# ASSESSMENT OF EUTROPHICATION LEVEL OF MUNICIPAL SURFACE WATER, ABUJA NIGERIA

**BY**

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**M.Sc/SCIE/3692/2010-2011**

**A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF SCIENCE DEGREE IN ANALYTICAL CHEMISTRY**

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**AUGUST, 2015**

## DECLARATION

I declare that the work in this Dissertation entitled "Assessment of Eutrophication level of Municipal Surface Water, Abuja Nigeria" has been carried out by me in the Department of Chemistry. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

| _____ | _____ | _____ |
|---|---|---|
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## CERTIFICATION

This dissertation entitled ASSESSMENT OF EUTROPHICATION LEVEL OF MUNICIPAL SURFACE WATER, ABUJA NIGERIA by Daniel Chukwuka OKIBE meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

| | | |
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## ACKNOWLEDGMENT

I wish to express my profound gratitude to my supervisors, Prof. C.E Gimba and Dr. S.E Abechi for their valuable advice, constructive criticisms and guidance in the course of this research work. I am also grateful to Mr. Silas Egwurube in the Multi-User Science Laboratory in Ahmadu Bello University, Zaria who calibrated some of the equipments used for this work and provided the manuals and technical skills to carry out some experiments in this research. My appreciation also goes to other staff in the Multi-User Science Research Laboratory, especially Mr.Bashir and Mohammed Muazu for their cooperation during the experiments in the laboratory. My appreciation also goes to Mr. Ochigbo Celestine in the M.Sc research laboratory who provided valuable ideas, reagents, distilled water and administrative assistance within and outside the Department of Chemistry to make this research work a success. I also want to thank Mr. Silvanus Ojih in the Biological Science Department of ABU Zaria who freely gave me access to the biological science laboratory and Mr. Y. Tanimu who provided the biological reagents, manuals and assisted in the algae count experiments. I will not fail to mention Mr.Jibril Modi and Mr. Solomon Sunday in the Federal Capital Development Authority (FCDA) Office and their staff who gave me lessons on auto card map and provided the Abuja auto card map soft copy, the sampling route and other information needed for this research. My special appreciation goes to Dr. Ishaya Gandu and Mr. Abbas in the National Research Institute for Chemical Technology, (NARICT) Zaria who assisted in the analysis of COD, BOD and potassium. I wish also to thank my friend and colleague Elizabeth Ogbe who provided the statistical software and convey messages to my supervisors and Mr. Paul Omali who assisted in the statistical analysis.

## DEDICATION

This project work is dedicated to the Greatest Creator of all time, the Almighty God and also to everyone who appreciates and cherishes the knowledge of chemistry.

## ABSTRACT

The level of some nutrient elements in Abuja surface water were investigated for six months to determine the eutrophication profile and make logical inference on the fate of surface water system in the nearest future. Samplings were done monthly for a period of six months covering October to March and standard methods were used for the measurement of some nutrients constituting the indices of eutrophication. The results showed high levels of microbial activities. Biochemical oxygen demand (BOD) showed high levels of pollution which varied with time and velocity of water current. Other parameters investigated were chemical oxygen demand (COD), nitrate concentration, total dissolved solid (TDS), conductivity, algae count, temperature, pH, phosphate and potassium concentrations. Maximum and minimum values of some eutrophication parameters in the sites were recorded as follows: BOD ( Orozo 38mg/L- 7.37mg/L, Gidan Mangoro 31.2mg/L- 5.08mg/L, Nyanya 32.4mg/L- 10.05mg/L, Wuse 40.30mg/L- 7.007mg/L, Jabi 26.50mg/L- 3.10mg/L). Similarly total dissolved solid maximum and minimum values in the sites were given as Orozo 1222mg/L- 105.1mg/L, Gidan Mangoro 861.0mg/L- 148.8mg/L, Nyanya 676.0mg/L- 127.6mg/L, Wuse 200.0mg/L- 86.2mg/L, Jabi 846.0mg/L- 151.8mg/L. These results point to eutrophication indicators in Abuja surface water system. The results showed that the concentrations of nitrogen, phosphorus and potassium may be significantly increased beyond their compensation level by the growing human population in Abuja metropolis.

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## ABBREVIATIONS, DEFINITIONS AND SYMBOLS

| | |
|---|---|
| N | Nitrogen |
| P | Phosphorus |
| K | Potassium |
| Mg | Milligram |
| % | percent |
| DO | Dissolved oxygen |
| BOD | Biochemical Oxygen Demand |
| $PO_4^{2-}$ | Phosphate |
| $NO_3^-$ | Nitrate |
| TDS | Total Dissolved Solid |
| µg | Microgram |
| NaOH | Sodium Hydroxide |
| HCl | Hydrochloric Acid |
| $NH_4VO_3$ | Ammonium Metavanadate |
| $H_2SO_4$ | Tetraoxosulphate (VI) Acid |
| $KH_2PO_4$ | Anhydrous Potassium Dihydrogen Phosphate |
| mg/L | milligram per liter |
| NIMET | Nigerian Metrological Agency |
| COD | Chemical Oxygen Demand |

| | |
|---|---|
| GIS | Geographical Information System |
| ANOVA | Analysis of Variance |

# CHAPTER ONE

## 1.0 INTRODUCTION

Eutrophication is the natural process whereby a confined water body (e.g. lake or dam) ages with time due to accumulation of silt or organic matter in the lake (Ademoroti, 1996).

A young lake is characterized by low nutrient level and consequently low plant productivity and at this stage is described as oligotrophic (few food) lake. The water body gradually acquires inorganic and organic nutrient from catchment areas and these promote aquatic growth and increased biological productivity causing the lake to become murky with decaying organic matter and phytoplankton. The water body is said to be eutrophic (well fed) and consequently, the decaying organic matter depletes its available oxygen. Increase in the accumulation of silt and organic matter, makes the water body shallower and sunlight penetrate slowly to the bottom, making the water warmer. Plants take roots along the shallow edges and the lake slowly transforms into a marsh or swamp which may eventually lead to dry land (Ademoroti, 1996).

Anthropogenic impact and seasonal climatic changes have aggravated eutrophication in water bodies worldwide. Advancement in science and technological innovation in agricultural practices has resulted in increased usage of natural and synthetic manures rich in phosphorus, potassium, and calcium in farming. These have accelerated the natural process of eutrophication worldwide. Nations of the world are conscious of the famous Malthusian economic theory and hence fight against this detrimental prediction by increasing food production through the construction of dams for irrigation and energy. Nations in arid regions are also making efforts to conserve their existing water resources to

meet the increasing food demand through water storage reservoirs to conserve and harness this precious resource more efficiently. Such reservoirs and lakes are subject to several kinds of degradation and losses through evaporation, inefficient storage and consumption waste in addition to the growth of all kinds of aquatic organisms such as plankton, insects, fish and angiosperms. These changes lead to the phenomenon of eutrophication (Rashid and Anjum, 1985).

Eutrophication therefore causes progressive deterioration of water quality especially lakes due to luxuriant growth of plants with the effect that the overall metabolism of the water is affected (Richard, 1970).

A research carried out by Rashid and Anjum (1985) showed that the presence of *Euglena, oscillatoria and Anabaena Spp* indicate high organic pollution responsible for eutrophication and this affects the species of microinvertebrates and macrovertebrates including the species of fish in the water. It was found that the predatory specie *Notopterus hotopterus* was gradually increasing causing threat to the survival of some useful fish in the water body. Eutrophication is therefore detrimental to crop production, fish farming and provision of portable drinking water.

Eutrophic water bodies receive large amount of aquatic plant nutrients relative to their surface area and volume and have high production of aquatic plants (Fred and Ann, 1978). Oligotrophic water bodies tend to be poorly fertilized and have low aquatic plant production, mesotrophic water bodies receive moderate amount of aquatic plants nutrients.

Thermocline is a term used in describing the depth in a water body in which there is rapid change in temperature with depth as a result of the division of the water body into

layers with different densities (Fred and Ann 1978). These are the epilimnion the warmer and less dense surface waters and also the hypolimnion which describes the cooler, more dense bottom waters. The thermocline provides a barrier of mixing water between these two layers and is normally present between early June to October in temperate water bodies (Fred and Ann 1978). During this thermal stratification, waters of the hypolimnion are isolated from the atmosphere by the thermocline and cannot replenish their oxygen. Algae which have grown in this area died and decomposed leading to reduction of oxygen at the bottom. In many eutrophic waters, this depletion is sufficient to cause anoxic conditions (Zero dissolved oxygen) in the hypolimnion (Fred and Ann 1978; Muir, 2001).

It was discovered that the river Jordan which is currently the largest and longest river that flows into Israel was under threat of extinction following eutrophication. Adequate measures were taken to keep it alive for utility and consumption since major rivers in Israel were contaminated by agriculture and industrial wastes which made the Jordan River the only natural and clean river in the country (Shoshana, 2012). Biodiversity of algal communities in the upper Jordan River formed as a result of natural climatic and anthropogenic impact was used to predict the disastrous outcome.

## 1.1 CAUSES OF EUTROPHICATION

### 1.1.1 Natural Sources

Eutrophication can also be described as the process of fertilization of natural waters (Fred and Ann, 1978). There is no place in Abuja where Eutrophication has been described as an algal bloom. Nevertheless, there is the need to put drastic environmental measures to prevent its occurrence in the near future. Any process which favours the growth of aquatic

plants or plant life can lead to eutrophication. Nutrients required for plant growth include sulphur, calcium, magnesium ,sodium ,iron, zinc, copper etc. The major nutrients required by plants are nitrogen, phosphorus and potassium. Nitrate-nitrogen is most often obtained from urea. When urea is excreted by animals it hydrolyses rapidly to ammonia which is then acted upon by the bacteria Nitrosomonas and is oxidized to nitrite. Another bacterium called Nitrobacter oxidizes the nitrite to nitrate which is available as plant nutrient (Ademoroti, 1996). The triple bond of Nitrogen, N≡N present as $N_2$ in the atmosphere can be broken by thunderstorm to make it soluble in water during rain and all these form a natural process for nitrogen fixation into the soil which can be washed along with sand and silt to cause eutrophication in water body (Ababio 1990).

In stabilization ponds, nitrate acts as an algal nutrient thereby reinforcing the symbiotic relationship between algal and bacteria and this is the basis of wastewater purification in facultative ponds (Ademoroti, 1996).

**Hydrolysis of urea**

$$NH_2CONH_2 + H_2O \rightarrow 2NH_3 + CO_2$$

**Oxidation of ammonia by Nitrosomonas**.

$$55NH_3 + 76O_2 + 5CO_2 \rightarrow \underset{\text{(bacteria cells)}}{C_5H_7NO_2} + 54NO^-_2 + 52H_2O + 54H^+$$

**Oxidation of nitrite by Nitrobacter.**

$$400NO^-_2 + 195O_2 + 5CO_2 + NH_3 + 2H_2O \rightarrow \underset{\text{(bacteria cells)}}{C_5H_7NO_2} + 400NO^-_3$$

Other natural sources leading to eutrophication include rock weathering and erosion. Erosion can transport clay, silt and plant nutrients such as calcium and phosphorus in suspension into water bodies for eutrophication (Lathrop *et al* 1998). The nutrients available in an environment therefore also depend on the topography (Likens, 1972).

### 1.1.2 Anthropogenic Sources

#### Domestic Activities

Human activities in urban and rural areas have led to an increase in plant nutrients such as nitrogen, phosphorus, and potassium through improper disposal of sewage rich in urea from faeces and urine, food waste and other municipal waste products. The use of detergents with branch chain hydrocarbon cannot be degraded by bacteria and hence lead to the death of aquatic animals and subsequent enrichment of water body with nitrogen. The use of detergents with optical brighteners for aesthetic beauty of clothes has led to the enrichment of water bodies with nitrogen because these optical brighteners and perfumes often contain chromophore structure –N=N- to enhance red shift and desirable colour characteristics (Ababio, 1990).

#### Agricultural Practices

Human agricultural practices such as the use of organic and inorganic fertilizers have led to increase in plant nutrients and consequently the phenomenon of eutrophication. Agricultural run-off from irrigated farms and leaching of fertilizer to water bodies have enormously increased these nutrients to favour the growth of algae (Lathrop, 1998). Nutrients from agricultural systems can pollute natural waters through drainage water, soil

erosion and animal waste and soil water, making these nutrients mobile and enhancing eutrophication (Eckert 1995; Gimba, 2011).

**Industries**

Developing nations of the world are embracing industrialization to improve their economies and standard of living and this trend has led to the production and discharge of various contaminants to the aquatic environment. Fertilizer industries, detergent industries, food industries among others discharge a lot of waste which can find their ways into lakes, streams or rivers or even directly to the municipal sewer system (Weibel, 1970).

## 1.2 STATEMENT OF PROBLEM

The increasing population density in the Federal Capital Territory (FCT) Abuja, have resulted in increasing discharge of domestic and industrial waste into water bodies. This could trigger eutrophication and hence the need for continuous monitoring for strategic planning in the FCT.

## 1.4 AIMS AND OBJECTIVES

The aim of this research work is assess eutrophication parameters in surface water bodies in Abuja.

The objectives include among others to;

I. Establish the physicochemical parameters of the surface water of the selected sites.
II. Determine the nutritional level of the surface water using standard methods.
III. Investigate the level of algal bloom in the selected sites.
IV. Correlate the algal bloom with nutritional level of the water bodies.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

Eutrophication is a natural process that may take many years. These years can be shortened by anthropogenic activities leading to a rapid eutrophication process with detrimental effects on the man and animals.

## 2.1 FACTORS CONTROLLING EUTROPHICATION

Availability of sunlight and nutrient are factors controlling eutrophication. Sunlight and nutrient stimulate photosynthetic reactions, algal bloom and vegetative productivity. The amount of sunlight available in a water body is proportional to the transparency of the water which in turn is a function of the level of eutrophication (Ademoroti, 1996). An eutrophic lake may become so murky that photosynthesis can only take place at the surface and the top layer (eutrophic zone) where plants grow and produce more oxygen by photosynthesis than they can remove by respiration. The lower zone is called the profundal zone. The transition between these two zones is termed the light compensation level (Ademoroti 1996).

Algal can undergo photosynthesis, multiply and cause odourous clumps of rotten debris when they decay. This clumps of rotten debris is biodegradable by bacteria to cause oxygen depletion which is detrimental to the survival of fishes especially those who live in colder regions at the bottom. Under this anaerobic condition hydrogen sulphide is formed and metals such as iron and manganese tied up as sediments dissolve and are released into the lake (Ademoroti, 1996).

Nutrient enrichment by human and agricultural activities cause cultural eutrophication hence nutrient enrichment control can be used to control eutrophication. Justus Liebig in 1840 developed the idea that the growth of plant is dependent on the amount of food stuff that is presented to it in minimum quantity (Ademoroti, 1996). This implies that algal growth will be limited by the nutrient that is least available relative to its needs hence eutrophication can be controlled by identifying limiting nutrients and reduce its concentration. Liebig's law deduces that reduction in non-limiting nutrient will not provide effective control unless its concentration is reduce to the point where it becomes a limiting nutrient. If a lake is known to be nitrogen limited, reduction of phosphorus loading will have no effect and vice versa (Ademoroti, 1996).

### 2.1.1 Algal Bloom

Algal bloom is a term used in describing the rapid increase or accumulation in the population of algae (typically microscopic) in an aquatic system (Van-Dolah, 2000). Algal bloom may occur in fresh water as well as marine environment and usually a small number of phytoplankton species are involved leading to discoloration from high density of pigmented cells. Algal blooms are often green but they can also be other colors such as yellow- brown or red depending on the species of algae. In eutrophic lakes where the dominant species of algae are often blue-green which can obtain nitrogen directly from the atmosphere, the only practical method to control its growth is to focus on phosphorus removal (Ademoroti, 1996).

Bright green blooms are as a result of cyanobacteria (blue-green algae) such as microcystis. Bloom may also involve macro algal (non-phytoplanktonic) species that can

be recognized by large blades of algae that are washed up onto the shoreline. Some species form what is known as harmful algal blooms (HABs) which refer to algal bloom events involving toxic or harmful phytoplankton such as dinoflagellates of the genus *Alexandrium* and *Karenia* or diatoms of the genus *pseudo-nitzschia*. These often take red or brown hue and are known colloiquially as red tides (Sellner *et al;* 2003).

Freshwater algae blooms are as a result of excess plant nutrient particularly phosphorus originating from fertilizers or agricultural runoff (Lathrop *et al;* 1998).

Algae blooms can be observed in freshwater aquarium when fish are overfed leaving excess nutrient in the water. Algae tend to grow very quickly but each is short lived giving rise to dead organic matter which decay and consume dissolved oxygen leading to oxygen deficiency in aquatic animals. This condition is unhealthy to the fish and the situation can be corrected by changing the water in the tank or reducing the quantity of food (Landsberg, 2002).

