the genus level for the rapid biological assessment of rivers. *Freshwater Biology*, **41**: 317–331.

Chia, A.M. (2007). Occurrence and abundance of algal species in relation to heavy metals content and physicochemical parameter of selected ponds in Zaria, Nigeria. M.Sc. Thesis. Unpublished. Ahmadu Bello University, Zaria. 112pp.

Chia, A.M. and Bako, S.P. (2008). Seasonal Variation of Cyanobacteria in Relation to Physico-Chemical Parameters of Some Fresh Water Ecosystems in the Nigerian Guinea Savanna.Sengupta, M. and Dalwani, R (Ed). (2008) *Proceedings of Taal2007: The 12th World Lake Conference,* p: 1383-1387.

Chia. A.M, S.P Bako, S. Alonge and A.K Adamu (2011). Records of Diatoms and Physicochemical Parameters of Seasonal Ponds in Zaria-Northern Nigeria

Chinasa Uttah,Emmanuel Chukwunenye Uttak, Christiana Okonofua, Emmanuel Ogban, Lawrence Usip and Jude Ogbeche (2013).Pollution Biotic Index and the Biota Indicative Signatures of Transects in Calabar River Around A BusyJetty Facility Calabar.

Chindah, A.C. (2004) Response of periphyton community to Salinity gradient in tropical estuary. *Niger Delta Pollution Journal of Ecology*, **52(1):** 83-89.

Chindah, A.C. and Brailde, S.A. (2004). The Physico-chemical quality and Phytoplankton community of tropical water: A case of four Biotopes in the lower Bonny River, Niger Delta, Nigeria.*Cardena de Pesqiusa serie Biologia*, **16(2):** 7-35.

Cholnoky, B.J. (1968) Die Ökologie der Diatomeen in Binnengewässern.

Colwell, R. K., and D. C. Lees. (2000). The mid-domain effect: geometric constraints on the geography of species richness. *Trends in Ecology & Evolution*, **15**:70–76.

Comin, F.A., Lopez, P. and Counelles, M. (1983). Limnology of Corallocantia Lake, Argon, North Eastern Spain *Hydrobiologia*, **105**: 207-227.

Connel, *et al*. (1984). Water Quality Group. In: Water Resource Characterization, North Carolina State University. File:///c:/users/user/Documents/hmetals water Management.htlm

Courtney, L.A. and Clements, W.H. (1998). Effects of acidic pH on benthic macro invertebrate communities' microcosm *Hydrobiologia*, **379**:145.

Cramer, J. and Lehre, G.A. (1979). Textbook of Limnology, C.V. Mosby, St. Louis, 426pp.

Creel, L. (2003). Ripple effects: Population and coastal regions. (policy brief). Washington, DC: Population Reference Bureau.

Cristofer, S., Vadineanu, A., Ignat, G.and Cinbric, C.(1994). Factors affecting light penetration in shallow lakes. *Hydrobiologia*, **275/276**: 493-498.

Davies, B. and Day, J. (1998). *Vanishing Waters*. University of Cape Town Press. University of Cape Town. Rondebosch. 487 pp.

Davies, O.A., Abowel, J.F.N. and Tawari, C.C. (2009). Phytoplankton community of Elechi Creek, Niger Delta Nigeria – A Nutrient polluted Tropical Creek. *American Journal of Applied Science*, **6(6):** 1143-1152.

Delarey, P.A., Taylor, J.C., Laas, A., Vanrensburg, L. and Vosloo, A. (2004). Determining the possible application value of diatoms as indicators of general water quality - A comparison with SASS 5. *Water SA*, **30 (3)** 325-332.

Descy, J.P. and Micha, J.C., (1988).Use of biological indices of water quality. – *statistical journal of the United nations* ECE, **5:**249-261.

Descy, J.P. and Coste, M., (1990).Utilisation des diatomees benthiques pour l' evaluation de la qualite des eaux courantes. –CEE contract B-7=23, final report, UNICED, FNDP, Namur (Belgium) and CEMAGREF, Bordeaux (France), 64pp. +3 ann.

DFID. (1999). A simple methodology for water quality monitoring. (Pearce GR, chaudhry Ghulumed.). Department for International Development, Walling ford: 234-289.

Dixit, S.S., Smol, J.P., Kingston, J.C. and Charles, D.F. (1992). Diatoms: powerful indicators of environmental change. *Environmental Science Technology***, 26**:22-33.

Dodson, S.I., Arnott, S.E and Cottinghan, K.L. (2000). The relationship in lake communities between primary productivity and species richness. *Ecology*, **81:** 2662-2679.

Duong, T., Coste, M., Feurtet-Mazel, A., Dang, D., Gold, C., Park, Y. (2006). Impact of Urban Pollution from the Hanoi Area on benthic diatom communities collected from the Red, Nhue and Tolich Rivers (Vietnam) *Hydrobiologia*, **563:** 2-1-216.

Edward, J.B. and Ugwumba, A.A.A. (2010). Physico-Chemical Parameters and Plankton Community of Egbe Reservoir, Ekiti State, Nigeria.*Research Journal of Biological Sciences,* **5 (5):** 356-367.

Eekhout, S., Brown, C.A. and King, J.M. (1996). National Biomonitoring Programme for Riverine Ecosystems: Technical Considerations and Protocol for the Selection of Reference and Monitoring Sites. NBP Report Series No.**3.** Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

Egborge, A.B.M. and M.O. Kadiri, (2001). *The Plants (Phytoplankon)*. In: Egborge, A.B.M. (Ed.), Water Pollution in Nigeria River 2. Ben Miller Books Ltd., Nigeria, pp: 64-75.

Emmanuel, B.E. and Onyema, I.C. (2007). The plankton and fishes of a tropical Creek in South Western Nigeria. *Turk Journal of Fish Aquatic Sciences*; **7**:105-113.

EPA QPWS (1999). Water Quality Assessment. Retrieved June 16, 2012 from http://www.epa.gld.gov.au/environment-management/water-quality-monitoring/assessing

Ezra, A.G. and D.I. Nwankwo, (2001). Composition of phytoplankton algae in Gubi Reservoir, Bauchi, Nigeria. Journal of Aquatic Sciences, **16(2)**: 115-118.

Fathi AA and Flower RJ (2005). Water quality and phytoplankton communities in Lake Qarun (Egypt). *Aquatic Sciences*. **67**: 350-362.

FEDERAL REPUBLIC OF NIGERIA (2000). Water supply and sanitation interim strategy note November 2000.

Furnas, M.J. (1990). "In Situ growth rates of marine phytoplankton: Approaches to measurement, community and species growth rates". *Journal of Plankton Resources.* **12(6)**: 1117-1151.

Garba, Z.N., Hamza, S.A and Galadima, A. (2010). Arsenic level speciation in fresh water from Karaye Local Government Area, Kano State, Nigeria. *International Journal of Chemistry*, **20(2):** 113-117.

Gasse, F. Juggins, S. and Khelifa, L.B. (1995). Diatom based transfer functions for inferring past hydrochemical characteristics of African Lakes. *Palaeogeography Palaeoclimatology Palaeoecology*, **117**: 31-54.

Gensemer, RW. (1991). The effects of pH and aluminum on the growth of the acidophilic diatom `*asterionella ralfsii var. americana. Limnology Oceanography*, **36(11):** 123‑131.

Gleick, P. (2000). An introduction to global fresh water issues. In Peter Gleick (Editor), Water in crisis: Oxford University Press, New York, pp. 3 –12.

Go´mez, N. and Licursi, M. (2001). The Pampean Diatom Index (IDP) for assessment of rivers and streams in Argentina. *Aquatic Ecology*, **35**: 173–181.

Goldman, C.R. and Horne, A.J. (1983). Limnology Research Book.

Gonzalo, M. and Maria, R.F. (2012). *Diatoms as indicators of water Quality and Ecological Status*: Sampling, analysis and some ecological water quality treatments and Re-use.Dr.Vondouric(Ed), ISBN: 978-953-51-0508-4,In Tech.Hach.

Gore, A.L. (1993). *Earth in the Balance Ecology and the Human Spirit*, New York: Penguin Book, pp. 105-9.

Guasch, H. and Sabater, S. (1995). " Seasonal Variation in photosynthesis-Irradiance Responses by Biofilms in Mediterranean Streams," *Journal of Phycology*, **31**(**5**): 727-735.

Guy, D. (1992). *The ecology of the fish pond ecosystem with special reference to Africa*. Pergamon press. 220-230pp.