In the marine environment this single-celled microscopic plant-like organism called phytoplankton or microalgae form the base of the food web upon which nearly all other marine organisms depend. Over five thousand species exist worldwide with about 2% known to be harmful or toxic (Durbin, 2002). These harmful algal blooms can cause adverse effects to varying species of marine mammals and sea turtles with each presenting specific toxicity-induced reduction in developmental, immunological, neurological and reproductive capacities. In 2004 a mass mortality of 107 bottlenose dolphins occurred along Florida Panhandle due to ingestion of contaminated menhaden with high level of brevetoxin (Flewelling, 2005).

Harmful algal bloom can cause high mortality in fish, sea turtles, marine mammals, human illness or death through the consumption of sea food contaminated by toxic algae. The occurrence of harmful algal bloom in some locations seemed to be attributed to natural process of eutrophication or climate change while some appear to be caused by human activities. All these seem to be an interplay between climate changes as a result of human activities such as radioactive exploration, emission of green house gases, destruction of the ozone layers, availability of nitrates and phosphates and other plant nutrients from fertilizer applications and agricultural runoff. Harmful algal blooms have also been attributed to seasonal occurrence of certain ocean currents (Trainer *et al;* 2000).

### 2.1.2 Organic Manure Application

In the United Kingdom, research showed that faecal deposits from sewage sludge and livestock waste applied to farmlands dominated urban waste water during flow conditions. The main sources of pollution came from grazing animals, septic tanks and defaecation by indigenous fauna (Wyer *et al* 1996; Obiri-Danso and Jones 1999; Geldreich 1999).

Large amounts of animal faecal waste were applied to agricultural land in UK and it was estimated that about 68 million tones of (wet weight) faeces were produced by housed livestock in 1997. In England and Wales most of these were recycled back to agriculture because of its fertilizer value (Nicholas *et al;* 2000; Nicholas *et al;* 2002).

Eutrophication is prone to take place if an overflow event occurs soon after feacal waste is applied to land. A number of environmental factors have been shown to influence

the survival of the attendant pathogens. These include temperature, moisture content, sunlight, pH and availability of organic matter (Van Donsel *et al;* 1967).

Eutrophic waters contaminated by animal waste are potential hazards with pathogens, including *verocytoxigenic Escherichia coli* (VTEC) that may remain viable for considerably long period (Tiden *et al;* 1996).

In other to boost agricultural production, farmers apply organic or inorganic fertilizers both of which if in excess, accelerate eutrophication in water. However, due to high cost of inorganic fertilizers, organic fertilizers have become popular. In America and some other developed nations of the world, it was discovered that inorganic fertilizer food products and processed foods were responsible for the high rate of cancer and this has given support to the discharge of compost and other organic nutrients to increase soil fertility and produce organic crops. The market prices of processed organic products are usually higher compared to their inorganic counterpart (George *et al;* 2006). Compost manure now forms a significant source of nutrient in many developed nations as can be seen in compost content expressed in 100t/ha in UK (Chima, 2008).

**Composition of Typical Compost Manure in UK**

| | | |
|---|---|---|
| Nitrogen | 700kg | N |
| Phophorus | 320kg | $P_2O_5$ |
| Potassium | 540kg | $K_2O$ |
| Magnesium | 100kg | Mg |
| Sulphur | 96kg | S |

The above figures show that compost manure also has a significant impact on eutrophication level on surface water system considering the large discharge of nitrogen, phosphorous and potassium onto surface water comes from compost manure.

### 2.1.3 Water Hyacinth Invasion

The invasion of water hyacinth in Lagos State of Nigeria was attributed to climate change and indiscriminate disposal of faeces by the high density population in Lagos. Water hyacinth is a type of water weed that grows into enormous size hindering water transportation and fishing activities. It can easily change a river into a dry land following its big size. Water hyacinth form an extensive weed mat on water surface and their death on the water surface seal off breeding, nursing, feeding and fishing grounds for various inshore fish species such as tilapia and young Nile perch. They also block sunlight, reduce oxygen level, and allow poisonous gases such as ammonia and hydrogen sulphide to accumulate (Twongo, 1998).

### 2.1.4 Impact of Erosion

Soil erosion is another phenomenon with significant impact in the level of eutrophication. Soil erosion scientist have divided soil erosion process into three namely: detachment, transport and deposition and these can occur as a result of the action of raindrops or the action of flowing water or both. It is assumed that microorganisms positioned on the soil surface have the same process acting on them as in a soil particle (Meyer and Wischmeier 1969). Research by Erhunmwuse *et al* (2013) confirmed that it takes thousands of years on the time scale for a water body (oligotropic) to turn into

eutropic water body through the natural process that is based on nature of minerals and watershed weathering.

## 2.2 APPROACHES TO CONTROLLING EUTROPHICATION AND WATER LOSS

The challenge to combat eutrophication and global loss of potable drinking water has led to the proliferation of dams in different parts of the world which has aggravated the debate on "Dams or No Dams" (Zankhama and Kumar 2008). Opposition to dam building is based on environmental, financial, economic and human right whereas proponents of large dams push their support based on enhanced food production, drinking water, security, hydropower generation and flood control (Braga *et al;* 1998; Verghese 2001).

According to records, there are more than 47,000 large dams constructed all over the world and another 1700 dams were under construction (Zankhana and Kumar 2008). Asia was quoted to have the largest number of large dams in the world and according to World Commission of Dams (WCD) database dated 2000. China had the largest number of large dams followed by the rest of Asia. This is immediately followed by North and Central America. Etiosa (2006) reported that Nigeria had witnessed an accelerating trend in dams construction in the past three decades and that between 1970 and 1995, 246 dams were constructed. These have interfered so much with streams, rivers and lakes and now they can hardly be described as natural. Storage dams alter the natural distribution and timing of stream flow. These changes compromise the dynamic aspects of rivers that are fundamental in maintaining the characteristics of aquatic ecosystem. Siltation resulting from blockade or basal river flow with erection of barricade to mimic waterfall can enhance nutrient

accumulation in certain sections of the river to create a eutrophic environment Erhunmwuse *et al;* (2013); Nwanebu *et al*; (2011).

### 2.2.1 Nutrient Control

Eutrophication which is the fertilization of natural water can be effectively controlled by controlling the nutrient discharged into surface waters. When the nutrients are not readily available in water, then the growth of plankton or plants will be inhibited and eutrophication retarded. Phosphorus is one major nutrient in water that encourages the growth of algae and other plants or water weeds. Phosphorus can be obtained as phosphate from various sources such as the atmosphere, agricultural waste, urban drainage, domestic and industrial wastewaters. Phosphorus can be removed from water by using iron or aluminum salts for its precipitation and subsequent removal by filtration. Research has shown that aluminum and to a lesser extent iron could keep phosphorus in a form unavailable for algal growth (Fred and Ann, 1978).

It will be difficult to adopt this method for the large bodies of water on the earth surface to preserve our natural surface water for human utility. Chemical coagulation of water nevertheless is useful for the removal of inorganic and organic substances, turbidity, colour, harmful bacteria and pathogens, algae and plankton organisms, taste and phosphates. This method had been effective for decades in removing unwanted substances from water to control eutrophication (Cooper and Thomas, 1974). Erhunmwuse *et al* (2013) reported that controlling non-point source of eutrophication had always been difficult as the cause and effect cannot be directly documented. However, the research showed that analysis could be carried out with the aid of mathematical models and the value of

nitrogen/phosphorus of a water body from non-point source could be determined as follows:

N/P (non-point source) = MT of N/P – N/P (point source).

Where N/P = Nitrogen/Phosphorous

MT = Mean Total Value

The Mean Total Value (MT) is the nitrogen/phosphorus of the water body minus value of nitrogen/phosphorus from point source of the same water body. Classical chemical analyses have been supplemented by instrumental methods of chemical analysis which generate results with speed and high degree of precision and accuracy. An example of this is the DR/890 colorimeter which is designed to analyze many ions including nitrate and phosphate.

It has been discovered that viruses and bacteria are bio-colloids and they are hydrophilic (water loving) and this implies that viruses and bacteria also form flocs and are precipitated by coagulation during flocculation and precipitation process (Ademoroti 1996). Available nutrients can also be controlled by removal of suspended solids in water such as leaves, flowers, twigs, paper and other colloids to ensure that the water bodies are not enriched with nutrients that encourage rapid eutrophication.

The presence of nitrate in water support eutrophication and many surface water system in Nigeria are eutrophic (Okibe, 2005). The presence of nitrate in water is known to cause a disease clinically known as methemoglobinemia in infants hence the need to control eutrophication through nitrate removal (Ademoroti, 1996).

**Plant Nutrients/Mineral Concentration**

Micro and macro nutrients that enhance plant growth such as $PO_4^{2-}$ , $NO_3^-$ , $SiO_2$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $NH_4^+$ , $HCO^-_3$ , $CO_3^{2-}$ ,$Cl^-$ , $SO_4^{2-}$ ,$Mn^{2+}$ have been implicated as eutrophication accelerators.

Research by Voinov *et al* (1984) showed the relationship below (The broken line indicates that there is no dry-material transformation).

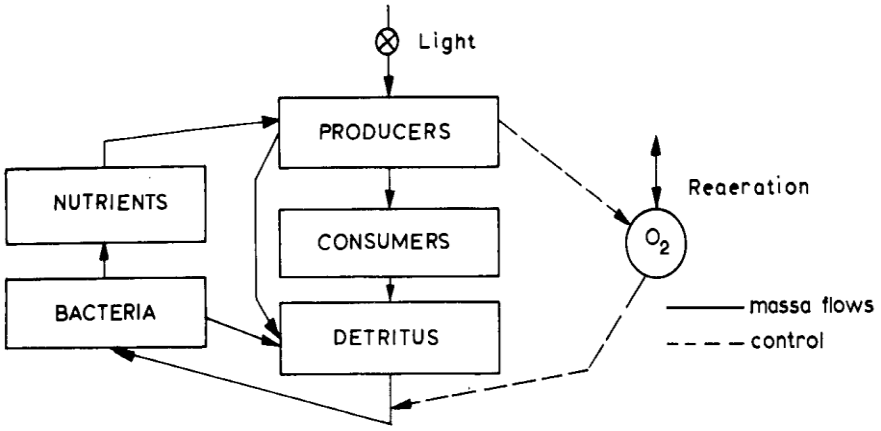



Figure 2.1 Food web relationship

The steady-state dynamic (quasi-stationary) process was studied and it showed that when the model parameters were in some specific relations, an increase in biogenic pollution in reservoir led to a steady state of the system corresponding to eutrophication. Further increase in biogenic elements caused further progress in eutrophication (Vinov *et al;* 1984).

The followings were taken into consideration:

i. Concentration of producers (phytoplankton).

ii. Concentration of consumers (zooplanktons).

iii. Concentration of biogenic elements (nutrients)

iv. Concentration of detritus.

v. Concentration of bacteria.

vi. Concentration of dissolved oxygen.

Oxygen enters the system mainly due to aeration and photosynthesis and these two are the greatest natural sources of oxygen. Dissolved oxygen is consumed mostly in the oxidation of various organic substances present as detritus. When oxygen becomes depleted, anaerobic process sets in.

Increased phytoplankton population results from the consumption of various biogenic substances. Detritus represent dead organic matter suspended in the water body or sedimented to the bottom or the reservoir. The activities of bacteria agents lead to its constant oxidation and mineralization. This process is also proportional to the dissolved oxygen concentration. Bacteria activities make nutrients more available and hence trigger eutrophication (Vinov *et al;* 1984).

A biogenic element is a concept used to indicate an aggregated variables which characterize the concentration of various available nutrients in the ecosystem that limit the growth of phytoplanktons. The source of nutrient in a closed system is the decomposition of detritus which describes the decay of organic matter and its transformation into more soluble and better digested inorganic compounds.

The consumer biomass is made up the zooplankton, benthic organisms, fish, and so on. Phytoplanktons are eaten, detritus is excreted and these work together to bring conditions favourable for eutrophication to take place.

## 2.3 URBANIZATION AND EUTROPHICATION PROFILE.

Urban development encroaches on agricultural or natural areas and can cause temperature alteration of water bodies, which is detrimental to the well being or survival of some fish species (Erickson and Stefan 2009).

Urbanization also alters the hydrology in the watershed through changes in land cover and introduction of new water collection and conveyance systems (Schillings and Libra 2003). This prolonged urbanization activities must have triggered eutrophication in various parts of Nigeria with solid particles clogging water ways and some rivers becoming shallow, resulting in massive flooding in various states in year 2012 rainy season.

Satellite images show that Abuja is the fastest growing city in Africa and this call for the need to create an environmentally friendly structure to prevent the detrimental effect of eutrophication.