Hach, C.C., Klein Jr, R. L, and Gibbs, C. R. (1990). Introduction to Biochemical oxygen demand. Technical information series-booklet No 7. Hach Technical center for Applied Analytical Chemistry. Hachcoy; Loreland, Colarado, USA. 27pp.

Haylamicheal, I.D. and Moges, A. (2012), "Assessing Water Quality of Rural water Supply Schemes as a measure of Service delivery sustainability", A Case Study of Wondo Genet District, Southern Ethiopia", *African Journal of Environmental Science and Technology*, **6**(**5**): 229 –236.

Hamed, M. A. (1998). Distribution of trace metals in the River Nile ecosystem, Damietta branch between Mansoura city and Damietta Province. *J. Egypt. Ger. Soc. Zoo.*, **27(A):** 399-415.

Hanaa, M., Salem, E.A. and Azza, F. (2000). Heavy Metals in Drinking Water and their environmental impact Impact on Human Health.

Harding, W.R., Archibald, C.G.M. and Taylor, J.C. (2005). The relevance of diatoms for water quality assessment in South Africa: A position paper. *Water SA*, **31(1**): 41-46.

Hardman, D.J., Mceldowney, S. and Watte, S. (1994). Pollution, ecology and biotreatment. Longman Scientific, Technical, England, 322 pp.

Harris, J.M. and Vinobaba, P. (2012). Impact of Water Quality on Species Composition and Seasonal Fluctuation of Planktons of Batticaloa lagoon, Sri Lanka. *J Ecosyst Ecogr*, **2**: 117 – 122.

Hasle, G.R., Syvertsen, E.E. (1997). *Marine Diatoms*. In Tomas, C.R. (1997). Identifying Marine diatoms and Dinoflagellates. Academic Press. Pp. 5-385. Accessed 17/7/2012.

Hassan, A.S. (1998). Biological and Physicochemical Quality Assessment of Rural Water Sources for Domestic use in Selected rural Communities in Zaria, Kaduna state, Nigeria. Unpublished Ph.D. Thesis. Pp 8-29.

Hawkes, H.A. (1975). River Zonation and Classification. In: River Ecology Whitton B.A(ed). Uni. California press 312-374.

Hering, D., Johnson, R.K., Kramm, S., Schmutz, S., Szoszkiewicz, K. and Verdonschot, P.F.M. (2006). Assessment of European streams withn diatoms, macrophytes, macroinvertebrates and fish: a comparative metric-based analysis of organism response to stress. *Freshwater Biology*, **51:** 1757-1785.

Hooper, D.U. and Vitousek, P.M. (1998). Effects of Plant composition and diversity on nutrient cycling. *Ecological Monographs*, **68**: 121-149.

Horner, R.A. (2002). A Toxonomic Guide to Some Common Marine Phytoplankton. Biopress Ltd. Pp. 25-30 ISBN 0-948737-65-4.

Hossain M.Y., Begum, Z.F., Hoque, M.A., Karim, M.A. and Wahab, M.A. (2006). A study on the effects of iso-phosphorus fertilizers on plankton production in fish ponds. *South Pacific Studies*, **26:** 101-110.

Huang Q.A., Wang, Z.J., Wang, C.X. and Ma, M. (2005). Origins and mobility of phosphorus forms in the sediments of lakes Taihu and Chaohu. *China Journal of Harzardous materials*, **20**: 183-186.

Hujare, M. S. (2005**)**. PhD thesis submitted to Shivaji University, Kolhapur, India.

Huynh, M. and Serediak, S. (2006). Algae Identification Field Guide. Agriculture and Agri-Food Canada.

Ibe, P.A. (1993). A general review of pollution dynamics of aquatic macro –invertebrates of the tropical fresh water system. Unpublished MSc. Thesis, University of Jos Nigeria 88pp.

Ibrahim, B.U., Auta, J. and Balogun, J.K. (2009). An Assessment of the Physico-chemical Parameters of Kontagora Reservoir, Niger state, Nigeria. *Bayero Journal of Pure and Applied Sciences,* **2(1):** 64 – 69.

Ibrahim, H.J. and Aliyu, S. (2010). "Lead Poisoning", Weekly Trust Newspaper, Nigeria. Saturday 12 June 2010, pp. 1 and 6.

Ibrahim, N. A. and G. O. El-Naggar. (2006). Assessment of heavy metals levels in water, sediment and fish at cage fish culture at Damietta Branch of the river Nile. *J. Egypt. Acad. Environ. Develop.*, **7**(1): 93-1114.

Ikeda, Y. and Okuda, O. (2005). Restructuring Water quality Monitoring of Lake Biwa. *In: order of proceedings: World Lake conference, Nairobi, Kenya.* Pp13-17.

Ikem, A.O. and Sobande, A.J. (2006). Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria. Water, Air and Soil Pollution Publication **7:**307-333.

Indabawa, I.I. (2009). Studies on Limnological Parameters and Phytoplankton Dynamics of Nguru Lake. Yobe State. *Nigeria.Biosciences Research Communications,* **21(4)** 183-184.

Ireland Environmental Protection Agency (IEPA) (2001). Parameters of Water Quality: Interpretation and Standards," Environ- mental Protection Agency Johnstown 133.

Islam, M.S. (2008). *Phytoplanktonic diversity index with reference to Mucalinda Serovar,* Bodh-Gaya. Proceedings of the Taal'2007: The 12th World Lack Conference, October 28-November 2, 2007, Jaipur, India, pp: 462-463.

John, J. (1991). Climaconeis stromatolitis, a new species of diatom from Shark Bay, Western Australia. *Diatom Research* 16**(1**): 49-54.

John, J. (2000). A Guide to Diatoms as Indicators of Urban Stream Health. LWRRDC Occasional Paper 14/99 (Urban Sub Program, Report No **7**. Land and Water Resources Research and Development Corporation, Canberra.

Johnson, R.K., Hering, D., Furse, M.T., and Verdonschot, P.F.M. (2006). Indicators of ecological change: comparison of the early response of four organism groups to stress gradients. *Hydrobiologia,* **566**: 139-152.

Julius, J.I. (2014). Assesment of Heavy Metals Concentration in Water, Sediment and Fish Species from Kubani Reservoir, A.B.U.Zaria.

JÜttner, I., Sharma, S., Dahal, B.M., Ormerod, S.J., Chimonidek, P.J. and Cox, E.J. (2003). Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology,* **48:** 2065-2084.

Slim, K., Saad, Z., El-Samad, O. and Kazpard, V. (2005). "Charactérisation chimique et algologique des eaux superficielles de la rivière Oronte (Liban) dans un climat semi-aride," Sécheresse, **16**(**2**): 131–135.

Kadiri, M.O. (2000a). Seasonal trend in the chemical limnology of a shallow Nigerian man-made lake. *Acta. Hydrobiol.*, **421(2)** 29-40.

Kadiri, M.O. (2006). Phytoplankton Flora and Physicochemical attributes of some waters in the Eastern Niger-Delta area of Nigeria. *Nigerian Journal of Botany*, **19(2)**: 188-200.

Kalff, J. (2002). Limnology: Inland Water Ecosystem prentice hall, New Jersey, USA.

Kari, A.B. and Asarre, A.J. (2006). Physiochemical and microbial water quality. Assessment Journal of Applied Ecology vol. 10. Karaye Local Government Area, Kano State, Nigeria. *International Journal of Chemistry*, India .

Karikari, A.Y., J.K. Bernasko and E.K.A. Bosque – Hamilton.(2007). An assessment of water quality of Angaw – River in South – Eastern coastalplains of Ghana. *West African Journal of Applied Ecology*, **2(1**): 33 – 46.

Karr, J.R. and Chu, E.W. (1997). Biological monitoring: Ecological foundation for ecological risk assessment. *Human Ecol. Risk Assess*, **3(6):** 993-1004.

Karr, J.R. and Chu, E.W. (1999). Restoring Life in Running Waters: Better BiologicalMonitoring. Island Press, Washington D.C. 200 pp.

Karthick, B., Jonathan. C.Y., Mahesh, M.K., and Ramachandra, T.V. (2010). Protocols for collecting, preservation and enumeration of diatoms from aquatic habitats for water quality monitoring in India. *The inter-university programme (IUP) journal of water and soil sciences*, **3(1):** 25-60.

Kaunzinger, C.M.K. and Morin, P.J. (1998). Productivity Controls Food-chain Properties in Microbial Communities. *Nature*, **395**: 495-497.

Kaushal, S. S. (2005). Increased salinization of fresh water in northeastern United States. *PNAS*, **102 (38)**: 13517-13520.

Kawecka, B. (1986). " The effect of Light Deficiency on Communities of Sessile Algae in the Olezyski Stream (Tatra Mts., Poland)", *Acta Hydrobiol.*, **28(**4): 379-386.

Kelly, M.G., Cazaubon, A., Coring, E., Dell'uomO, A., Ector, L., Goldsmith, B. (1998). Recommendations for the routine sampling of diatoms for water quality assessments in Europe. *Journal of Applied Phycology*, **10:** 215-224.

Kemdirim, C.E. (1987). Limnology and trace elements studies of an upland and lowland impoundment of Plateau State Nigeria. Unpublished Ph.D. thesis. University of Jos.

Kolo, R.J. and Oladimeji, A.A (2004). Water quality and some nutrient levels in Shiroro Lake Niger State. Nigeria. *Journals of aquatic sciences*, **19(2)**: 99 - 102.

Kori-Siakpere, D. and Ubogu, E. (2008), "Sub lethal Hematological Effects of Zinc on the Fresh Water Fish. *Heteroclarias Sp. (Osteichthyes: Claridae)", African Journal of Biotechnology*, **7**(12): 2068 – 2073.

Kostick, D.S. (2010). Salt *USGS*. Retrieved from http://minerals.usgs.gov/minerals/pubs/commodity/salt/saltmyb01.pdf

Krammer, K. and Lange-Bertalot, H. (2000). Bacillariophyceae" in Gerloff H, Heynig JH and Mollenhauer D (Eds.*). Siifswasserflora von Mittleuropa. Band 2. Ettl.*, Spektrum Akademischer Verlag, Heidelberg, Berlin

Kumari, P., Dhadse, S., Chandhari, P.R. and Wale, S.R. (2008). Biomonitoring of Plankton to Assess Quality of water in the Lakes of Nagpur City. Proceedings of Taal 2007: 12th World Lake Conference, Published by Ministry of Environment and Forests India and International Lake Environment Committee Foundation (ILEC) Pp. 160-164.

Kutka, F.J. and Richard, C. (1996). Relating diatoms assemblage structure to stream habitat quality. *Journal of North America Benthol Society*. **15**: 469-480.

Kwandrans, J., Eloranta, P., Kawecka, B. and Woitan, K. (1998). Use of benthic diatom communities to evaluate water quality in rivers of Southern Poland. *Journal of Applied Phycology.* **10** 193-201.

KYWWP. (2009). Dissolved Oxygen. Retrieved October 22, 2010 from http://www.stae.ky.us.wrepc/water/wcparint.htm.

Lacerda, S. R., Koening, M. L., Neumann-Leitao, S. and Flores-Montes, M. J. (2004). Phytoplankton nyctemeral variation at a tropical river estuary (Itamaracá - Pernambuco - Brazil). *Brazil Journal of Biology***. 64 (1**): 81–94.

Lee, J.J. and Xenophontes, X. (1990). The unusual life cycle of Navicula muscatinei. *Diatom Research* 4:

Leira, M. and Sabater, S. (2005). Diatom assemblages distribution in Catalan rivers, NE Spain, in relation to chemical and physiographical factors. *Water Resources*. **39 (1),** 73-82.

Lepom, P., Brown, B., Hanke, G., Loos, R. and Quevauviller, P. (2009). Needs for reliable analytical methods for monitoring chemical pollutants in surface water

under the European Water Framework Directive. *Journal of chromatogr*, **1216**: 302-315.

Lewis, M.W. (2000). Basis of the protection and management of tropical lakes and Reserviours, Research and Management, **5:** 35-48.

Lind, O.T. (1979). A hand book of limnological methods. CV Mosbyco. St Louis.199pp.

Lobo, E.A., Callegaro, V.L.M., Hermany, G., Go´mez, N. and Ector, L. (2004). Review of the use of microalgae in South America for monitoring rivers, with special reference to diatoms. Vie et Milieu – *Life*. *Environment*., **54 (2/3**): 105-114.

Lobo, E.A., Collegaso, V.L.M., Oliveira, M.A., Salomoni, S.E., Schuler, S. and Asai, K. (1996). Pollution tolerant diatoms from lotic systems in the Jacui Basin, Rio Grande do Sul, Brazil. *Iheringia Serie Botanica*, **47**: 45-72.

Loez, C.R. and Topalian, M.L. (1999). Use of algae for monitoring algae in Argentina with special emphasis for Reconauisita River (region of Buenos Aires). In J. Prygiel, B.A. Whitton, & J. Bukonska (Eds) use of algae for monitoring rivers III (Pp. 72-83). Douai: Agence de l'Eau Artois – Picardie.

Lowe, R.L. and Pan, Y. (1996). *Benthic algal communities as biological indicators*. In: RJ Stevenson, ML Bothwell, RL Lowe (Eds), Algal Ecol. Freshwater Benthic Ecosystems Academic Press, San Diego. pp: 705-739.

Madani, F.E., Chiaar, A. and Chafi, A. (2011). Phytoplankton composition and Abundance Assessment in the Nador Lagoon (Mediterranean Coast of Morocco)(Report).

Magurran, A. E. (1991). *Ecological Diversity and its Measurement*. Princeton University Press, Princeton, NJ.

Mahar, M.A. (2003). Ecology and Taxonomy of Plankton of Manchhar lake (Distt. Dadu), Sindh, Pakistan.Unpublished PhD. Thesis University of Sindh, Pakistan. Retrieved from: http://usindh.edu.pk.mukhatiar.ahmad/Dessertation_mukhatiar

Maitland, P.S. (1978). Biology of fresh water. R.M. and company Great Britain, 315pp.

Mann, D.G. (1999). The species concept in diatoms. *Phycologia*, **38 (6),** 437-495.

Margalef, R. (1987). Diversity. In Sournia, S. (ed) Phytoplankton manual: Monographs on oceanographic methodology. pp. 251-260. Page Brothers (Norwich) Ltd., United Kingdom.

Mark, E.E. (2012). Recent Diatoms Reported from the Central United States: Register of Taxa and Synonyms. Report Number 77, state Biological Survey of Kansas 2045 Avenue A, Campus West, Lawrence, Kansas, 66044 USA.

Mary, K.V. (2011). Inter-relationship between Physico-chemical Parameters and Phytoplankton Diversity of two Perennial Ponds of Kulasekharam area, Kanyakumari district. *Tamilnadu. Plant Science Feed*, **1(8)**: 147-154.

Mason, C.F. (2002). Biology of freshwater pollution. 4rd ed. Essex Univ. England. 387 pp.

McCormak, P.V. and Carins, J.R.J. (1994). Algae as indicators of environmental change. *J. Applied Phycology.* **6** 509-526.

McCullough, G.P., Aebischer, A. and Irvine, K. (2003). Satellite tracking of flamingos in southern Africa: the importance of small wetlands for management and conservation. *Oryx* **37**: 480-483.

McIntosh, R. I. (1967). An index of diversity and the relation of certain concepts to diversity. *Ecology*, **48**:392–404.

Mengel, K. and Kirkby, E.A. (1987). Principles of plant nutrition. 4th ed. IPI, Bern. 687 pp.

Meybeck, M., Chapman, D. and Helmer, R. [Eds] (1989). *Global Freshwater Quality: A First Assessment.* Blackwell Reference, Oxford, 306 pp.

Merovich, G.T., Stiles, J.M., Petty, J.T., Ziemkiewicz, P.F., and Fulton, J.B. (2007). Water chemistry-based classification of streams and implications for restoring mined Appalachian watersheds. *Environmental Toxicology and Chemistry* **26**: 1361-1369.

Mitchell, S.F. (1975). Some effects of Agricultural development and fluctuation in water level of Newzealand Reservoir. *Freshwater Biology*, **5**: 547-562.

Mohammed, M.A. and Saminu, M.Y. (2012). A Water Quality and Phytoplankton of Salanta River Kano, Nigeria.

Monteiro, T.M., Oliveira, R. and Vale, C. (1995). Metal stress on the plankton communities of Sado River (Portugal). *Water Research,* **29(2**): 695-701

Moss, B. (1993). *Ecology of fresh water-man and medium* 2nded. Blackwell Scientific Publications. London. 417pp.

Moustafa, A., Beszteri, B., Maier, U.G., Bowler, C. and Valentin, K. (2009). Genomic footprints of a cryptic plastid endosymbiosis in diatoms. *Sciencei,* **324**: 1724- 1726.