3-D$_1$model of Abuja

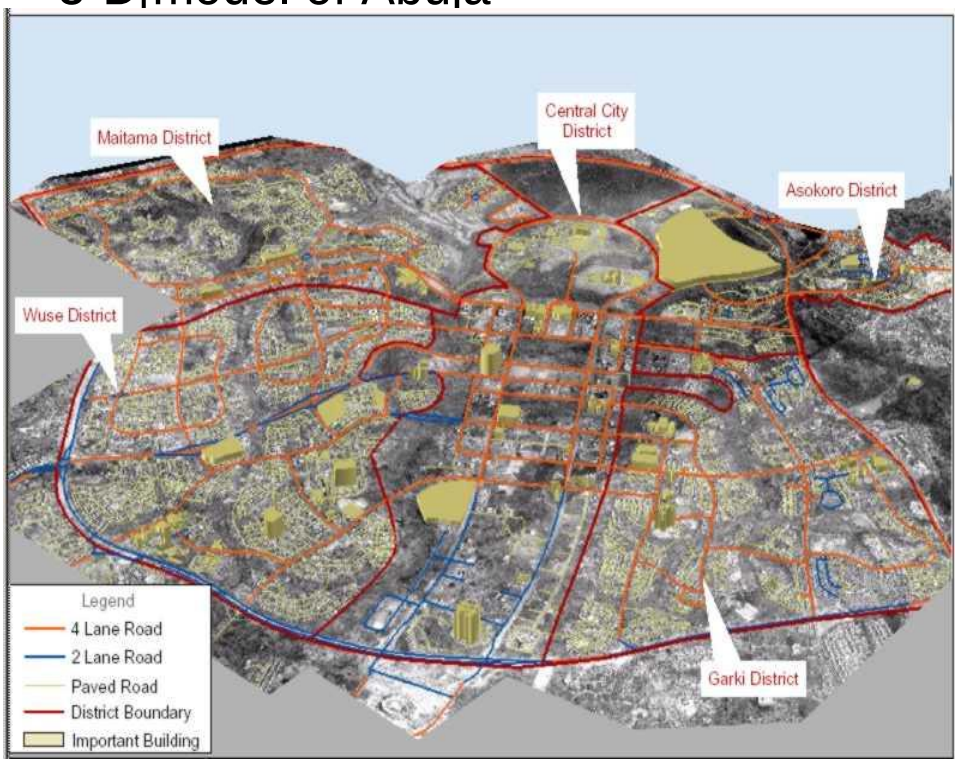



**Figure. 2.2 $D_1$Model of Abuja. Courtesy of Federal Ministry of Environment, Abuja Nigeria 2012**

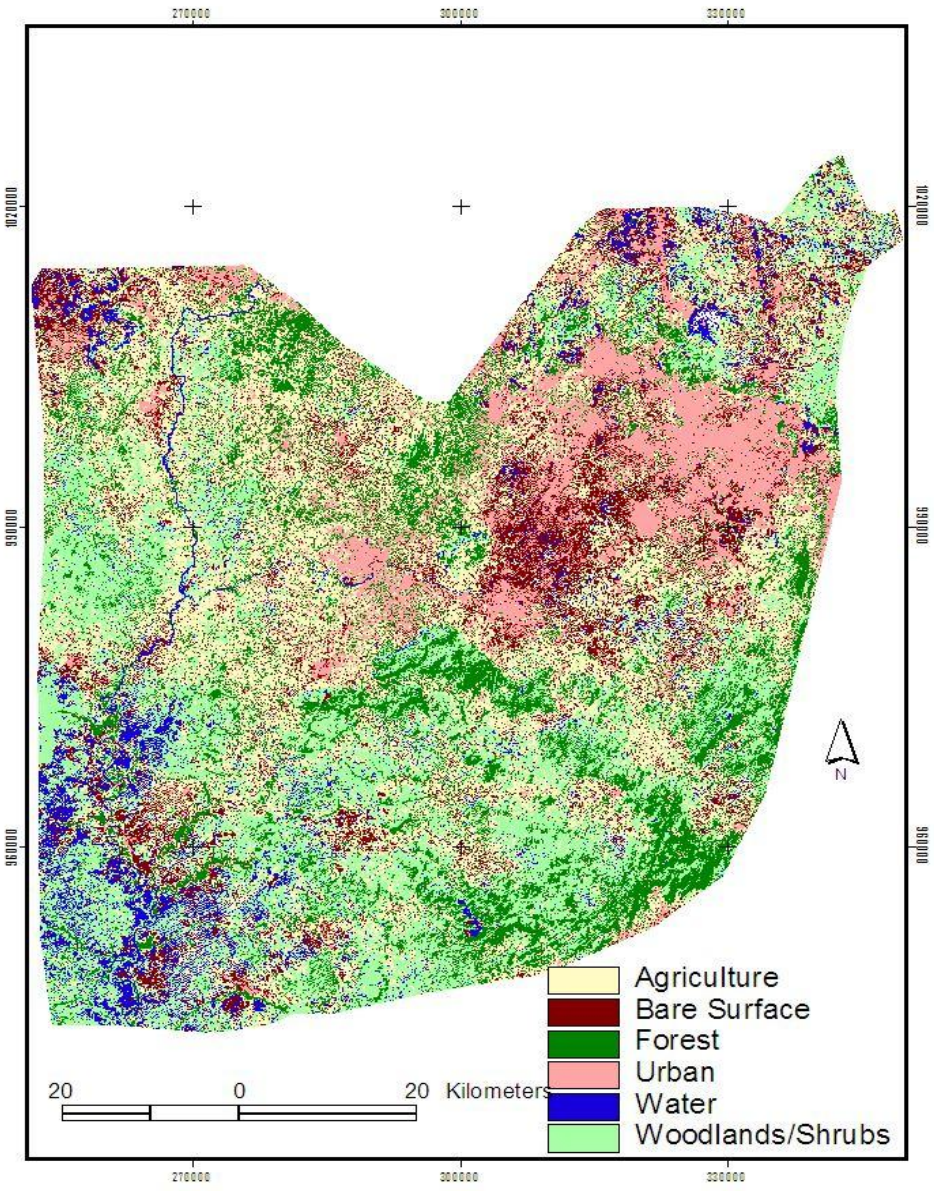



**Figure 2.3. Surface water distribution in Abuja from Federal Ministry of Environment, Abuja**

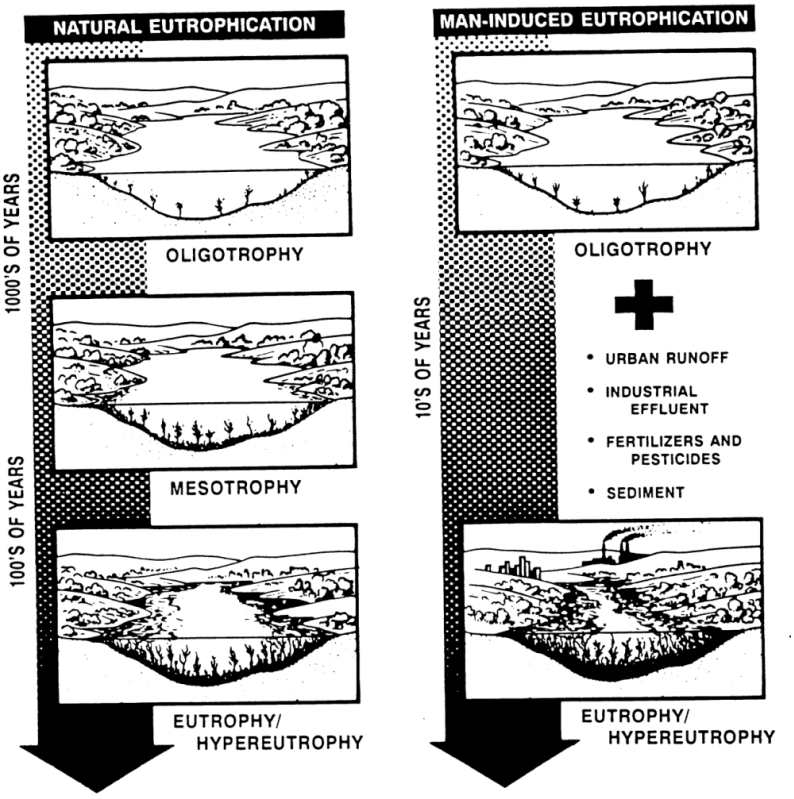



**Figure 2.4 Natural and manmade eutrophication processes.** Bill, (2010).

Clean Water Act in America requires that all surface waters in the United States be monitored to ensure compliance with their established water-quality standards. Waters that do not meet the water quality standard are declared to be impaired and contaminated. They are measured and rated according to their degree of purity or impurity by assigning contaminated load allocations on a chosen scale. The standard adopted by Nigerian government for monitoring water quality after the dumping of toxins in Koko Port in the old Bendel State was put at 20mg/L for nitrate in surface water, 5mg/L for phosphate in surface waters and 10mg/L for phosphate in land use. Most researchers consider nitrate and phosphate the major indices for eutrophication Erhunmwuse *et al* (2013).

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

Samples were collected in 2000$cm^3$, 1000$cm^3$ and 500$cm^3$ containers at various strategic sites. The samples were collected in clean plastic containers, acidified with HCl (conc.) and stored at temperatures less than four degree Celsius to inhibit undesirable reactions that may interfere with the analytical accuracy.

The samples for algae count were preserved using Lugol solution which was made by mixing 20 g of potassium iodide with 200 $cm^3$ distilled water then dissolving 10 g of pure iodine in this solution. 20 g of glacial acetic acid was added few days before usage. The solution was stored in dark glass bottle and could remain effective for at least 12 months.

All other samples for biological oxygen demand analysis were not acidified to keep the organisms alive for proper analysis. Glass containers were avoided because potassium can be adsorbed unto the surface thereby producing a lower concentration during analysis.

### 3.1 Sampling sites

### 3.2 Sample collection and preservation

Abuja does not have natural rivers but artificially built dams and drainage systems. Five sites were selected considering the interconnectivity of water channels at strategic points and the availability of water flow throughout the year.

Site 1: Orozo Water Channel

This site is located in suburban area of Abuja where the main sources of pollutants are agricultural waste and domestic effluents. Irrigation farms for sugar cane, vegetable and rice plantation can be seen at some stages along the water channels and it serves as a washing site for the inhabitants of that area.

Site 2: Gidan Mangoro Water Channel

This is located in another suburban area of Abuja and collects water flow from various areas with relatively higher water velocity than the Orozo water channel. It is transparent enough to see tiny fishes with golden strips and other tiny fingerlings swimming close to the surface to feed on the microscopic planktons. It serves as a source of domestic water to many and is in close contact with farmlands. The geography of the area can easily permit agricultural runoff into the water during heavy down pour.

Site : 3 Nyanya Water Channel

This collects water effluents from a densely populated area and is characterized by an offensive odour and greenish appearance. The effluents include refuse dumps, human and animal waste and agricultural runoff. This area is a beehive of economic activity and the water flow allows fine granules of sandy and silt soils ranging from 0.002-2mm to accumulate at the bottom of the channels. This is a source of income to some people who defy the aesthetic and sanitary nuisance to collect and heap up trips of sands for sale and onward transportation to cement industries and building construction sites. The sand particles have the capacity to adsorb some analyte concentrations. Cement block industries are sited along the channels to provide water for block moulding. This water is not usually

consumed but serves as a source of irrigation for crops like maize, vegetable and construction activities.

Site 4: Wuse Water Channel

This sample site collects pollutants from different zones in Wuse and the major sources are domestic waste and improper sewage disposal. Many traders who are not domicile in this area, characterized by the popular Wuse market, simply discharge their faeces close to the water channel because the bridge across the channel provide good hiding places.

Site 5: Jabi Dam

This dam is located in Kado Estate and is officially recognized as Jabi Lake Resort West Coast Phase 1. It was built by Julius Berger Construction Company and commissioned on 7$^{th}$ May 2007 by the former president Olusegun Obasanjo of Nigeria. It has a beautiful blue colour characteristic of most lakes, serene environment and pleasant balmy air around the surroundings. Tiny golden fishes and other species could be seen around the edge with fine sandy soil from transparent shallow edges. It serves as a relaxation center and the trees around some of its edges provide shade for recreation. This site was free from indiscriminate discharge of pollutants and was relatively clean for human usage.

The physical parameters measured include total dissolved solid and temperature; chemical parameters measured include conductivity, nitrate, phosphate, potassium, and chemical oxygen demand. Biological parameters measured included algae count and

biochemical oxygen demand. All measurements were carried out three times and the average values are reported.

### 3.3 Measurement of Physical Parameters

#### 3.3.1 Temperature:

The temperatures of the samples were measured using electro analytical instrument which gave similar data and these were recorded in the laboratory before analysis.

#### 3.3.2 Measurement of Total Dissolved Solid

A Hach Sension5 instrument was used to measure the total dissolved solid by measuring out 100 $cm^3$ of the samples into several conical flasks and allowed to attain equilibrium with the electro analytical probe rod that was dipped into the solution. The solution was allowed some time to stabilize after which the data obtained was read in the digital meter and recorded. The electronic probe was rinsed thoroughly with distilled water followed by rinsing with the solution whose parameter was next to be determined.

#### 3.3.3 Measurement of Conductivity

The Hach Sension5 instrument was used in the determination of conductivities of the samples. It is an analytical instrument with many analytical capabilities which includes the determination of conductivity. This was achieved by dipping the analytical probe into 100 $cm^3$ of the sample and allowed to stabilize after which the value was read and recorded. The rod was rinsed with distilled water after each determination followed by rinsing with the next sample to be determined to prevent the dilution of the measured sample from experimental error.

### 3.3.4 Measurement of Chemical Oxygen Demand (Titrimetric method)

Standard potassium heptaoxodichromate (VI) ($K_2Cr_2O_7$) solution (0.125M) was made by dissolving 12.259 g of $K_2Cr_2O_7$ (Analytical grade) previously dried at 103 degree Celsius for 2 hours in distilled water and made up to the one liter mark. $Ag_2SO_4$-$H_2SO_4$ solution was made by dissolving 11g $AgSO_4$ crystal using concentrated tetraoxosulphate (VI) acid ($H_2SO_4$) (specific gravity 1.84g/$cm^3$ and 98 percent purity) and allowed to stay 24 to 48 hours for complete dissolution. Mercury (II) sulphate powder (0.4 g) was used for each determination. 2 mg of sulphamic acid was used to counter the effect of $NO_2$-N which could interfere with the determination. Standard iron (II) ammonium sulphate (0.05M) was prepared which contained 20 $cm^3$ concentrated $H_2SO_4$ added during preparation, cooled and diluted to the one liter mark, shaken very well and standardized daily against standard $K_2Cr_2O_7$ solution. 0.4g $H_2SO_4$ was placed in refluxing flask and 20$cm^3$ sample was added followed by 2 mg sulphamic acid to remove interference resulting from $NO_2$-N. 10$cm^3$ standard $K_2Cr_2O_7$ was added with the aid of a pipette followed by several glass beads previously dried for an hour. $Ag_2SO_4$-$H_2SO_4$ solution (30$cm^3$) was added slowly while swirling. The flask was then connected to a condenser and refluxed for 2 hours before cooling. A blank mixture was prepared after this reaction. The condenser was washed with distilled water into Erlenmeyer flask and diluted to 150 $cm^3$, cooled to room temperature and then titrated the excess $K_2Cr_2O_7$ with FAS using 2 drops of ferroin indicator.

The COD was calculated as follows:

$$\text{Mg/L COD} = \frac{(V_b - V_s) \times M \times 16{,}000}{\text{Ml sample}}$$

Where

$V_b$ = $cm^3$ of ferrous ammonium sulphate (FAS) used for blank

$V_s$ = $cm^3$ FAS used for sample

M = Molarity of FAS

### 3.3.5 Measurement of pH

The pH meter was turned on and allowed to warm up. It was then calibrated before the pH readings of the samples were taken.

### 3.3.6 Measurement of Biological Oxygen Demand (Titrimetric method).

High quality distilled water obtained from all-glass distiller. The water was free from chlorine, chloramines, caustic or organic materials. Phosphate buffer solution was prepared by dissolving 8.5 g $KH_2PO_4$, 21.75 g $K_2HPO_4$, 33.4 g $Na_2HPO_4$ .$7H_2O$ and 1.7 g $NH_4Cl$ in 500 $cm^3$ distilled water and diluted to one liter and preserved in stock bottles. Magnesium sulphate solution was prepared by dissolving 22.5 g $MgSO_4$ .$7H_2O$ in one liter distilled water. Calcium chloride solution was prepared by dissolving 27.5 g anhydrous $CaCl_2$ in one liter distilled water. Iron (III) chloride solution was prepared by dissolving 0.25 g $FeCl_3$ .$6H_2O$ in one liter distilled water. 0.5M $H_2SO_4$ and 1M NaOH were prepared to neutralize basic and acidic solutions respectively.

Water used for dilution was prepared by storing distilled water in a large aspirator with mouth plugged with clean cotton wool to permit saturation with dissolved oxygen (DO). 1 $cm^3$ each of the following reagents were added to the distilled water: Phosphate buffer, magnesium sulphate, calcium chloride and iron (II) chloride solution. The phosphate was not added until the dilution water was about to be used. Several dilutions of

the prepared samples were made to obtain adequate drop in oxygen content and suitable amounts of sample measured into BOD bottles in duplicates by the aid of large-tip volumetric pipette. Dissolved oxygen was determined immediately and the blank and other sets were left in the dark for 5days at 20 degree celsius cooled in an incubator.

The biochemical oxygen demand was determined as follows:

BOD mg/L = $( DO_o - DO_d ) \div$ Percent dilution

Where:

$DO_o$ = Dissolved oxygen found in the sample on the initial day.

$DO_d$ = Dissolved oxygen found in the dilutions of the sample after titration on the final day.

### 3.3.7 Measurement of Potassium

Potassium was determined using flame emission spectrophotometric method which is the routine method suitable for alkaline and alkaline earth metals. The instrument was a direct reading digital machine designed for use in clinical, industrial and educational applications. Calibration curve was done by using 1 $cm^3$, 2 $cm^3$, 3 $cm^3$, 4 $cm^3$ and 5 $cm^3$ standard potassium chloride solution diluted to 50 $cm^3$ using distilled water and aspirated into the flame photometry where measurements were made and standard curve prepared. The percentage transmittance of the sample solutions were noted and read against concentrations on the calibration curve and results recorded.

### 3.3.8 Determination of Nitrate (Colorimetric Method)

The DR/890 colorimeter is designed to analyze many ions including the nitrate ion from zero to 30.0mg/L. It is a direct reading digital instrument designed for use in clinics, industries and academic researches.

### 3.3.9 Determination of phosphate

The DR/890 colorimeter was also used in the determination of phosphate and the results displayed in numerical digits after the final operation.

### Determination of Algae Concentration

Lugol solution for preservation of algae was prepared from potassium iodide solution, pure iodine solution and glacial acetic acid and stored in the dark. The samples were inoculated with Lugol solution immediately after collection and transferred to the laboratory where the samples were kept in 100 $cm^3$ containers unstirred for about 48 hours to concentrate the algae at the bottom of the containers. The solution was later decanted carefully and sub-samples examined under a microscope and systematically. Algal units were identified and counted using counting chambers in conjunction with a grid system to examine a known area of chamber and corresponding volume of sample. The chamber was used with an upright microscope. The drop method was used in conjunction with chamber counting method and average taken. In the counting method, a drop of the sample was placed on a microscope slide and counted using different magnifications and the number of algae in 1 $cm^3$ evaluated and recorded.

### 3.4 Principles of operation of colorimeter DR/890

A sample cell was be filled with 10ml sample and the content of one Nitraver 5 Nitrate reagent powder added to the sample and capped. The stored number for high range nitrate nitrogen entered by pressing the programmed button 51 followed by the button ENTER and this was programmed to a timer of one minute during which the mixture was carefully agitated and shaken vigorously for proper reaction to take place. The instrument after the elapse of one minute reaction displayed another five minutes timer during which the blank of 10ml sample was put in another cell and capped till the beeping of the timer. The blank was put into the cell holder and tightly covered and the zero button pressed for the cursor to display 0.0Mg/L $NO_3^-$ . The blank was removed and the prepared sample placed in the cell holder, covered and the READ button pressed to give the numerical value corresponding to the concentration of nitrate ions. A soft tissue was used to remove all finger prints on the cell before reading to eliminate experimental error and the cells were washed and rinsed thoroughly with distilled water to prevent contamination before analyzing the concentrations of other samples in the collection.

The determination of nitrate by this colorimetric method is based on the fact that sodium salicylate reacts with nitrate ions in tetraoxosulphate (IV) acid medium to produce sodium nitrosalicylate which has a yellow colour under alkaline condition. The intensity of the yellow colour is proportional to the nitrate concentration.

The stored programme 77 was pressed for $PO_4^{3-}$ and cell filled with 25ml deionised water as blank, another cell was filled with 25ml of the sample to be analyzed and 1.0ml molybdovanadate reagent added to each sample cell, capped and inverted

severally to ensure a proper mixture. The five minute timer was set and on expiration, the blank was put into the cell holder and tightly covered. The zero button was pressed to give a zero reading. The blank sample was be replaced by the sample to be analyzed and the READ button pressed to display the digital concentration of phosphate in mg/L. This was carried out on other samples to determine the various concentrations of phosphate in the collections.