Mulholland, P.J. (1996). Role in nutrient cycling in streams. In: *Algal Ecology: Freshwater Benthic Ecosystems* (Eds R.J. Stevenson, M.L. Bothwell & R.L. Lowe), pp. 605–639. Academic Press, San Diego, CA**.**

Mustapha, M.K (2008). Assessment of the water quality of Oyun Reservoir Offa, Nigeria, using selected physicochemical parameters. *Turk. J. Fish. Aquat. Science*, **8**: 309-319

Nathan, J.S. (2010). Using Diatom and Biofilms to Assess Agricultural and Coal Mining Impacts on Streams, Spatio-Temporal Variability, and Successional Processes.

Necchi, J.O., Branco, L.H.Z. and Branco, C.C.Z. (2003). Ecological distribution of stream macroalgal communities from a drainage basin in the Serra da Canastra National Park, Minas Gerais, south-eastern Brazil. *Brazil journal of Biology*, **63(4)**: 635-646.

Nkwoji, J.A., Yakubu, A., Ajani, G.F., Balogun, K.J., Renner, K.O. and Igbo, J.K. (2010). Seasonal variations in water chemistry and benthic macro invertebrates of a South Western Lagoon, Lagos. *Nigeria J Am Sci*, **6(3):**85-92.

NRC (National Research Council) (1992). Restoration of Aquatic ecosystems.National Academy Press. Washington DC. USA.

OECD (1982). Cited by Lind, O.T (1978) Spatial and temporal variations in hypolimnetic oxygen deficit of a multi-depression Lake. *Limnol Oceanogr*, **32(3)**: 740-744.

OECD (1982). *Guideline for testing of chemicals No. 471 "Genetic toxicology: Salmonella typhimurium, Reverse Mutation Assay",* Organisation for Economic Co-operation and Development, Paris.

Odiete, W. O. (1993). Environmental planning and National Development In-house training workshop for the environmental assessment division Federal Ministry of Works and Housing Ikoyi, Lagos, JAMCOM Consult 60pp.

Okoye, B.C.O., Oladapo, A.A. and Emmanuel, A.A. (1991). Heavy Metals in the Lagos Lagoon sediments. *International Journal of Environmental Studies*, **37**: 35-41.

Omoreige, U.A., Opukri, O.C. and Ibaba, I.S. (2002). Oil Induced Environmental Degradation and Internal Population Displacement in the Nigeria's Niger Delta. Journal of Sustainable Development in Africa 10(1) Civil and Environmental Research

Opute, F. (2002). Contribution to the knowledge of algae in Nigeria. Desmids from the

Osuide, S. (1990). Environmental pollution in Nigeria. *Habitat International*, **14**(1)5-15 press, San Diego. 1006p

Ovie, S.I., Adepoju, F. and Adayi, O. (2000). Limnological stock assessment productivity and potential fish yield of Dadin Kowa and Kiri Reservoirs. *Ann. Report* 4-7.

Oyekunle, J.A.O., Adekunle, A.S., Ogunfowokan, A.O., Akanni, M.S. and Coker, O.S. (2012). "Agama Lizard: A potential biomarker of Environmental heavy metal pollution Assessment", *African Journal of Environmental Science Technology*, **6**(12): 458 – 463..

Paerl, H.W., Dyble, J., Moisander, P.H., Noble RT, Piehler MF, Pinckney JL, Steppe TF, Twomey L, Valdes LM (2003). Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies. FEMS Microbiol Ecol 46:233 24http://www.britannica.com/EBchecked/topic/1778834/The-Diatoms-of-the-United-States-Exclusive-of-Alaska-and-Hawaii.

Palmer, M.C. (1970). Algae and water pollution. The identifications significance and control of algae in water supplies and polluted water illustrations in color by Harold J.W. and Adams. Castle House Publication Ltd. 1980.123pp.

Passy, S.I., Bode, R.W., Carlson, D.M., and Novak, M.A. (2004). Comparative environmental assessment in the studies of benthic diatom, macroinvertebrate, and fish communities. *International Review Hydrobiology*, **89**: 121-138.

Patra, A.K. (2011). Physico-chemical properties and ichthyofauna diversity in Karala river, a tributary of Teesta River at jalpaiguri district of west Bengal, India. *International journal of applied biology and pharmaceutical technology*, **2**:47-58.

Patrick, R. and Reimer, C.W. (1966). *The diatoms of the United States*. Philadelphia: Academy of Natural Sciences, 669 p. vol. **1**.

Patrick, R. and Hendrickson, J. (1993). Factors to Consider in interpreting diatom changes. NOVA Hedwigia Beihelf. **106**: 361-377.

Peerapornpisal, Y.C. Chaiubol, J.P., Kraibut, H., Chorum, M., Wannathong, P., Ngearnpat, N., Jusakul, K. Thammathiwat, A., Chuanunta, J. and Inthasotti, T. (2004). Monitoring of water quality in Ang Kaew reservoir of Chiang Mai University using phytoplankton as bioindicator from 1995-2002. *Chiang Mai Journal of Science*, **31(1):** 85-94.

Peerapornpisal, Y. (2006). Phycology. Chotana Print, Chiang Mai, Thailand.

Person, J.L. (1989). Enviromental Science Investigations J. M. LeBel enterprise Ltd.Ronkonkoma N Y. 131pp.

Peter, A.G., Jason, A.S., Michael, A.R., Marie, A.I. and Adam, J.S. (1999). An Illustrated Key to Common Diatom Genera from Southern Australia. Presented at the Inaugural Australian National Algal Workshop, University of Adelaide, 17-19 February, 1999. *Cooperative Research for Freshwater Ecology* (Australia); no. 26.

Pillsbury, L.A. and Byrne, R.H. (2007). Spatial and temporal chemical variability in the Hillsborough River system. *Marine Chemistry*, **104**: 4-16.

Polge, N. (2010). Epipelic Algal Flora in the Küçükçekmece Lagoon. *Turkish Journal of Fisheries and Aquatic Sciences*, **10**: 39-45

Pongpan Leelahakrienkrai and Yuwade Peerapornpisal (2010). Diversity of Benthic Diatoms and water quality of the Ping River, Northern, Thaland. Environmental Science Section, Department of Biology,Faculty of science, Chiang Mai University, Chiang Mai 50200, Thailand.

Potapova, M.G. and Charles, D.F. (2005). Choice of substrate in algaebased water-Receiving Domestic and Oil Refinery Effluents. In: Islam. S.M. Plankton diversity index with reference to Mucalinda serovar Bodh-Gaya, 12th World Lack Conference, Taal, India, 2007.

Potapova, M. and Charles, D.F. (2003). Distribution of benthic diatoms in US rivers in Relation to conducting and ionic composition. *Freshwater Biology*, **48,** 1311-1328.

Poulkov, A., Duchoslav, M. and Dokulil, M**.** (2004). Littoral diatom assemblages as bioindicators of laketrophic status: A case study from perialpine lakes in Austria. *European Journal Phycology*, **39 (2):** 143–152.

Prescott, G.W. (1977). *The Fresh Water Algae.* WMCBrown Company Publishers, Dubuque, Iowa Pp 12-12.

Prygiel, J. and Coste, M. (1999). *Progress in the use of diatoms for monitoring rivers in France*. In: J Prygiel, BA Whitton and J Bukowska (eds.) Use of Algae for Monitoring Rivers III. Agence de l'Eau Artois-Picardie, Douai. pp. 165-179.

Pruetiworanan, S., Leelahakriengkrai, P. and Peerapornpisal, Y. (2008). Diversity of algae and water quality in Mekong River passing Chiang Rai Province, Thailand. Abstract in the 2nd International Conference on Science and Technology for Sustainable Development of the Greater Mekong Sub-region, Faculty of Agronomy, Hanoi Agricultural University, Hanoi, Vietnam. P: 158.

Rabalais, N.N. (2002). Nitrogen in Aquatic Ecosystem Bioone, **31**:102-112.

Rabiu, M.K., Mohammed, M.A. and Mohammad, L.B. (2014). The Plankton as Indicator of Water Quality in Kusalla Reservoir. A Shallow Man Made Lake. *IOSR journal of pharmacy and biological sciences*. **9**(1): 12-15.

Rainwater, F.H. and Thatcher, L.L. (1961). Methods for Collection and analysis of water samples. US. Geological Water Supply Paper 1454. US. Government Printing Office. Washington. D.C. 301Pp.

Ramachandra, T.V and Malvikan S. (2007). *Ecolgical Assessment of lentic Water bodies of Bangalore*.enviromental information system (ENVIS) centre for Ecological sciences, Indian institute of science, Bangalore.560012, India.