The instrument works on the principle that phosphate combines with heptamolybdate to form a yellow-coloured complex which reacts with ascorbic acid to reduce molybdenum from +6 to +5 state forming a blue-coloured complex and measurable spectrophotometrically at 660nm (Ademoroti 1996).

$$7H_3PO_4 + 12(NH_4)_6MoO_{24} + 51H^+ \rightarrow 7(NH_4)_3PO_4.12MoO_3 + 51NH_4^+ + 36H_2O$$

# CHAPTER FOUR

## 4.0 RESULTS

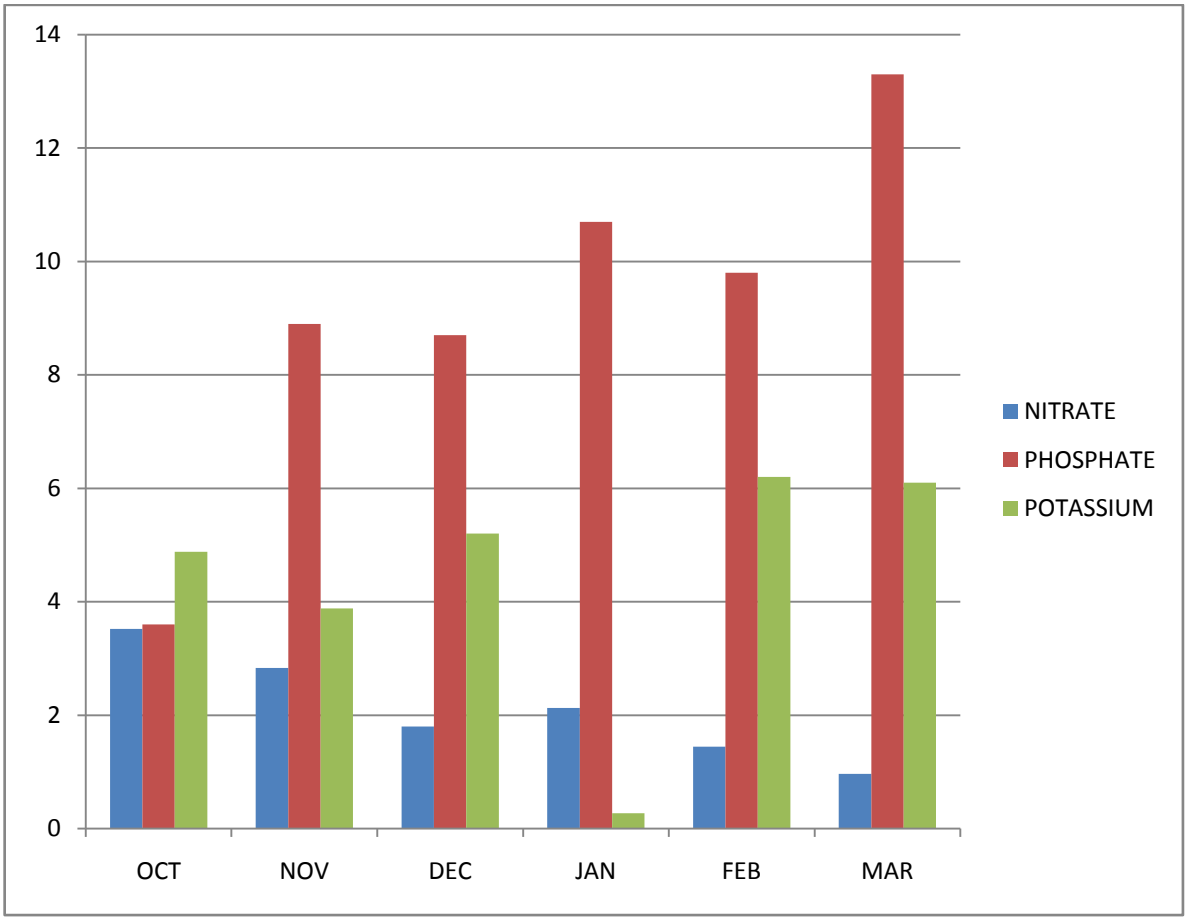



**Figure 4.1 Mean concentrations of nutrients at site 1.**

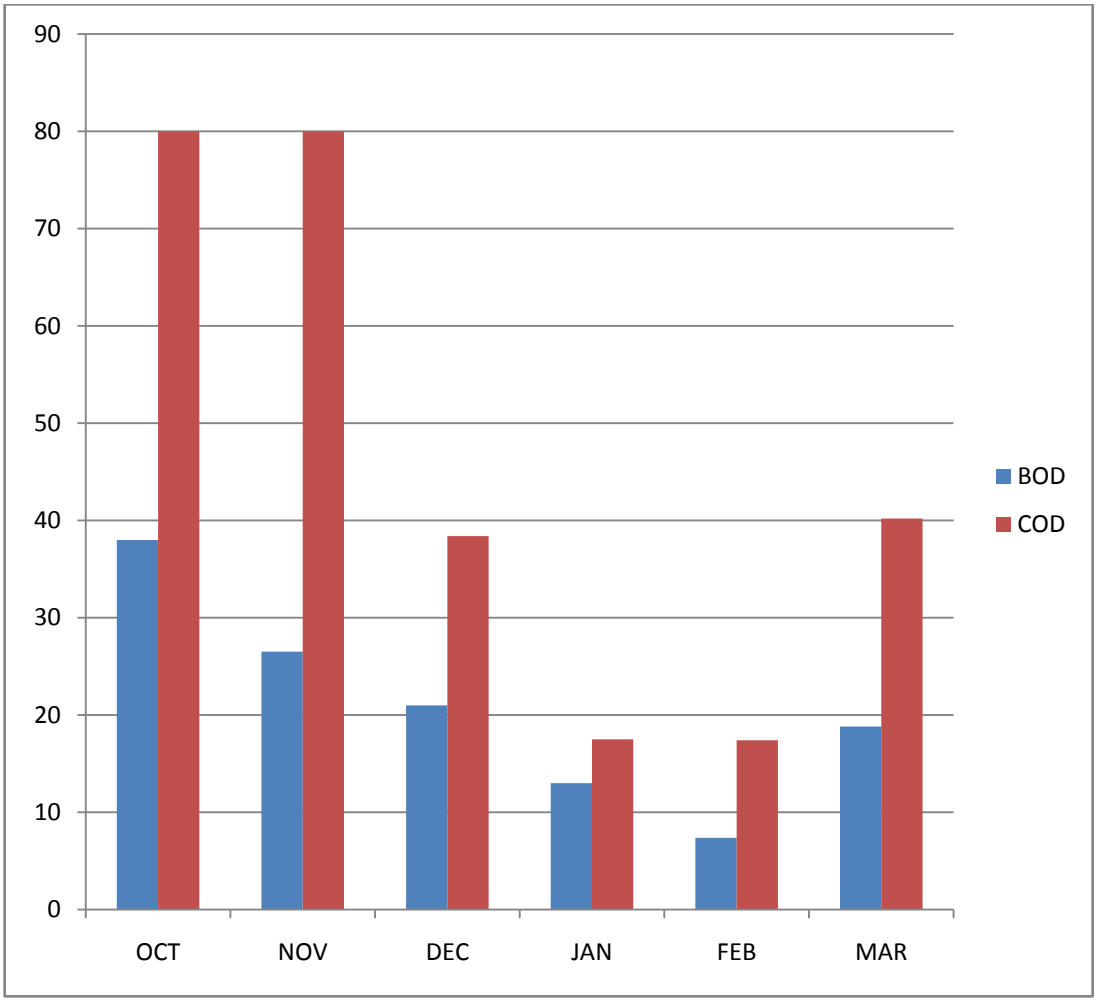



**Figure 4.2 Variation of BOD and COD within the sampling period at site 1**

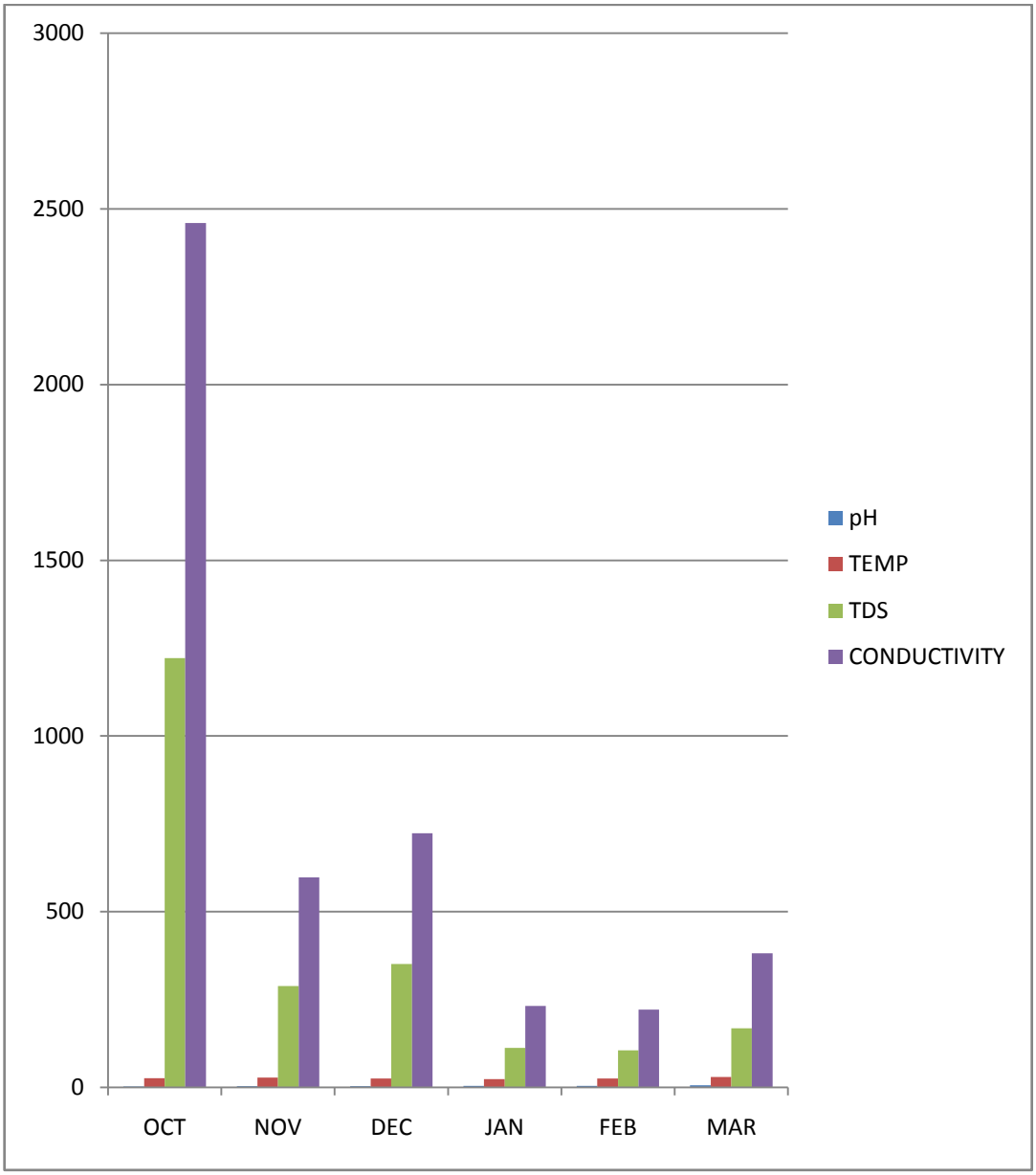



**Figure 4.3 Variation of physicochemical parameters within the sampling period at site 1**

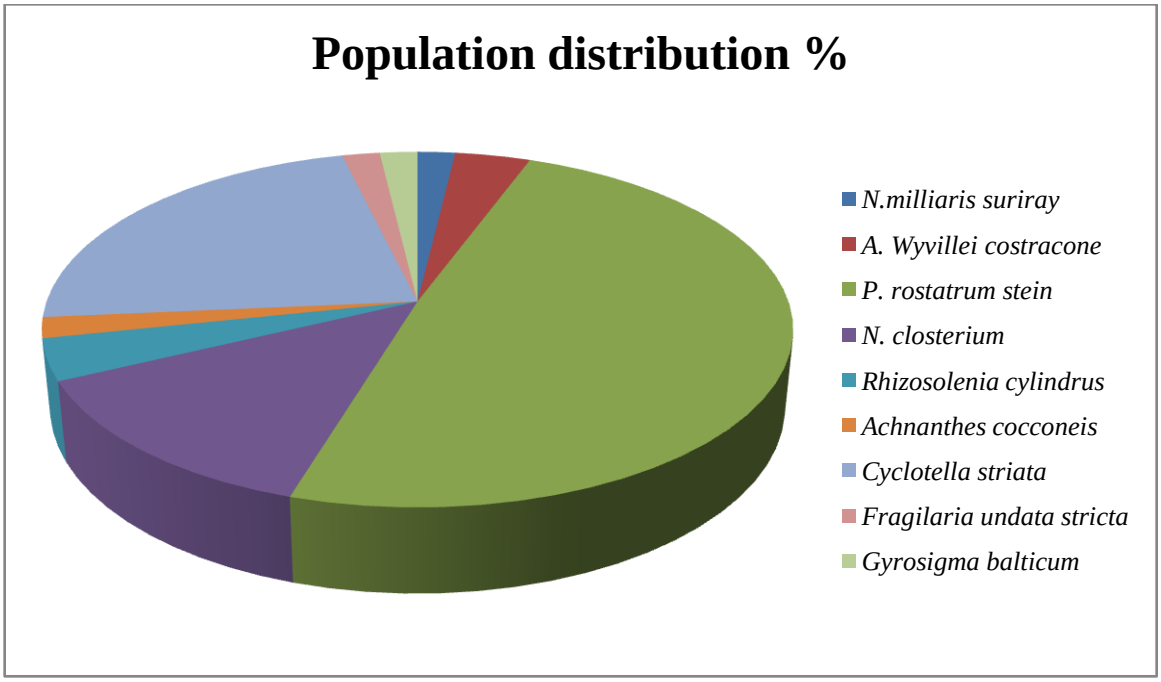



**Figure 4.4 Algae distribution during the sampling period at site 1**

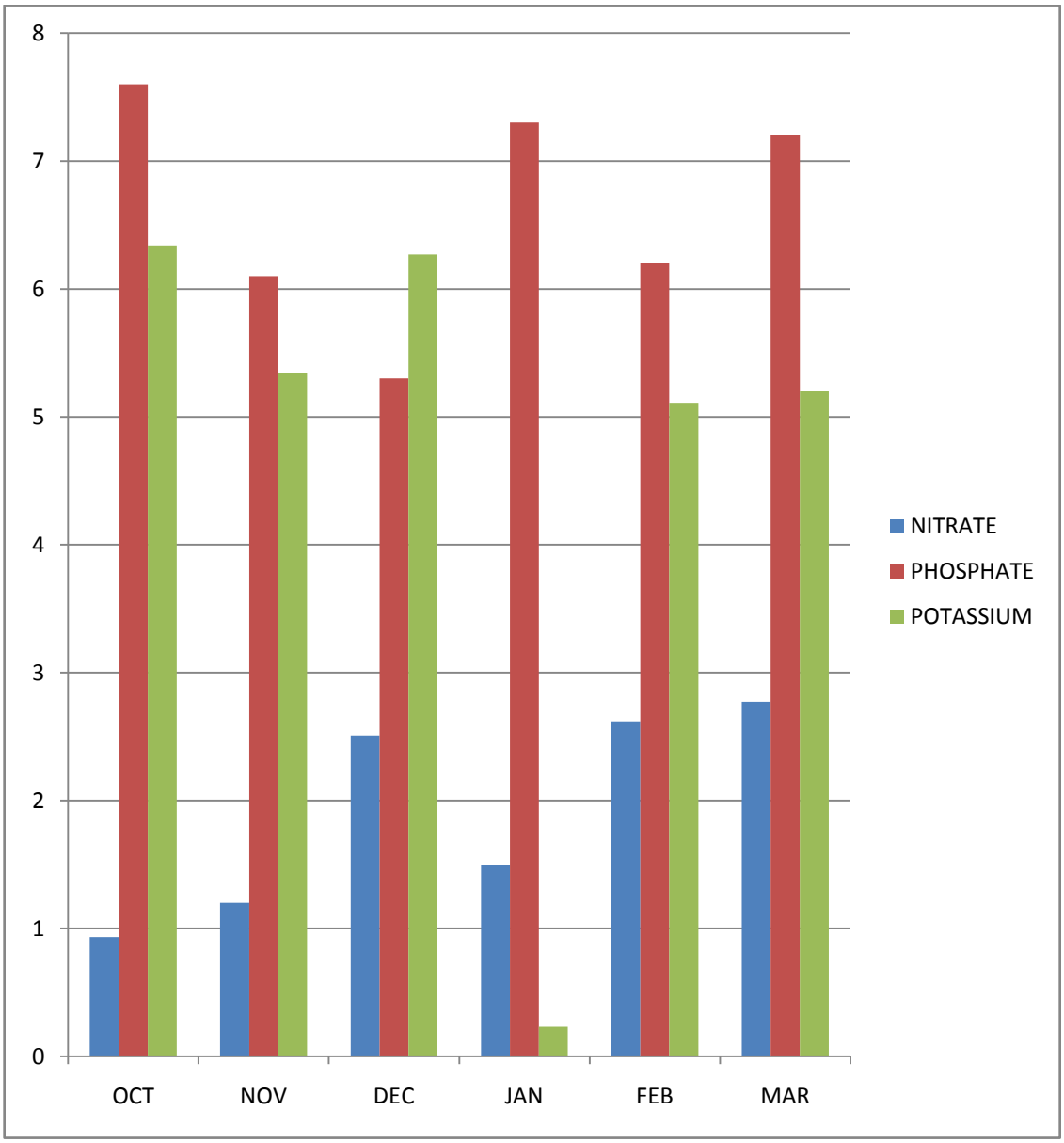



**Figure 4.5 Mean concentrations of nutrients at site 2**

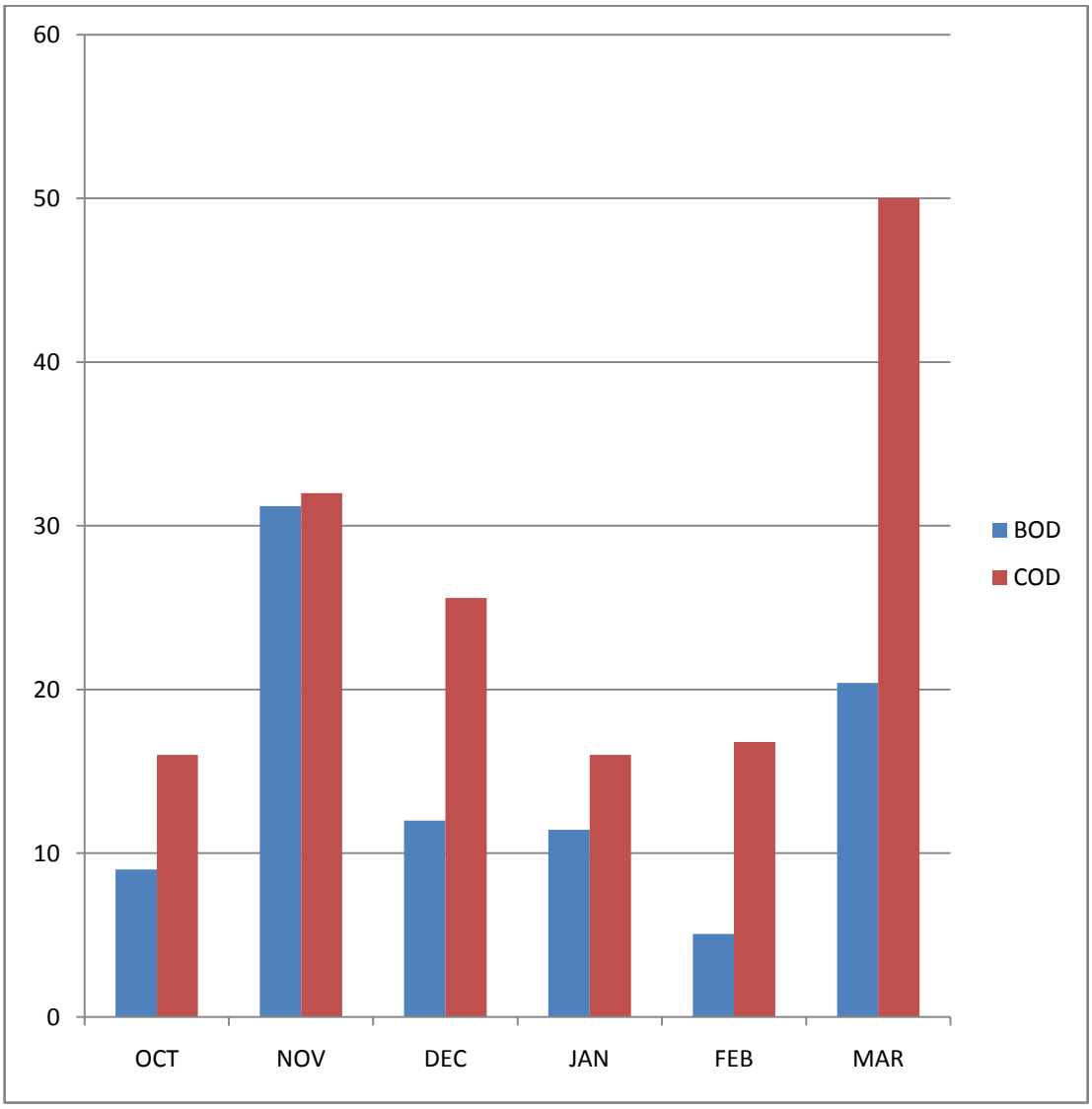



**Figure 4.6 Variation of BOD and COD within the sampling period at site 2**

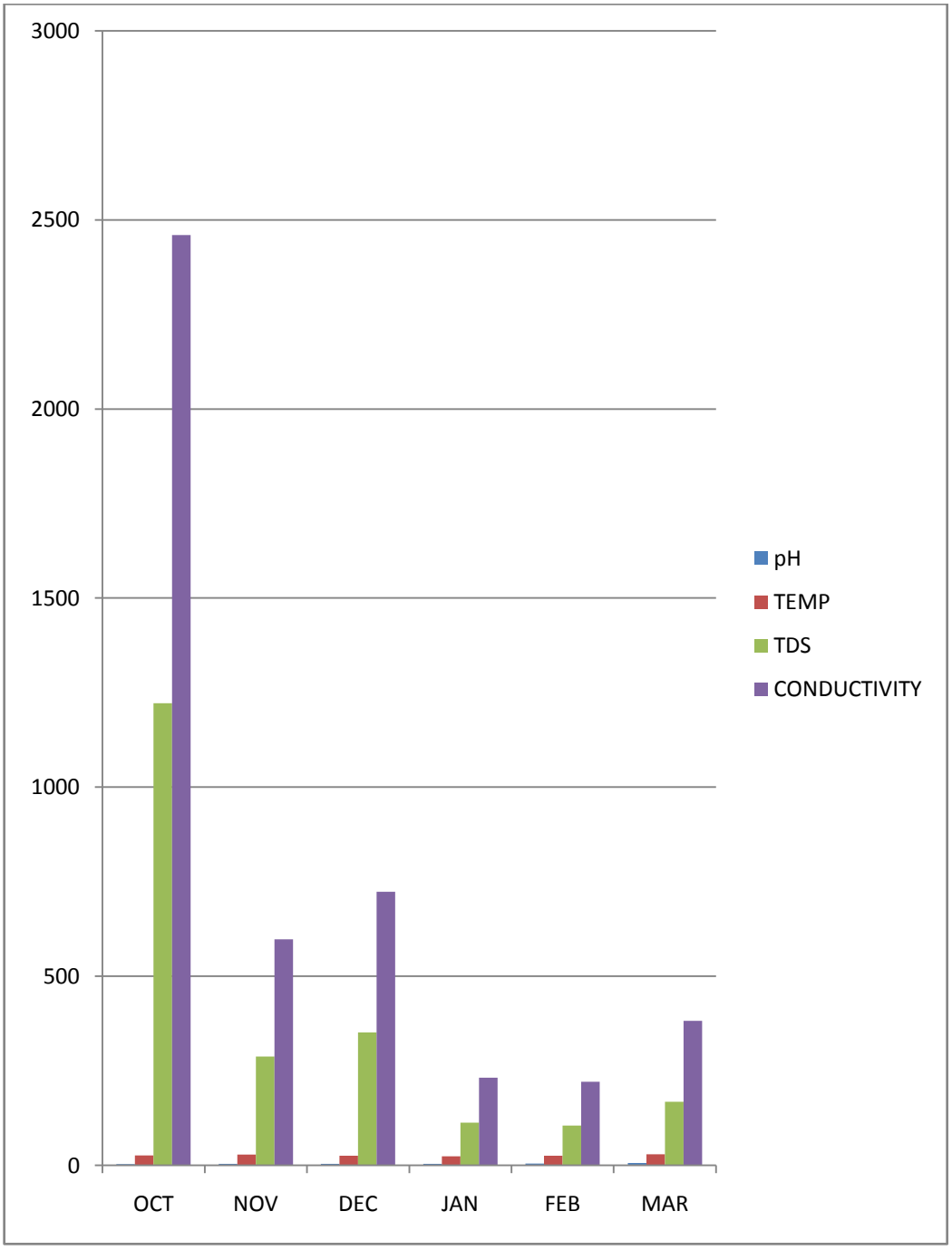



**Figure 4.7 Variation of physicochemical parameters within the sampling period at site 2**

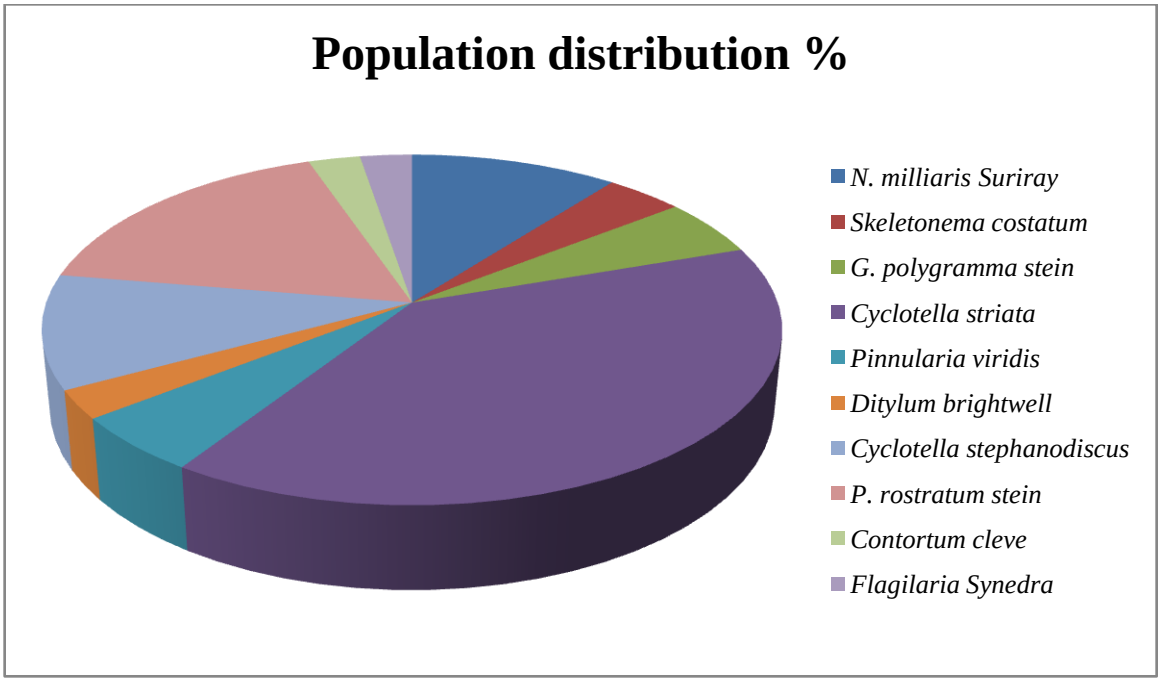



**Figure 4.8 Algae distribution during the sampling period at site 2**

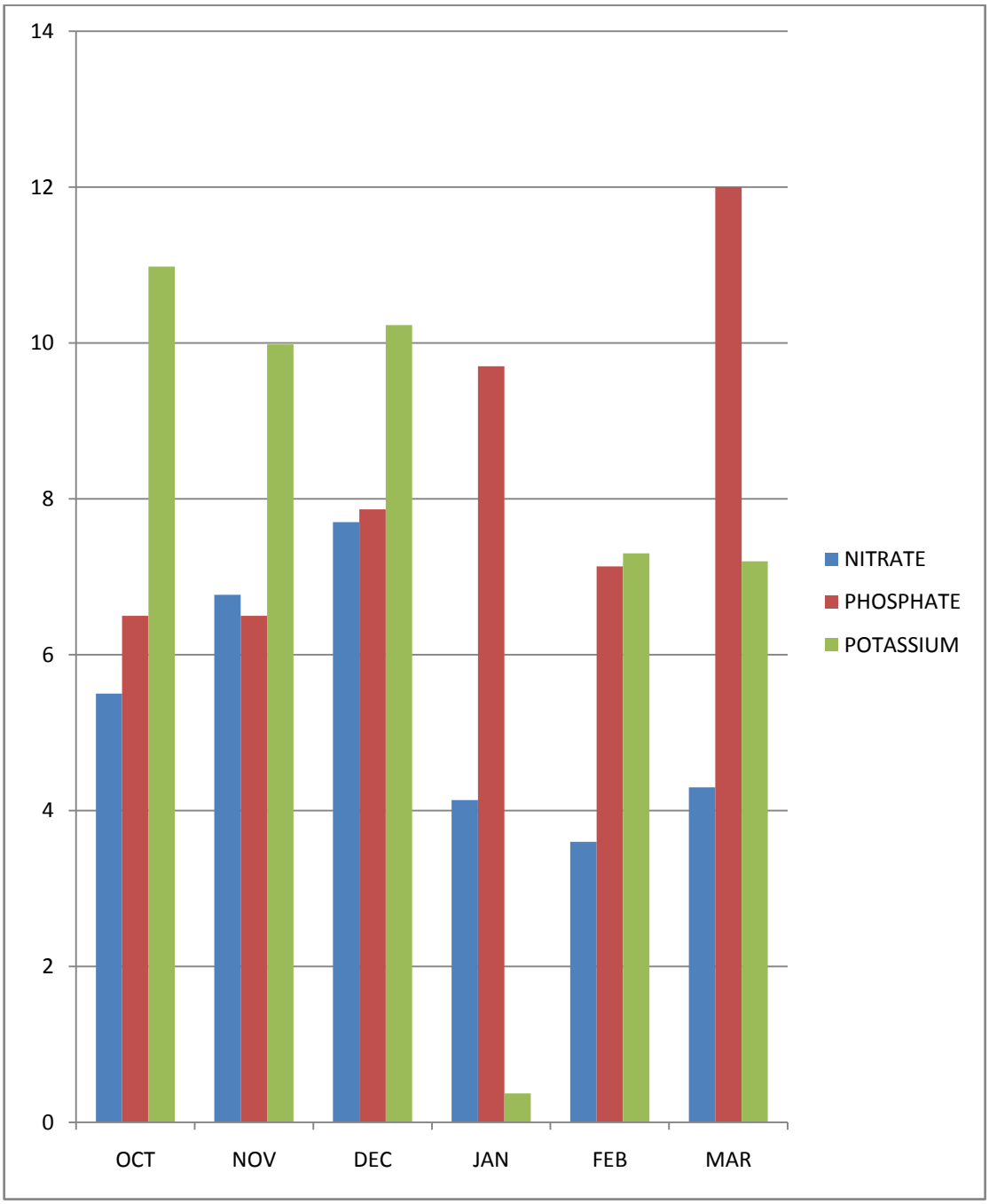



**Figure 4.9 Mean concentrations of nutrients at site 3**

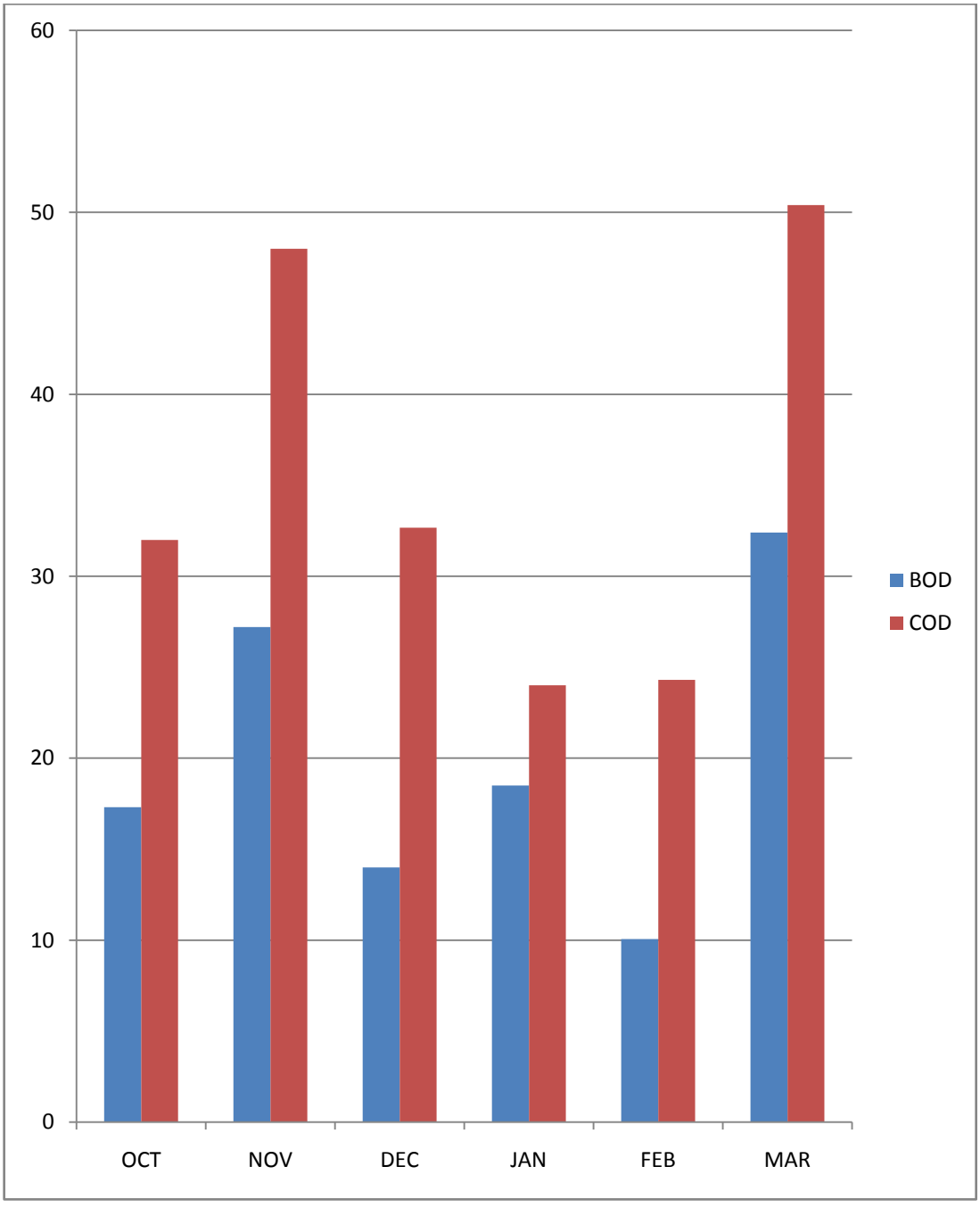



**Figure 4.10 Variation of BOD and COD within the sampling period at site 3**

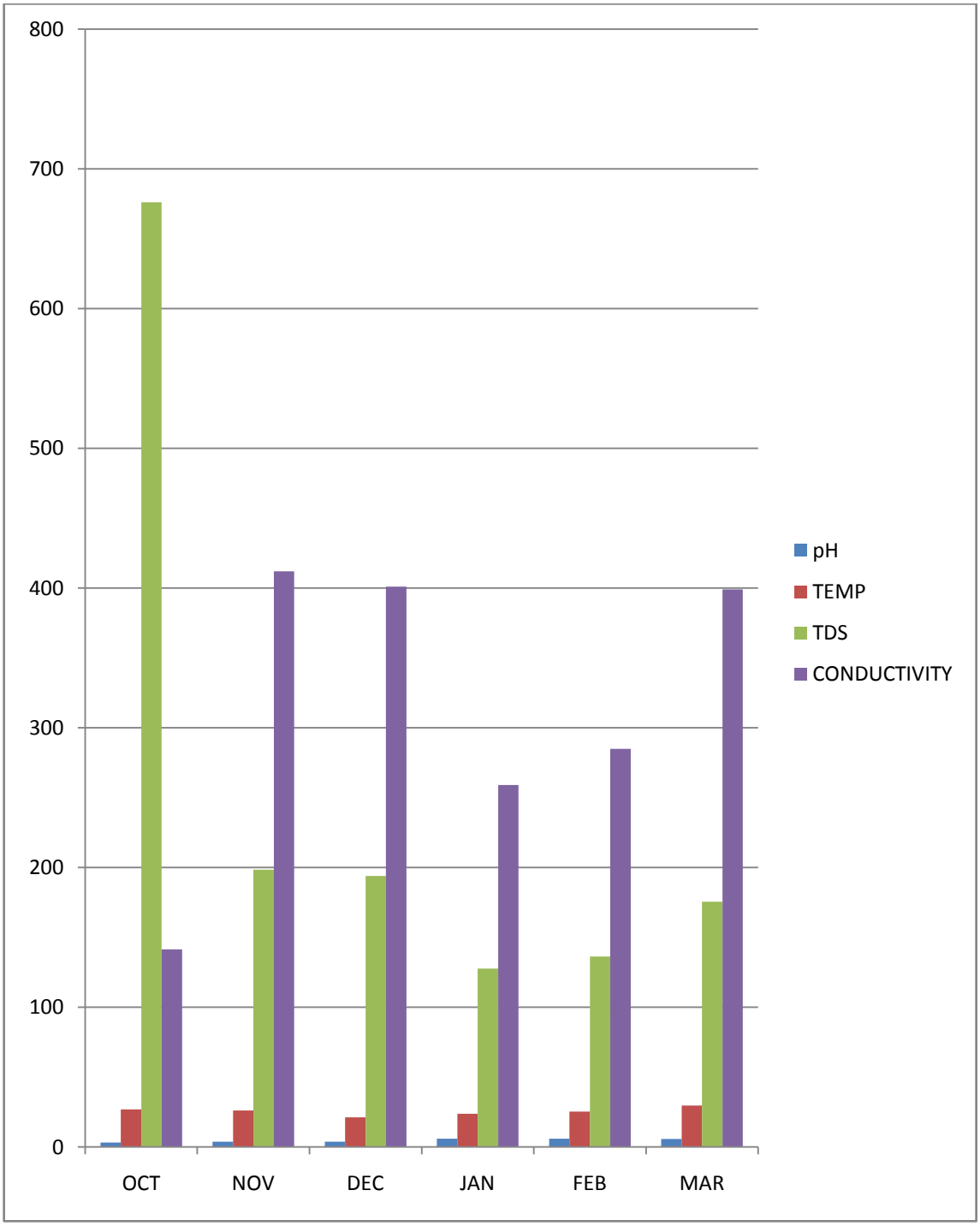



**Figure 4.11 Variation of physicochemical parameters within the sampling period at site 3**

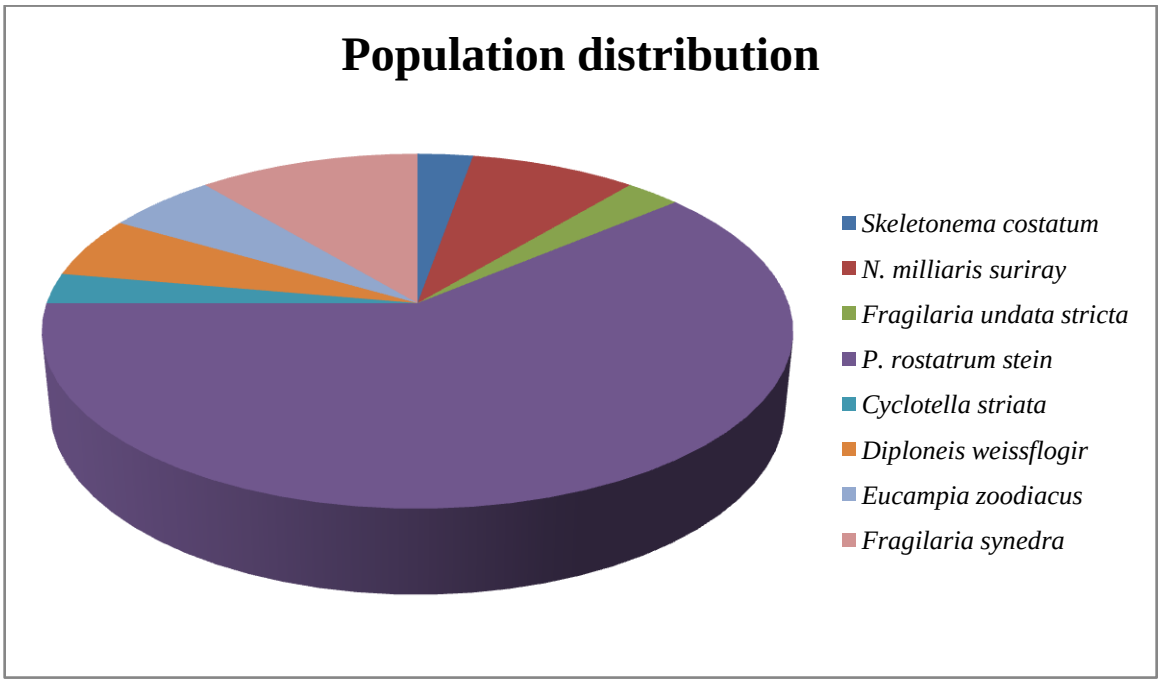



**Figure 4.12 Algae distribution during the sampling period at site 3**

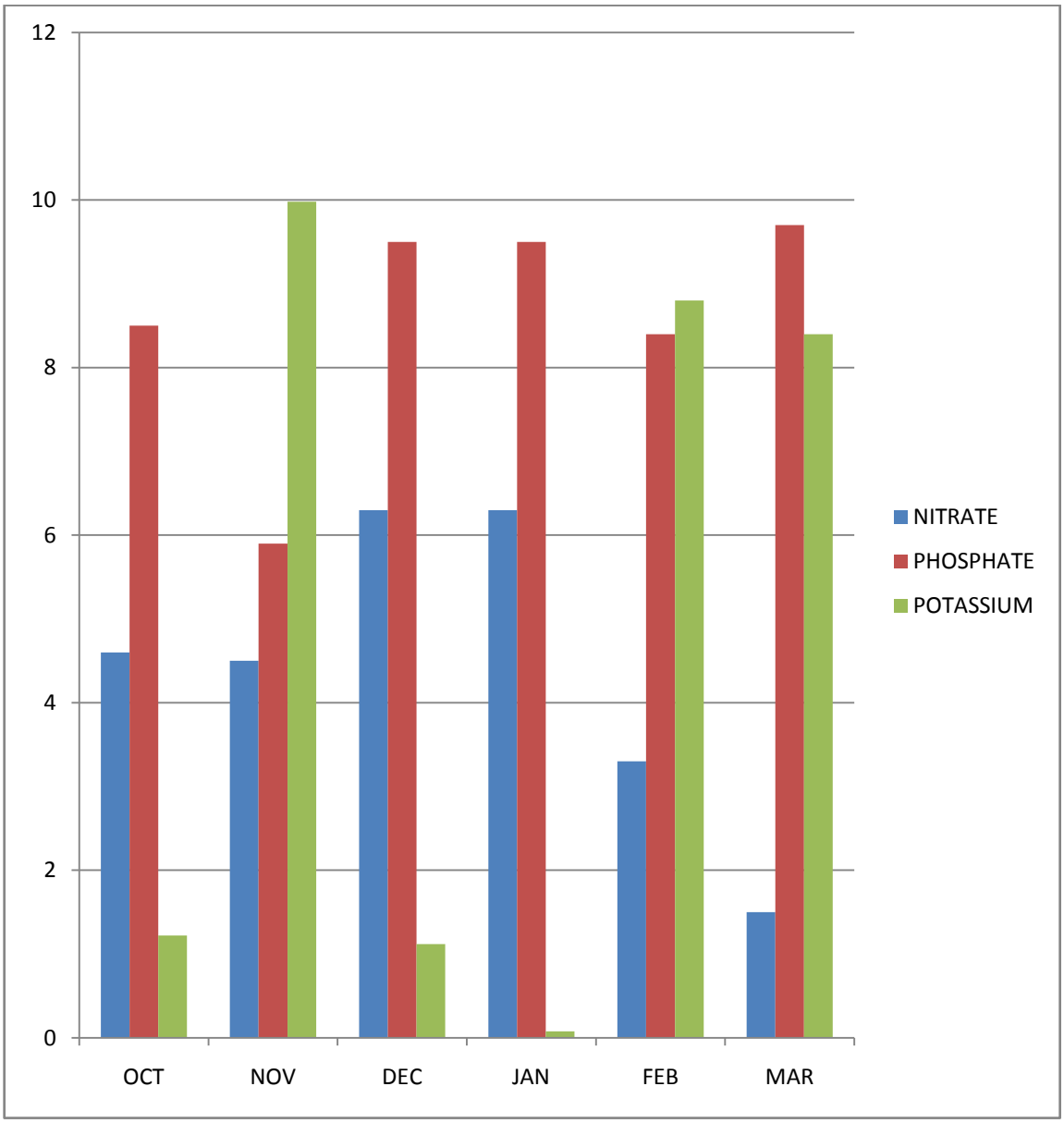



**Figure 4.13 Mean concentrations of nutrients at site 4**

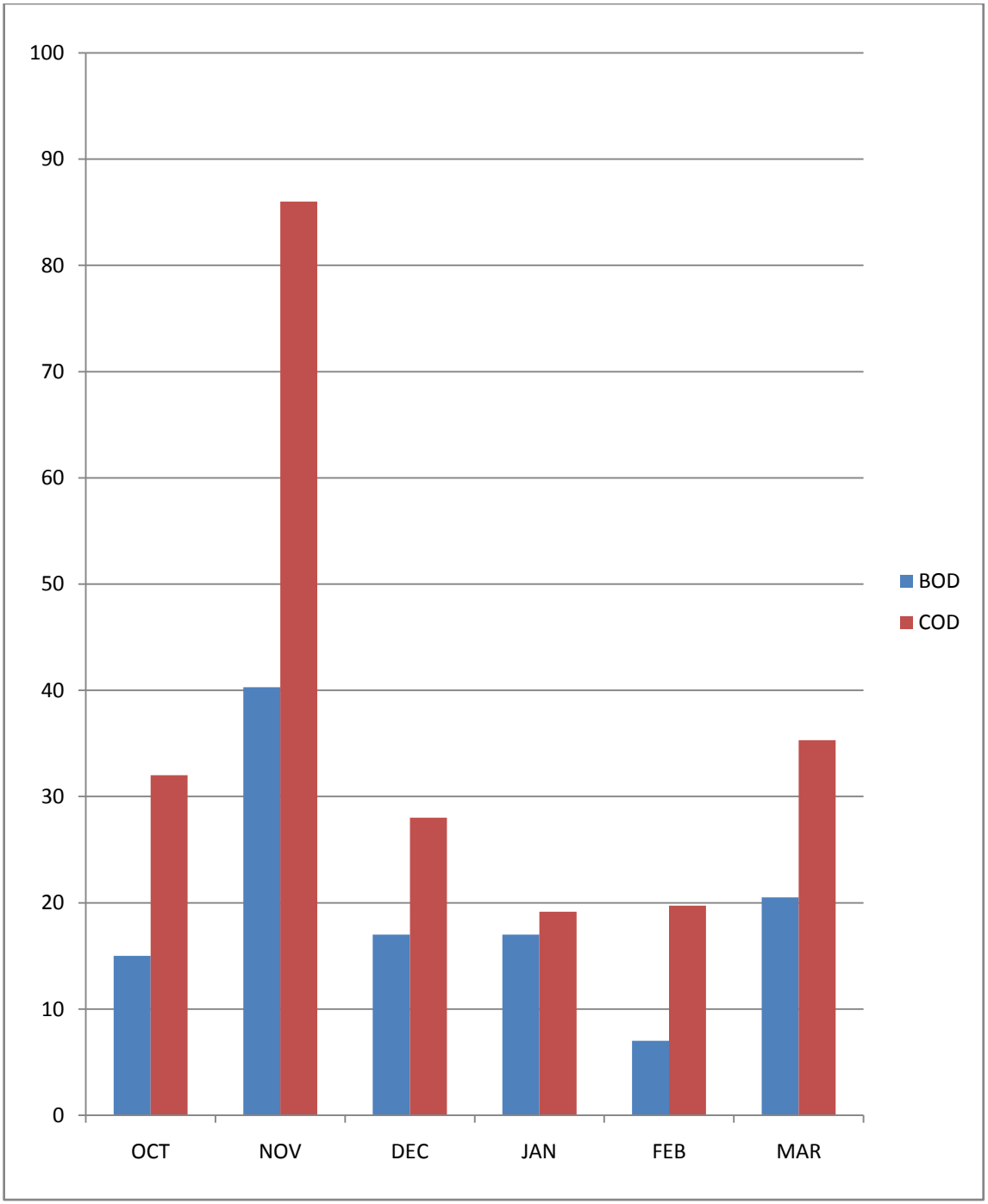



**Figure 4.14 Variation of BOD and COD within the sampling period at site 4**

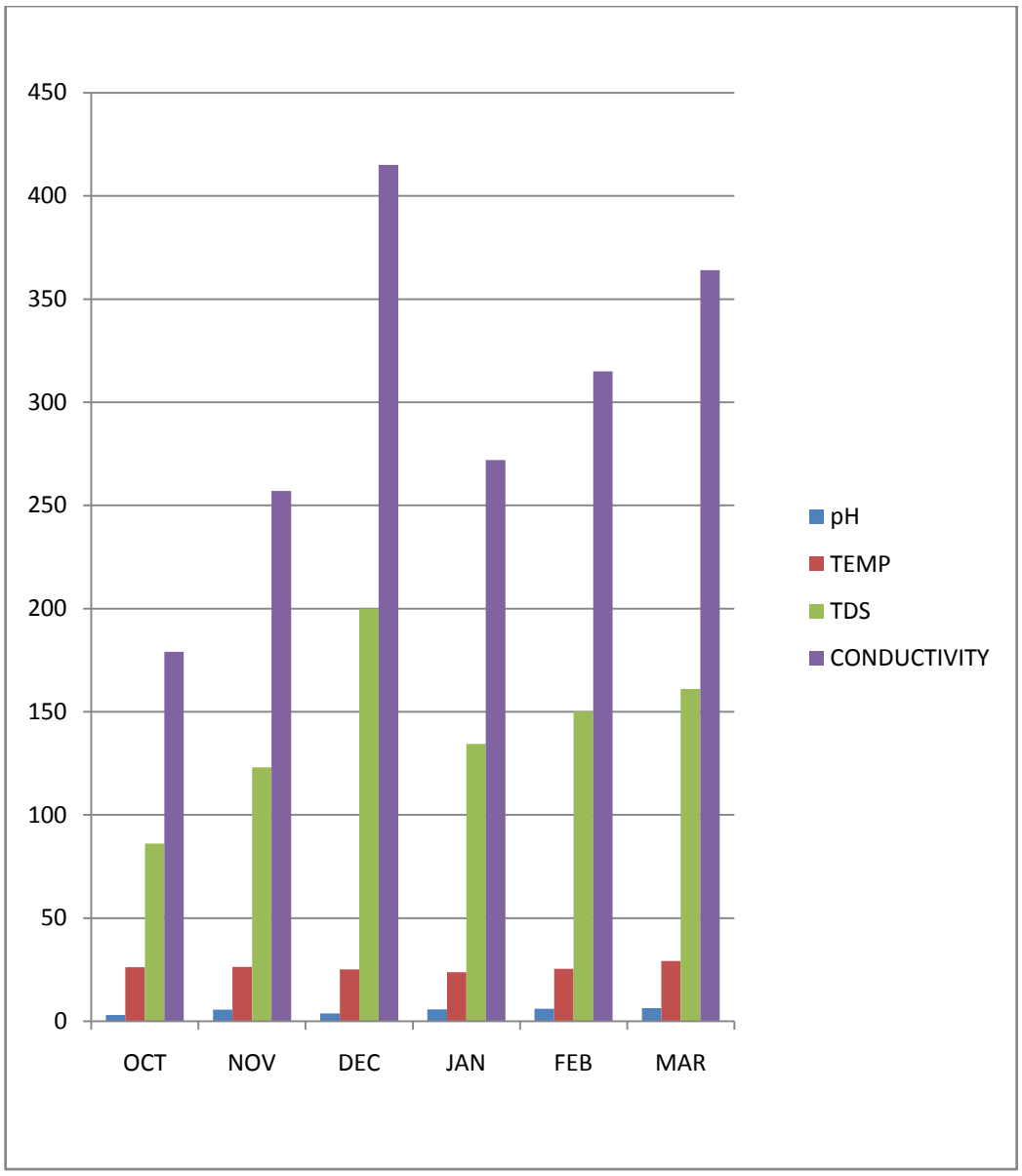



**Figure 4.15 Variation of physicochemical parameters within the sampling period at site 4**

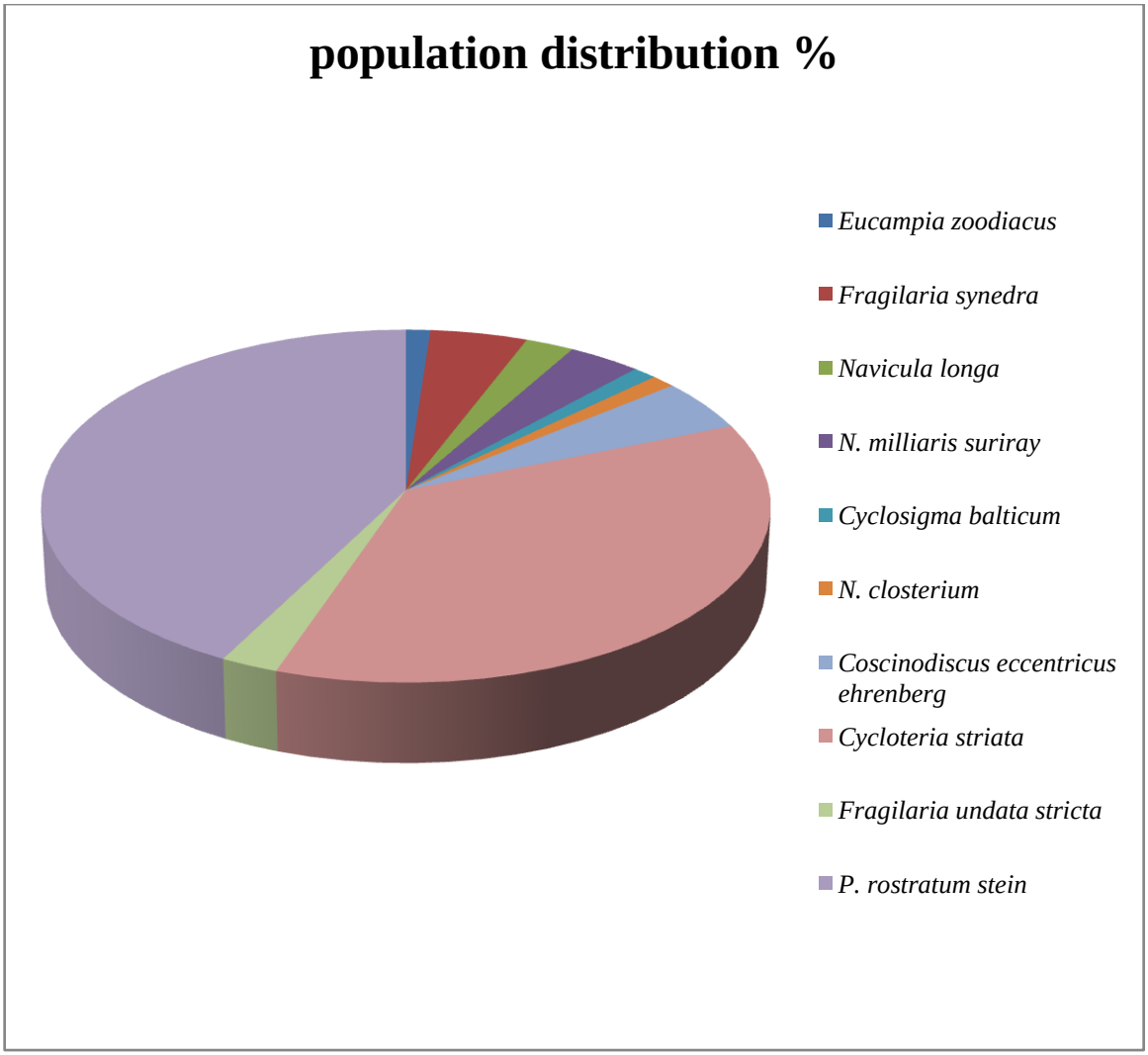



**Figure 4.16 Algae distribution during the sampling period at site 4**

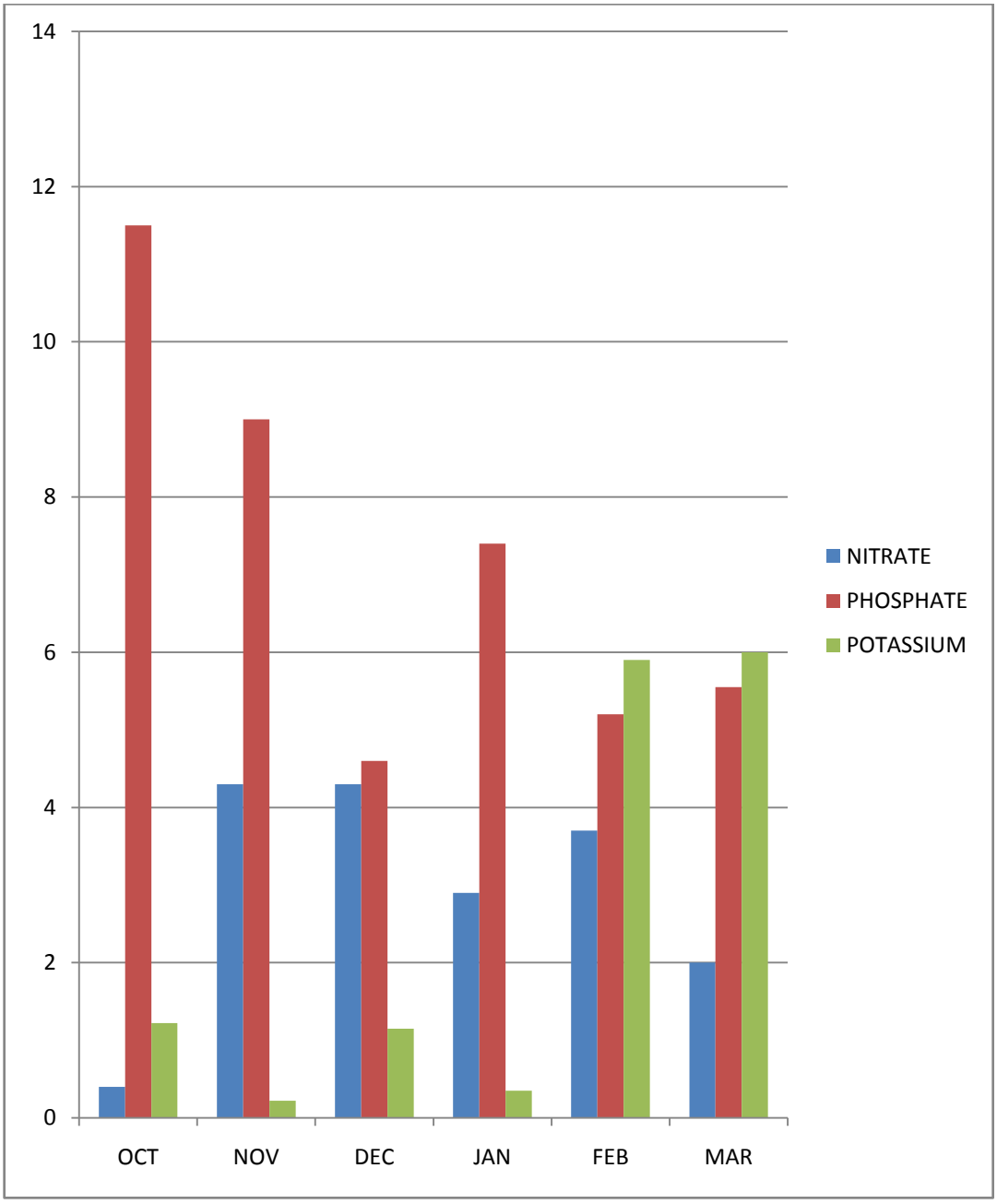



**Figure 4.17 Mean concentrations of nutrients at site 5**

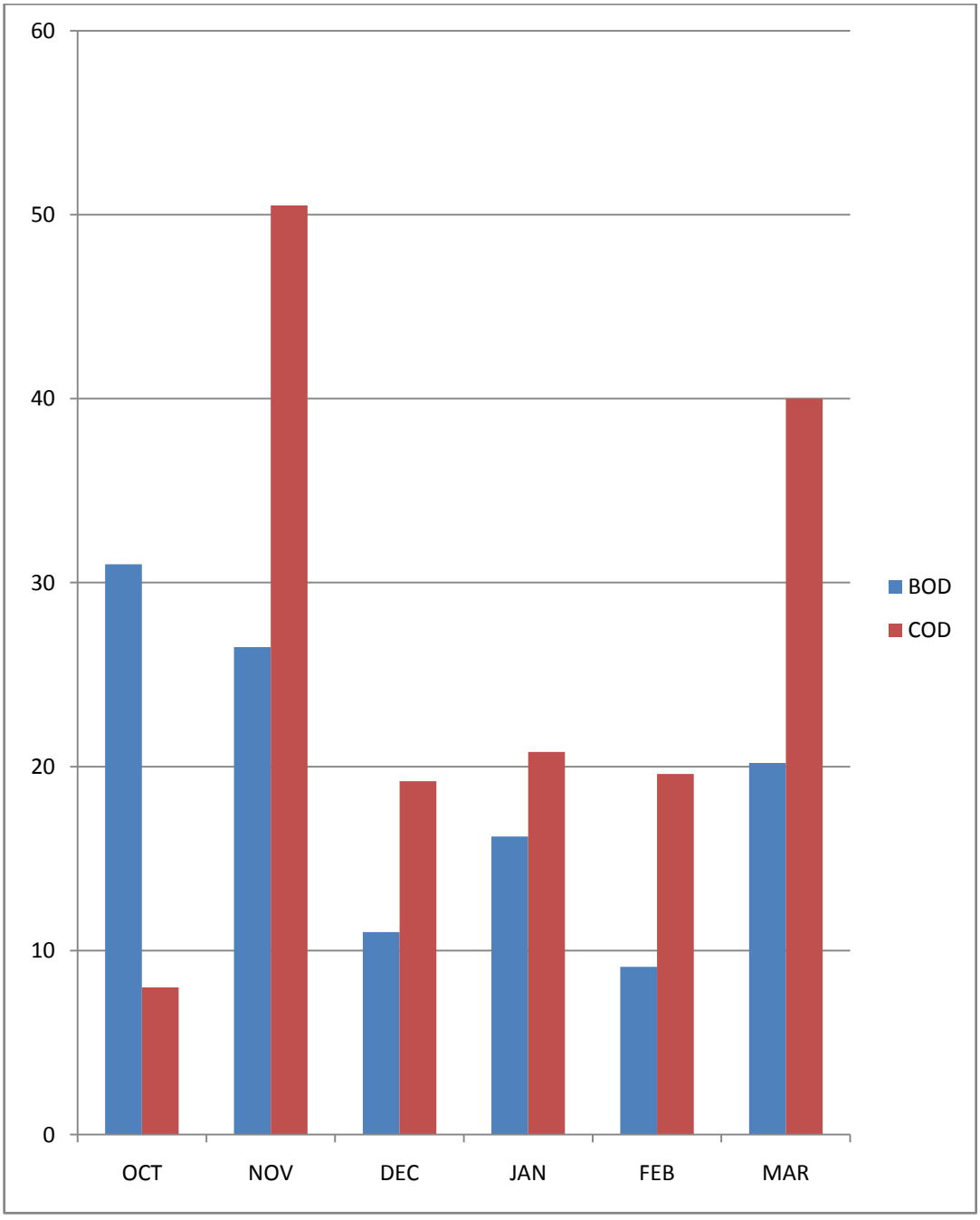



**Figure 4.18 Variation of BOD and COD within the sampling period at site 5**

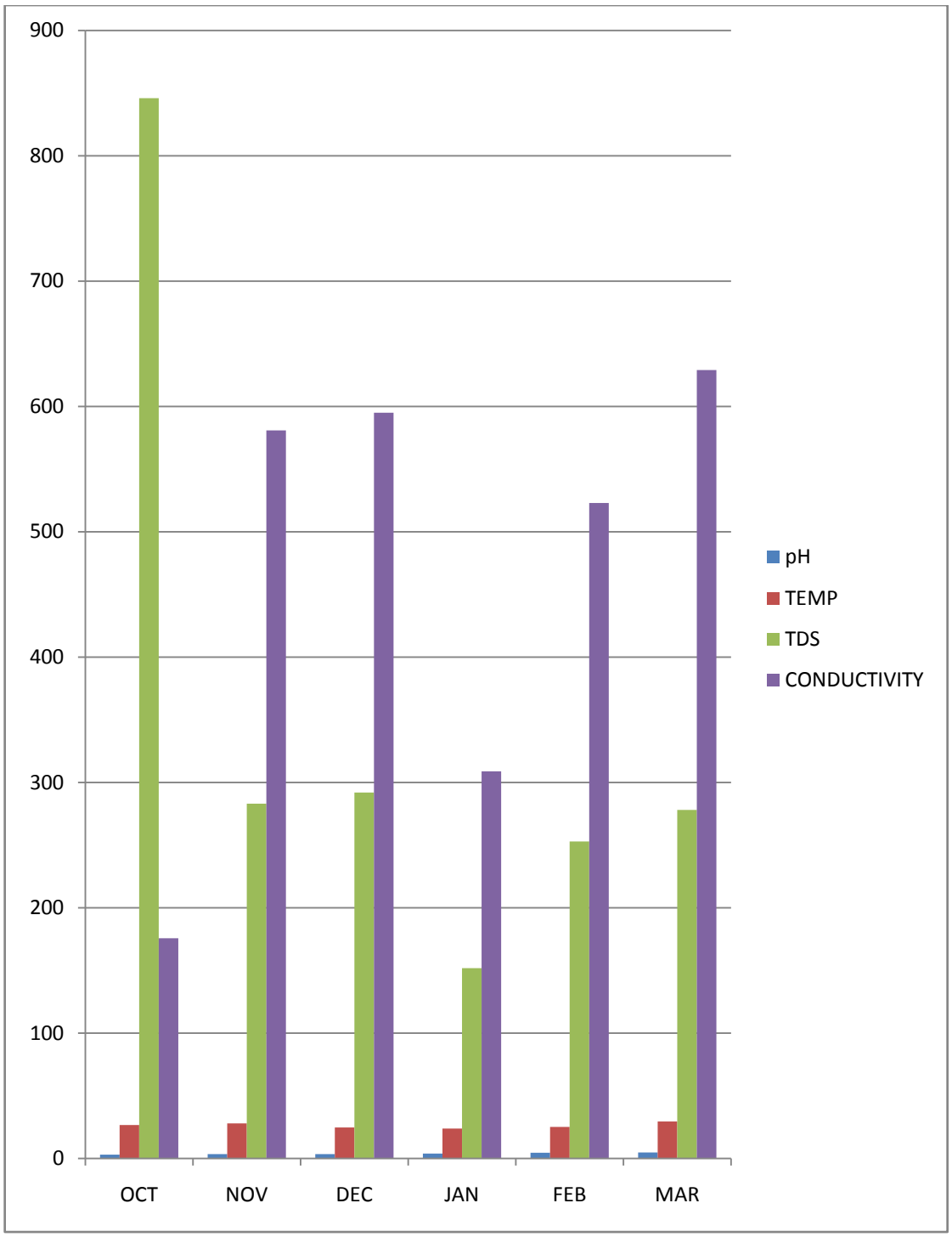



**Figure 4.19 Variation of physicochemical parameters within the sampling period at site 5**

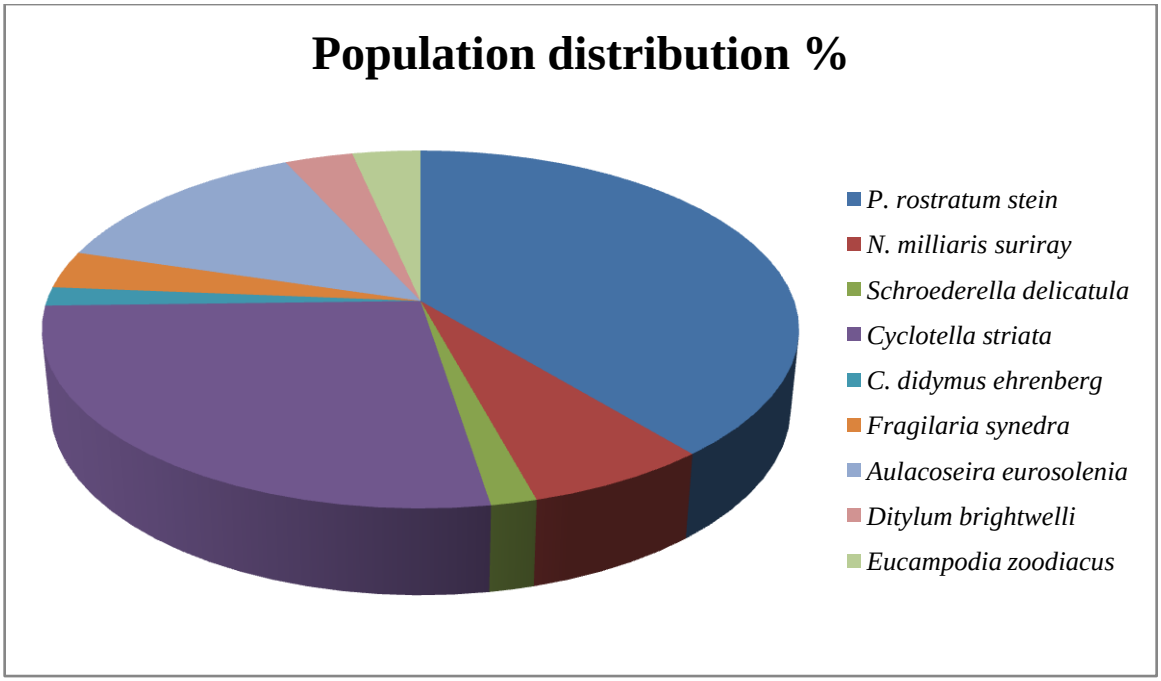



**Figure 4.20 Algae distribution during the sampling period at site 5**

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 BOD CONCENTRATIONS

Biochemical oxygen demand is the amount of oxygen required by bacteria for breaking down to simpler substances, the decomposable organic matter present in any water, waste water or treated effluent. BOD can be used to evaluate the concentration of organic matter present in that kind of sample. This is generally carried out by measuring the amount of dissolved oxygen present in any given sample before and after incubation in the dark at 20 degree celsius for five days. High BOD value is proportional to high eutrophication.