Raybaud, V. Tunin-Ley, A., Ritchie, M.E. and Dolan, J.R. (2009). Similar Patterns of Community organization characterize Distinct Groups of Different Tropic Levels in the Plankton of the NW Mediterranean Sea. *Biogeoscience*, **6**:431-438.

Reichardt, E.Z. (1999). Revision der Gattung Gomphonema. Koeltz Scientific Books, Iconographic Diatomologica **8**, Frankfurt, Germany.

Reid, G.K (1961). Ecolgy of Inland waters and Estuaries.376pp.

Reid, M.A., Tibby, J.C., Penny, D. and Gell, P.A. (1995). The use of diatoms to assess past and present water quality. *Australia journal Ecology*, **20**: 57-64.

Reimann, B. (1960). *Bildung, Bau und Zusammenhang Bacillariophyceenchalen", Nova Hedwigia*, Vol. 2, p.349.

Relyea, R.A. (2005). The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. *Ecol Appl*, **15**:618-627.

Resende, P.C., Resende, P., Pardal, M., Almeida, S. and Azeiteiro, U. (2010). Use of biological indicators to assess water quality of the Ul River (Portugal*). Environ Monit Assess*, **170**: 535-544.

Reynolds, C. S. (1984). The ecology of freshwater phytoplankton. Cambridge.
Retrieved from http;//www.academicjournals.org/AJB.on23/12/

Reynolds, C.S. (1998). What factors influence the species composition of phytoplankton in lake of different tropical status? *Hydrobiology*, **369/370**: 11-26.

Robert, J.V., Robert, E.B. (1988). River Ecology and Management Lessons from the Pacficic Coastal Ecoregion. Published by Springer Verlag New York LCC, U.S.A. Pp. 70.

Roelke, D. and Buyukates, Y. (2002). Dynamics phytoplankton succession coupled to species diversity as a system level tool for study of *Microcystis* population dynamics in eutrophic lakes. Limnol. *Oceanogr*, **47(4)**: 1109-1118.

Rothfritz, H., Juttner, I., Suren, A.M. and Ormerod, S.J. (1997). Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archiv. für Hydrobiol*. **138**: 465-482.

Round, F.E., Crawford, R.M. and Mann, D.G. (1990). The Diatoms. Cambridge University Press, New York. 747pp.

Round, F.E. (1993). A Review and Methods for the Use of Epilithic Diatoms for Detecting and Monitoring Changes in River Water Quality. Methods for the Examination of Waters and Associated Materials. HMSO, London.

Russo, A.R. (1978). Some ecological observations on permanent pond in Southern England: Primary production and planktonic seasonal succession. *Hydrobiologia*, **60**(1): 33-48.

Ryder, R.A.Q., Kerr, S.K., Lofus, K.H. and Regler, H.A. (1974). The morphoedaphic index, a fish yield estimator-review and evaluation. *J. Fish. Res.Bd. can.*, **31**:663-668.

Samir, M.S. and Ibrahim, M.S. (2008). Assessment of Heavy Metals Pollution in Water and Sediments and their Effects on Oreochromis niloticus in Northern Delta Lakes, Egypt.

Schindler, D.W. (2001). The Cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Can. *J. Fish. Aquat. Sci.*, **20(2)**: 113-117.

Senese, F. (2005). How can I Predict Oxygen Solubility in Water?https//antoniefrostburg.educ/chem./senese/101/solutions/faq/predicting DO.html

Seki, H. (1982). Organic Material in aquatic Ecosystem CRC press, inc.2100pp.

Shams, M. (2012). "Seasonal Variations in Phytoplankton Communities in Zayandeh-Rood Dam lake (Isfahan, Iran)," Turkish Journal of Botany, **36**, 715-726.

Slim, K.Z., Saad, O.E. and Kazpard, V. (2005), "Caractérisation chimique et algologique des eaux superficielles de la rivière Oronte (Liban) dans un climat semi-aride,". *Sécheresise*, **16(2)**: 131–135.

Smith, B. and Wilson, J. B. (1996). A consumer's guide to evenness indices. Oikos **76:** 70–82.

Smith, V.H. (1990). Phytoplankton responses to eutrophication in inland waters, p. 231-249 Zn I. Akatsuka [ed.]. Introduction to applied ecology. SPB.

Soininen, J. and Eloranta, P. (2004). Seasonal persistence and stability of diatom communities in rivers: are there habitat specific differences? *European Journal of Phycology*, **39**: 153-160.

Sonneveld, C. and Voogt, W. (2009). Plant nutrition of greenhouse crops. Springer Dordrecht Heidelberg London New York. 431 pp.

Stenger-Kovács, C., Buczkó, K., Hajnal, E. and Padisák J**.** (2007). Epiphytic, littoral diatoms as bioindicators of shallow lake trophic status: Trophic diatom index for lakes (TDIL) developed in Hungary. *Hydrobiologia* **589** (1): 141–154.

Stent, R.F. (1981). Grafham water. A discussion of Limnological events during the 5-year period 1974-1978. *Freshwater Biology*, **11:** 567-578.

Stevenson, R.J. and Pan, Y. (1999). Assessing environmental conditions in rivers and streams with diatoms. In: Stoermer E F, Smol J P. The Diatoms: Applications for the Environmental and Earth Science. Cambridge University Press, Cambridge. 11pp

Stevenson, R.J. and Smol, J.P. (2003). Use of algae in environmental assessments, *in* Wehr, J.D., and Sheath, R.G., eds., Freshwater algae of North America—Ecology and classification: San Diego, Calif., Academic Press, p. 775–804.

Stomp, M., Huisman, J., Mittelbach, G., Litchman, E. and Klausmeir, C. K. (2011). Large-Scale biodiversity Patterns in Fresh Water Phytoplankton. *Ecology*, **92(110)**: 2096-2107

Stumm, W. and Morgan, J.J. (1981). *Aquatic chemistry*: an introduction emphasizing chemical equilibria in natural waters. New York: Wiley Inter science, 789 pp.

Streamkeeper, F.G. (1991). Watershed Inventory and Stream Monitoring Methods. *Missouri Department of Natural Resources.* Environmental Services program.

Sverdrop, L.A., Duxbury, A.C.and Duxbury, A.B. (2003). An introduction to the world' s oceans, Seventh Edition.

Tanimu, Y. (2011). Diversity and abundance of phytoplankton in relation to water quality status of three reservoirs in kadauna state Nigeria. Unpublished, MSc. Thesis. Ahmadu Bello University, Zaria.

Tanimu, Y., Bako, S.P., Adakole, J.A. and Tanimu, J. (2011). Phytoplankton as bioindicators of water quality in saminaka reservoir, Northern Nigeria. Proceedings of the International Symposium on Environmental Science and Technology, June 1-4, 2011, Dongguan, Guangdong Province, China, pp: 318-322.

Tapia, P.M. (2008). Diatoms as bioindicators of pollution in the Mantaro River, Central Andes, Peru. *International Journal of Environment and Health*, **2(1):** 82- 91.

Taurai, B. and Tundisi, J.S. (2010). The effects of substrate type on Diatom based multivariate water Quality Assessment in a Tropical River (Monjo linho) Sao Carlos, SP, Brazil.

Taylor, J. C., Prygiel, J., Vosloo, A., Rey, P.A. and Ransburg, L.V. (2007). Can diatom based pollution indexes be used for biomonitoring in South Africa? A case of study of The Crocodile West and Marico water management area. *Hydrobiologia,* **592**: 455-464.

Taylor, J.C. (2003). "The Importance of Scanning Electron Microscopy in Diatom Ecological Studies"" *Proceeding Microscopy Society of South Africa*, **33:**55.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. (2007b). An illustrated Guide to Some Common Diatoms in South Africa.WRC Report NO TT 282/07. Water Research Commission, Pretoria, South Africa.

Taylor, J.C., De la Rey, P.A. and Rensburg, L., (2005), "Recommendations for the Collection, Preparation and Enumeration of Diatoms from Riverine Habitats for Water Quality Monitoring in South Africa*", Africa Journal of Aquatic Sciences,* **30**(**1)**: 65-75.

Templeton, R. (1995). Fresh water fisheries management. Second edition 241pp.

Ter Braak, C.J.F. (1986). Canonical correspondence analysis; a new eigen vector technique for multivariate direct gradient analysis. *Ecology*, **67**: 1167-1179.

Tewodros, K. and Afework, B. (2014). Phytoplankton Composition and Physico-chemical parameters study in Water Bodies of Abijalla – Shalla Lakes National Park (ASLNP) Ethopia. *Journal of Biological Science*, **4(2):** 069-076.