In Orozo the BOD showed a decreasing trend from 38.00 ± 0.00 in October to 7.370 ± 0.01 in February and leaped to 10.00 ± 0.00 in March. This shows that as the volume of water flow reduced, organic waste also reduced but at the onset of rainy season, it increased showing that organic wastes were being deposited and transported as water volume increased. In Gidan Mangoro BOD increased was from 9.00 ± 0.00 in October to 31.20 ±0.10 in November and then decreased to 5.08 ±0.01 in February then increased to 20.40 ±0.00 in March. This also gives support to the fact that water volume has influence on the magnitude of BOD. A similar trend was observed in Nyanya which increased from 17.30 ±0.10 to 27.20 ±0.00, decreased to 10.05 ±0.00 and at the onset of rainy season, increased to a very high figure of 32.400 ±0.10.

Wuse sampling site followed a similar trend with increase in BOD from 15.00 ± 0.00 in October to 40.30 ±0.10 in November then decreased to 7.007 ± 0.116 in February

then increased to 20.50 ±0.00 in March. A similar trend was also observed in Jabi and all showed lowest values in February probably due to reduced farming activities where the discharge of organic and synthetic fertilizers are minimal and lowest water velocity in the dry season where less biodegradable waste are transported from one place to another. Only Jabi site recorded a low value of 3.1mg/L in biological oxygen demand in October probably because it is a dam with legislation restricting human activities and is big enough to convey biodegradable waste very fast away from the immediate vicinity when water volume is high. Other sites (Orozo, Gidan Mangoro, Nyanya and Wuse) in the month of October had BOD greater than 5 mg/L hence not good for human consumption. Samples of water with BOD values greater or equal to 10 mg/L are said to be very bad with heavy biodegradable waste deposits. Taiwo *et al* (2012) reported that eutrophication research should not be limited to water assessment for consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life. Research by Taiwo *et al* (2012) also showed that BOD values were as high as 534mg/L and 1352.3 mg/L in two different sites in Lagos and 4374 mg/L in Port Harcourt, 300 mg/L in Kaduna. This is a pointer to the fact that eutrophication tend to be higher in densely populated areas with concentration of industry. The highest value of BOD in this research was 40.300mg/L which may be adduced to absence of concentration of chemical industries and relatively low population density compared to Lagos and Port Harcourt.

**5.2 Nitrates**

Variations in nitrate concentrations occurred in the various sites with Orozo showing a diminishing trend from 3.52 ±0.106 in October to 0.967 ±0.058 in March, Gidan mangoro showed an increase from October to March. Nyanya showed an irregular pattern

in concentration moving from 5.50 ±0.173 in October to 7.70 ±0.577 in December followed by a progressive decrease to 3.60 ± 0.10 and rose again to 4.30 ± 0.173. Wuse exhibited an alternating increment and decrement while the last site showed increments in the first three months (0.40 ±0.10 to 4.30 ±0.10) and then took an alternating trend in magnitude. The irregular pattern of nitrate concentration could be due to differences in pattern and period of rainfall in the various sites and reduction in farming activities. It may also be due to differences in bacteria conditions which participate in the natural nitrogen cycle producing nitrate for plant metabolism. The energy from lightening has the capacity to break the triple bond of atmospheric nitrogen gas ( $N_2$ bond energy 946kJ/mol) and dissolve it in rain water but in the absence of rainfall, nitrogen enters the soil through fertilizer application and putrefaction process which are both sporadic and uncertain. Appendix 6 on page 78 showed that there is no significant difference between the nitrate concentrations in all the sites. Moshood (2008) reported that COD was significantly higher in dry season, nitrate higher in dry season, phosphate and nitrate significantly higher in rainy season. Akin-Oriola (2003) research in Ibadan recorded very low values of nitrate with an average of 0.16±0.04mg/L and ranged from 0.00-0.40mg/L. Eutrophication profile in Abuja with respect to nitrate concentration, is therefore higher than that of Ibadan in Western part of Nigeria.

### 5.3 Total Dissolved Solid

The highest values out of the four sites were recorded in Orozo in the month of October with a value of 1222mg/L ± 0.00 and all the sites recorded their highest values also in the month of October. Gidan Mangoro (861. ± 0.00), Nyanya (676 ±0.00) and Jabi (846 ± 0.00). Only Wuse recorded its lowest value of 86.20 ± 0.00 in the month of October. This high value of total dissolved solid in the month of October could be due to higher rainfall

pattern compared to other months and hence higher water volume and consequently higher entropy in the solid particles making them to dissolve better in the water samples. Only Wuse deviated from this trend and Appendix 10 on page 82 showed that Wuse TDS correlation is significant at 0.01 confidence level in Orozo and Nyanya and significant at 0.05 confidence level in Gidan Mangoro. The differences in times and duration of rainfall also accounts for the non-linear pattern of decrease in TDS value from October to February. Increase from February to March in four sites gave support to the obvious fact that dissolved solids are higher in moving waters. Moshood (2008) adduced that setting of dissolved salts coupled with uptake of ions may be responsible for lower TDS in dry season and the result of this research followed a similar trend.

**5.4 Chemical Oxygen Demand**

Chemical oxygen demand is the amount of oxygen required for complete oxidation to carbon (IV) oxide and water of organic matter present in a sample of water, waste water or effluent. This is usually achieved by using strong oxidizing agents under acidic condition and the oxygen released will oxidize an equivalent amount of the waste to carbon (IV) and the unused is determined by titrating with a reducing agent of known strength. The amount used for the oxidation of the waste is known by the difference. Acidified potassium heptaoxodichromate (VI) ($K_2Cr_2O_7$) is the most suitable (Ademoroti 1996).

The reaction is given below

$$Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 4H_2O + 3(O).$$

The reducing agent is usually iron (II) ammonium sulphate ($FeSO_4(NH_4)_2SO_4.6H_2O$). The reaction is given below:

$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$. COD is proportional to eutrophication.

Eutrophication is more severe in pools of stagnant water bodies but all the sites used in this research were at various water volumes throughout the year. This must have been responsible for the irregular pattern of COD recorded in most sites across the months. Organic matters were always in motion in the moving waters and hence COD values displayed variability in time and space. Highest value in all the sites was recorded in Wuse in the month of October with a value of 86.000 ± 1.000 but in the month of March recorded it lowest value of 35.300 ±0.000. Jabi recorded the lowest value of 8.000 ±1.000 in October and a value of 40.000 ± 1.000 in March. Appendix 11 on page 83 showed irregular trends in all the sites suggesting that the major sources of waste may be due to anthropogenic activities with irregular discharges of waste with time. Research by Taiwo *et al* (2012) displayed high values of 850 mg/L and 2253 mg/L for COD in two sites of Lagos and 1800 mg/L in Kaduna. The research also showed that some surface and ground water quality parameters increased during rainfall and this is in corroboration with this study.