Tilman, D., Knops, J., Wedin, D., Reich, P., Ritchie, M. and Siemann, E. (1997). The influence of functional diversity and composition on ecosystem processes. *Science*, **277**: 1300-1302.

Tilman, D., Lehman, C.L. and Thomson, K.T. (1997).Plant Diversity and Ecosystem Productivity: Theoretical considerations. *Proceedings of the National Academy of Sciences***, 94**:1857-1861.

Tiseer, F.A., Tanimu, Y. and Chia, A.M. (2008). Seasonal occurrence of Algae and Physicochemcial parameters of Samaru Stream, Zaria, *Nigeria-Asian Journal of Earth Science,* **1(1**): 31-37.

Touliabah, H., Safik, H.M., Gab-Allah, M.M. and Taylor, W.D. (2002). Phytoplankton and some abiotic featuresof El-Bardawil Lake, Sinai, Egypt. *Africa journal of aquatic Science.* **27**: 97-105.

Townsend, C. R., Harper, J.L. and Begon, M. (2000). Essentials of Ecology. 3rd edition. Lackwell Science Publishers, London.

Townsend, S.A. and Gell, P.A. (2005). The role of substrate type on benthic diatom assemblages in the Dalp and Toper Rivers of the Australian wet/dry tropics. *Hydrobiologia* **548**: 101-115.

Ufodike, E.B.C., Kwanasie, A.S. and Chude, L.A. (2001). On-set of rain and its destabilizing effect on aquatic physicochcmical parameters. *Journal of aquatic sciences* 16(2) 91-94. Warri/Forcades Estuaries part 2. The elongate baculiform desmids. *Journal of Limnology.* **59(2**): 131-115.

Unanam, A.E. and Akpan, A.W. (2006). Analysis of physicochemical characteristics of some freshwater bodies in Essien Udim Local Government area of Akwa Ibom State, Nigeria. In: Proceeding of the 21st Annual Conference of the Fisheries Society of Nigeria (FI50N) Calabar, 13th -17th November, 2006. Mackereth, F.J.H (1963). Some methods of water analysis for limnologists. Fresh water BioI. Ass. Scient. PubIs. 21:72.

United Nations Development Program, (2006). *Niger Delta Human Development Report,*

UNICEF/WHO (2012), "Progress on drinking water and sanitation: 2012 update. WHO/UNICEF Joint Monitoring Programme for water supply and sanitation". UNICEF. New York. http://www.wssinfo.org/fileadmin/user-upload/resources/jmpreport 2012 – en. Retrieved on 30 March 2012

United States Environmental Protection Agency, USEPA (2002). Current drinking water standards. http/www.cpa.gov/safewater/mcl.html

USGAO (2000). Health Effect of lead in drinking water. U.S. General Accounting Office reports 2000.

Vaisamen, U., Misund, A. and Chekushin, V. (1988). Water, Air and Soil Pollution.**104**: 205-219.

Valiela, I. (1991). Ecology of water columns In Barnes, R.S.K and Mann, K.H.(eds) \nb *fundamental aquatic ecology.*pp 29-56 Blackwell scientific second edition.

Valiela, I., Collins, G., Kremer, J., Lajtha, K., Geist, M., Seely, B., Brawley, J., and Sham, C.H. (1997). Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. *Ecological Applications*, **7**: 358-380.

Venkateswarlu, N. and Reddy, P.M. (2000). Plant biodiversity and bioindicators in aquatic environment. http://envfor.nic.in/news/8900/plantbio.html.

Vitousek, P.M., J.D., Howarth, R.W., Likens G.E., Matson, P.A., Schlinder, D.W., Schlesinger, W.H., and Tilman, D.G. (1997). Human alteration of nitrogen cycle: Source and consequences. *Ecological Applications*, **7:**737-750.

Vollenweider, R.A. (1976). Manual on methods of measuring production in Aquatic environment. IBP-Handbook No 12 Blackwell Oxford p.225.

Walker, C.E. and Pan, Y. (2006). Using diatom assemblages to asses urban stream conditions. *Hydrobiol.* **516(1):** 179-189.

Walker, D., Perissinotto, R. and Bally, R. P. A. (2001). Phytoplankton / protozoan dynamics in the Nyara estuary; a small temporary open system in Eastern Cape (South Africa). *African Journal of Aquatic Science*, **26(1)** : 31 – 38.

Walmsley, R.D. (2000). Perspectives on Eutrophication of Surface Waters: Policy/Research Needs in South Africa. WRC Report No KV129/00. Water Research Commission. Pretoria, South Africa.

Wehr, J.D. and Sheath, R.G. (eds.) (2003). Freshwater Algae of North America: Ecology and Classification, Academic Press.

Welch, E.B. (1992). Ecological effects of wastewater, Chapman & Hall, London, UK.

Welch, E.B., and Perkins, M.A (1979). Oxygen deficit-phosphorus loading relations in lakes. *Journal of water.pollution control. Fed*, **51**: 283-288.

Wetzel, R.G. (2001). Limnology: Lake and River Ecosystems. Academic Press. Newyork, USA.

Whitton, B.A. and Patts, M. (2000). The Ecology of Cyanobacteria. Kluwer Academic Publishers, Netherlands.

Wilhm, J.L. and Dorris, T.C. (1966). Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. *Am. Midland Nat.*, **76**: 427-449.

Wilm, J.L. and Dorris, T.C. (2003). Species Diversity of Benthic Macroinvertebrates. In: A Stream

Winter, J.G. and Duthie, H.C. (2000b). Stream epilithic, epipelic and epiphytic diatoms: habitat fidelity and use in biomonitoring. *Aquatic Ecology*, **34**, 345-353.

Winter, J.G. and Duthie, H.C. (2000). Epilithic diatoms as indicators of stream total N and total P concentration. *Journal of North America. Benthol. Soc*.**, 19**: 32–49.

World Health Organisation, WHO (1963). *International Standards for Drinking Water*. Ed.2. WHO. Geneva, 1963. 206pp

World Health Organisation, WHO (1971). *International Standards for Drinking Water*, Ed.3. WHO, Geneva, 1971.67pp.

World Health Organisation, WHO (2000). Water Quality Standards for Freshwater Classifications. *Water Planning Branch* (**919**): 733-5083.

World Health Organization (2004). Guidelines for Drinking-water Quality. 3rd ed.Vol. 1 Recommendations. Pp 210-220

World Health organization (2011). Guidelines for drinking Water, 4rd ed

Yakubu, A.F., Sikoki, F.D., Abowei, J.F.N. and Hart, S.A. (2000). A comparative study of phytoplankton communities of some rivers, creeks and borrow pits in the Niger Delta Area. *Journal of Applied Science, Environment and Management*, **4(2)**: 41-46.

Yuan, L.L. and Norton, S.B. (2004). Assessing the relative severity of stressors at a watershed scale. *Environmental Monitoring and Assessment*, **98**: 323-349.

Yusuf, K.A. (2007). Evaluation of Groundwater Quality Characteristics in Lagos-City. *Journal of Applied Science* **7(13)**: 1780-1784.

Zalack, J.T., Smucker, N.J. and Vis, M.L. (2010). Development of a diatom index of biotic integrity for acid mine drainage impacted streams. *Ecological Indicators*, **10**: 287-295.

Zamora-Munoz, C., Sain-Canteno, C.E., Sancheztega, A. and Alba-terecedor, J. (1995). Are Biological indices BWPW and ASPT and their significance regarding water quality seasonally dependent?-Factor explaining their variations. *Water Research*, **29**: 285-290.

Zang, W.H. and Xu, X.Q. (2001). Determination of trace level of microcystins in water using solid-phase extraction and high performance liquid chromatography. *Chines Journal of Analytical Chemistry***, 29(5**): 522-525.

Zuber, S.M. (2007). Ecology and Economic valuation of Lake Mansar, Jammu. Ph.D. Thesis, University of Jammu, Jammu.