**5.5 Conductivity**

In metallic conductors, the charge carriers are the electrons but in liquid or molten solution, the charge carriers are the ions. This could be explained in terms of sequential decrease in water volume as the rainy season come to an end and consequently, increase in concentration and mobility of the ions in the water which gave rise to increase in the magnitude of the conductivity. A general decrease in all sites from December to January seemed to suggest that when optimum concentration of solutes in electrolytic cells are

exceeded, output current will begin to diminish. Another interesting speculation could be that as the water becomes less in volume or move with slow uniform velocity; most of the ions in solution migrate to the bottom leading to a reduced concentration on the top surface. Anake *et al* (2013) reported that conductivity is often used as a surrogate for TDS and that a conductivity of 1400 µs/cm is equivalent to 1000µg/L of dissolved solid. All the conductivities reported by Anake *et al* (2013) varied from 116 µs/cm to 396 µs/cm for surface waters and 36.5 µs/cm to 98.2 µs/cm for portable water. Standard Organization of Nigeria (SON) permissible limits for unpolluted water was fixed at 1000 µs/cm Anake *et al* (2013). Moshood (2008) observed higher conductivity records during rainy season which he attributed to increased in concentration of cations such as magnesium and sulphate while utilization of these salts by planktons and macrophytes produce reduction in conductivity. Moshood (2008) observed in Kwara State of Nigeria that 80.40µs/cm-178.80µs/cm would support diverse species of organism. In this research work, the values if conductivities obtained were far higher than 80.40µs/cm-178.80µs/cm so there is limitation placed on the survival of certain organisms in Abuja aquatic environment. TDS in Kwara State showed a positive concentration with conductivity and a similar trend was observed in this research.

Appendix 15 on page 87 showed that there is no significant difference in the conductivity of the samples in all sites throughout the period of research.

**5.6 Temperature**

All the sites exhibited almost the same temperatures across the months. The little discrepancies may be due to differences in biological activities and instrumental error. Appendix 18 on page 90 showed that there was no significant difference in temperature

across the sites under the duration of this research. Nwanebu *et al* (2011) reported that siltation and grasses covering rivers prevented direct sunlight on surface water which led to lower temperatures compared to other sites with higher temperatures due to direct sunlight on the surface waters. The differences in temperatures can result to differences in biological activities and changes in biological activities can induce changes also in temperatures.

### 5.7 Algae Count

The highest value of phytoplankton composition observed by Akin-Oriola (2003) was 319000 counts per $cm^3$ while lowest value observed was 1000 count per $cm^3$. However, it is observed that all sites in this study had phytoplankton composition less than 1000 count per $cm^3$ giving the impression that surface waters in Abuja were still relatively young. Akin-Oriola (2003) reported that certain groups of algae such as the desmids, chrysophytes and diatoms are referred to as oligotrophic species while cyanobacteria and euglenoids are classified as eutrophic species. Most of the species identified in Abuja surface water during this study belonged to the classes of diatom, indicating that eutrophication was still at its rudimentary stage. Neustupa *et al* (2013) reported that desmids and diatoms are small algae which usually predominate in oligotrophic waters due to their higher surface area to volume ratio and hence benefit from more efficient nutrient uptake rates per unit biovolume but larger species become more abundant in eutrophic conditions.