APPENDICES

Appendix i: Monthly mean variations of physicochemical parameters observed in River Galma

Physicochemical parameters	Nov	Dec	Jan	Feb	Mar	Apr	mean	WHO Standard
Biochemical Oxygen Demand(mg/L)	3.13^{b}	0.23^{c}	5.32^{a}	1.60^{bc}	3.23^{b}	3.19^{b}	2.78	5
Dissolved Oxygen	6.94^{b}	6.44^{b}	8.49^{a}	3.60^{c}	5.75^{b}	5.78^{b}	6.18	5
Electrical Conductivity	94.88^{c}	106.83^{c}	236.00^{ab}	194.00^{ab}	258.00^{a}	162.33^{bc}	175.34	300
Ph	7.34^{a}	7.33^{a}	6.95^{b}	6.98^{b}	7.32^{a}	7.53^{a}	7.24	6.5-8.5
Total Dissolved Solids	48.54^{d}	53.28^{d}	122.17^{ab}	97.17^{bc}	145.00^{a}	81.63^{cd}	91.29	200
Temperature Laboratory	23.68^{a}	27.17^{a}	26.79^{a}	27.22^{a}	30.67^{a}	29.33^{a}	34.14	23-35
Temperature Field	25.12^{abc}	24.93^{bc}	25.88^{abc}	23.50^{c}	26.67^{ab}	27.60^{a}	25.62	23-35
Hardness	0.94^{d}	1.13^{cd}	1.17^{bcd}	1.44^{b}	1.32^{bc}	2.02^{a}	1.34	300
Calcium	0.99^{c}	1.48^{abc}	1.26^{bc}	1.64^{ab}	1.72^{ab}	1.98^{a}	1.51	75
Magnesium	3.80^{b}	4.25^{b}	5.89^{b}	5.53^{b}	4.22^{b}	9.98^{a}	5.61	50
Potassium	3.44^{b}	3.45^{b}	3.38^{b}	5.24^{ab}	6.35^{a}	4.58^{ab}	4.41	12
Sodium	8.78^{c}	8.53^{c}	8.34^{c}	24.00^{b}	46.58^{a}	26.83^{b}	20.51	50
Ammonium	18.67^{ab}	25.20^{a}	25.25^{a}	9.46^{c}	15.50^{bc}	11.13^{bc}	17.54	NA
Chloride	29.83^{b}	28.55^{b}	58.05^{a}	54.28^{a}	64.50^{a}	33.67^{b}	44.81	250
Phosphate-Phosphorus	4.84^{a}	1.37^{ab}	0.88^{b}	1.06^{ab}	0.89^{b}	1.67^{ab}	1.79	≤75
Sulphate	152.12^{ab}	124.78^{bc}	79.70^{c}	198.62^{a}	133.28^{bc}	161.65^{ab}	141.69	200
Nitrate-Nitrogen	12.34^{c}	8.88^{c}	10.05^{c}	30.21^{a}	33.72^{a}	21.94^{b}	19.52	45
Cadmium	0.01^{b}	0.02^{a}	0.00^{e}	0.01^{d}	0.01^{d}	0.01^{c}	0.01	0.003
Cobalt	0.00^{c}	0.00^{c}	0.06^{a}	0.06^{a}	0.04^{b}	0.02^{b}	0.03	NA
Copper	0.03^{b}	0.04^{a}	0.01^{c}	0.02^{c}	0.02^{c}	0.01^{c}	0.02	2
Lead	0.13^{b}	0.19^{a}	0.10^{c}	0.12^{b}	0.14^{b}	0.13^{b}	0.14	0.01
Zinc	0.04^{a}	001^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.01	3

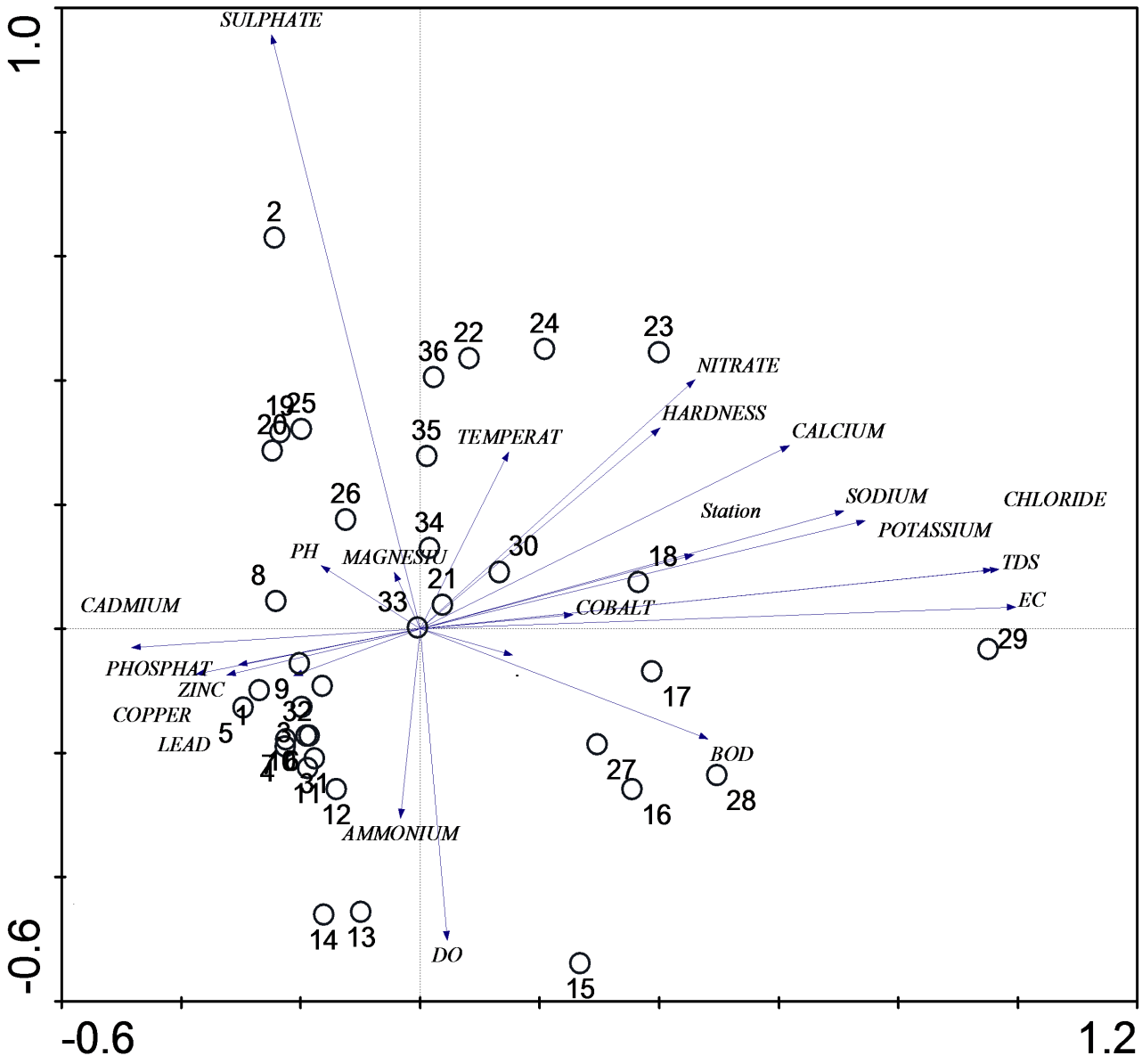
Means on the same row with the same alphabets are not significantly different ($p < 0.05$).

Appendix ii: Mean station values of physicochemical parameters of River Galma

STATION	1	2	3	4	5	6	Mean	WHO STD
BOD(mg/L)	1.64^{b}	2.31^{ab}	2.50^{ab}	2.93^{ab}	3.83^{a}	3.49^{ab}	2.78	5
DO(mg/L)	6.25^{a}	6.25^{a}	5.45^{a}	6.04^{a}	6.55^{a}	6.47^{a}	6.17	5
EC	105.72^{b}	109.55^{b}	186.28^{a}	206.83^{a}	244.55^{a}	199.12^{a}	175.34	300
PH	7.45^{a}	7.25^{abc}	7.18^{bc}	7.11^{c}	7.35^{ab}	7.12^{bc}	7.24	6.5-8.5
TDS(mg/L)	56.72^{c}	61.45^{c}	92.45^{bc}	103.67^{ab}	134.17^{a}	99.33^{ab}	91.3	200
TEMP Lab	28.19^{a}	28.18^{a}	27.06^{a}	26.92^{a}	26.76^{a}	67.75^{a}	34.14	23-35
TEMP FLD	26.00^{a}	25.30^{a}	24.43^{a}	24.97^{a}	26.00^{a}	27.00^{a}	25.62	23-35
AMMONIUM(mg/L)	18.83^{ab}	16.04^{ab}	13.83^{b}	17.67^{ab}	24.54^{a}	14.29^{b}	17.53	NA
CADMIUM(mg/L)	0.01^{c}	0.01^{bc}	0.01^{abc}	0.01^{abc}	0.01^{abc}	0.01^{a}	0.01	0.003
CALCIUM(mg/L)	1.07^{c}	1.32^{bc}	1.61^{ab}	1.55^{abc}	2.01^{a}	1.52^{abc}	1.51	75
CHLORIDE(mg/L)	25.78^{c}	25.41^{c}	44.10^{bc}	50.38^{ab}	69.92^{a}	53.28^{ab}	44.81	250
COBALT(mg/L)	0.04^{a}	0.04^{a}	0.03^{ab}	0.03^{ab}	0.02^{ab}	0.03^{ab}	0.03	NA
COPPER(mg/L)	0.02^{a}	0.02^{a}	0.02^{a}	0.02^{a}	0.02^{a}	0.02^{a}	0.02	2
HARDNESS(mg/L)	1.12^{c}	1.18^{bc}	1.32^{abc}	1.50^{a}	1.46^{ab}	1.44^{ab}	1.54	300
LEAD(mg/L)	0.13^{a}	0.12^{a}	0.14^{a}	0.14^{a}	0.14^{a}	0.14^{a}	0.14	0.01
MAGNESIUM(mg/L)	5.95^{ab}	5.24^{ab}	5.08^{ab}	6.51^{ab}	4.20^{b}	6.69^{a}	5.61	50
NITRATE(mg/L)	21.12^{a}	16.86^{a}	17.72^{a}	19.45^{a}	19.59^{a}	22.12^{a}	19.48	45
PHOSPHORUS(mg/L)	5.10^{a}	1.46^{b}	1.03^{b}	1.06^{b}	1.02^{b}	1.02^{b}	1.78	675
POTASSIUM(mg/L)	3.41^{b}	3.27^{b}	4.43^{ab}	4.64^{ab}	6.19^{a}	4.49^{ab}	4.41	12
SODIUM(mg/L)	12.61^{b}	13.05^{b}	21.32^{ab}	25.06^{ab}	28.63^{a}	22.40^{ab}	20.51	50
SULPHATE(mg/L)	141.38^{a}	171.38^{a}	112.77^{a}	129.72^{a}	143.13^{a}	151.77^{a}	141.69	200
ZINC(mg/L)	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.01^{a}	0.02^{a}	0.01	3

Means with the same superscript in the same column are not significantly different ($p < 0.05$).

Appendix iii: Principal component analyses of Physicochemical parameters.



Key:1,7,13,19,25&31=O1;2,8,14,20,26&32=O2,3,9,15,21,27&33=O3;4,10,16,22,28&34=O4;5,11,17,23,29&35=O5;6,12,18,24,30&36=O6.O=station:N1,D7,J13,F19,M25,&A31=O1,N2,D8,J14,F20,M26&A32=O2,N3,D9,J15,F21,M27&A33=O3,N4,D10,J16,F22,M28,&A34=O4,N5,D11,J17,F23,M29&A35=O5,N6,D18,J24,M30&A36=O6:N=November,D=December,J=January, F=February, M=March,A =April.

Appendix IV : Summary of Relative Abundance Periphytic Diatoms in a Segment of River Galma during the Months of November 2012 to April 2013

Family	Genus/ species	Nov	Dec	Jan	Feb	Mar	Apr	Total
	Melosira sp	6	6	6	5	6	5	34
	Cyclotella sp	3	5	6	6	4	4	28
Fragilariaceae	*Fragilaria capucina*	2	3	1	0	1	0	7
	Fragilaria virescens	0	1	3	1	2	3	10
	Frustulia rhomboids	0	0	0	0	4	1	5
	Opephora swartzii	0	1	3	4	4	0	12
	Synedra famlica	4	1	0	1	3	0	9
	Synedra fasciculate	1	3	4	4	4	0	16
	Synedra minusculata	0	1	0	0	2	0	3
	Synedra robusta	0	0	2	0	0	0	2
	Synedra tenera	2	3	3	0	0	0	8
	Synedra ulna	2	4	3	6	2	0	17
	Synedra ulna	2	2	2	0	0	2	8
	Synedra ulna	2	2	3	1	2	5	15
	Tabellaria fenestrata	5	2	5	6	5	6	29
Achnanthaceae	*Achnanthes deflexa*	1	3	3	1	2	2	12
	Achnanthes lanceolata	1	0	2	0	0	0	3
	Rhoicosphenia curvata	0	0	5	0	0	0	5
	Rhoicosphaenia curtala	1	2	0	0	0	3	6
Naviculaceae	*Amphipleura purpusila*	1	0	3	1	0	1	6
	Diatomelia balfouria	3	1	4	1	0	0	9
	Gyrosigma acuminatum	0	2	6	4	3	2	17
	Gyrosigma exilis	1	2	0	0	1	0	4
	Gyrosigma hummi	1	1	0	0	2	0	4
	Gyrosigma macrum	1	0	2	0	3	0	6
	Navicula arcensis	1	4	2	2	1	3	13
	Navicula circumtexta	0	1	1	1	1	3	7
	Navicula costulata	1	1	0	0	1	1	4
	Navicula cuspida	1	0	1	1	1	1	5
	Navicula elegans	1	0	1	0	1	0	3
	Navicula explanata	0	2	0	0	3	0	5
	Navicula falaisenses	1	1	0	2	0	0	4
	Navicula gysingensis	1	0	0	2	1	0	4
	Navicula imcomposita	0	0	2	1	2	0	5

	Navicula keelyi	0	0	0	1	0	1	2
	Navicula latelongitudinalis	0	2	0	1	2	1	5
	Navicula laterostrata	1	0	2	2	1	4	10
	Navicula mutica	0	1	2	0	1	0	4
	Navicula notha	0	1	2	0	0	1	4
	Navicula paucivisitata	0	2	0	1	3	1	7
	Navicula placenta	0	0	0	0	0	1	1
	Navicula protracta	0	2	0	0	1	5	8
	Navicula simula	2	0	0	3	2	1	8
	Navicula spicula	0	1	0	0	1	1	3
	Navicula subtillisima	0	1	0	2	0	0	3
	Navicula tenelloides	2	3	0	0	1	0	6
	Navicula variostrata	1	0	0	0	2	0	3
	Navicula wardii	0	1	0	0	0	0	1
	Neidum affine	0	0	1	2	0	0	3
	Neidum hercyanicum	0	1	0	1	1	0	3
	Pinnularia abaujenensis	1	1	0	1	2	0	5
	Pinnularia abaujenensis	0	0	0	1	0	0	1
	Pinnularia divergens	1	0	1	0	4	2	8
	Pinnularia mesolepta	0	4	1	1	1	0	7
	Pinnularia termitina	0	1	0	0	1	0	2
	Pleurosigma angulatum	0	0	4	1	4	0	9
	Pleurosigma delicatulum	0	2	0	1	2	0	5
	Pleurosigma salinarum	0	1	1	0	0	2	4
Gomphonemaceae	*Gomphonema affine*	0	1	0	1	1	0	3
	Gomphonema affine	0	3	1	0	1	0	5
	Gomphonema angustatum	0	1	1	0	0	0	2
	Gomphonema brasiliense	1	1	1	1	0	0	4
	Gomphonema eriense	0	0	0	1	0	0	1
	Gomphonema granuwii	2	1	1	2	4	0	10
	Gomphonema montanum	2	1	1	1	0	0	5
	Gomphonema olicaceum	1	0	0	4	3	2	10
	Gomphonema olivacoides	2	1	1	1	0	0	5
	Gomphonema olivacoides	1	5	1	1	1	6	15
	Gomphonema parvulum	0	1	2	0	0	2	5
	Gomphonema tenellum	1	0	0	1	0	0	2
Epithemiaceae	*Denticula tenuis*	3	3	0	4	1	2	13
	Epithemia adnata	0	0	2	0	0	1	3
	Epithemia turgid	0	4	3	0	3	2	12

Eunotiaceae	*Eunotia vauheurkii*	0	3	0	1	2	2	8
	Peronia intermedia	3	5	0	0	1	0	6
	Semiorbis hemicyclus	0	2	1	0	3	0	6
Plagiotropidiceae	*Plagiotropis Lepidoptera*	0	1	1	0	0	0	2
Cymbellaceae	*Amphora submontana*	0	0	0	5	3	2	10
	Amphora veneta	2	0	1	3	0	4	10
	Cymbella angustata	3	6	2	5	0	0	18
	Cymbella cistula	1	5	4	1	0	0	11
	Cymbella minuta	3	1	4	2	0	1	11
	Cymbella minuta	4	1	2	0	0	1	8
								629