In site 1, *N. milliaris suriray* occupied 2% and *P. rostatum* occupied 49% which gives eutrophic water loving division of Dinophyceae a total of 51% and the remaining 49% made up of Bacillariophyceae with seven species. Diatoms might have occupied

almost 100% percent of algae population at the initial stage but as eutrophication level increased some of the species might have become extinct as a result of increase in the number of Dinophycea competing for nutrients and sun light. In site 2, eutrophic species of algae occupied 31% while the oligotrophic loving species occupied 69% with cyclotella striata alone occupying 39% among the Bacilliarophyceae. Dinophyceae (*N. milliaris suriray, P. rostatum)* occupied 69% leaving Bacilliarophyceae with 31% at site 3. The surface water in site 3 was aesthetically offensive with organic waste from decomposing refuse dump and animal dungs. The distribution of algae in site 4 is such that Dinophyceae had two species which occupied 46% while algae belonging to diatoms occupied 53% and desmid 1%. The oligotrophic water loving species were predominant in this site. Akin-Oriola (2003) reported that desmids and diatoms are usually found in oligotrophic waters. The two species belonging to eutrophic water samples occupied 46% while seven species belonging to oligotrophic water loving species occupied 54% in site 5.

Diatoms have deposited most of the earth's limestone and this brings the interesting speculation that samples of hard water (water samples that do not form lather easily with soap due to $Ca^{2+}$ or $Mg^{2+}$ usually their trioxocarbonate IV or tetraoxosulphate VI or both) will be dominated by species of algae belonging to groups of diatoms or that they initially contained diatoms before they were succeeded by eutrophic species with better adaptive feature or characteristics. Research has shown that surface mud of a pond, ditch or lagoon will almost always yield some diatoms (Neustupa *et al* 2013; Taofikat, and Dike, 2010). Calcium, magnesium and silicates are important elements influencing the distribution of Bacillariophycae which are diatoms ( Beata *et al* 2012; Ravishankar *et al* 2009). The dominant presence of Bacillariophycae is an indication that the Abuja surface water is at

the early stage of eutrophication. However, this alga is likely to be succeeded by eutrophic species if measures are not taken.

Pinto-Coelho (1998) conducted a study on eutrophication to show that heterotrophic zooplanktons and metazoans in addition to phytoplankton showed positive correlation between total phosphorous and microscopic animals.

### 5.8 pH Level

All the sites showed increase in pH value from October to March suggesting that there was a decreasing trend in fertilizer application such as $(NH_4)_2SO_2$ contained in some fertilizers which when dissolved in water, ionize to give a mixture of a strong acid and a weak conjugate base resulting to low pH. Most synthetic fertilizers used in irrigation have pH in the acid range and sometimes are neutralized by farmers using slake lime for optimum harvest. Another possible explanation for this could be the switch from synthetic fertilizers to organic manure which does not increase the hydrogen ion concentration. This could be responsible for the sharp discrepancy between October and March values as shown in Appendix 23 on page 95

Appendix 24 on page 96 showed that there was no significant difference between the pH values in all the sites and they correlate positively with one another. Anake *et al* (2013) reported that low level of pH could be attributed to presence of excess $CO_2$ and $SO_2$ caused by microbial activities.

### 5.9 Phosphate

Only Orozo showed a progressive increase from October (3.600 ± 0.000) to March (13.300 ± 0.100), Gidan Mangoro exhibited an alternating pattern in magnitude from October to March with an overall decrease from 7.600 ± 0.100 to 7.200± 0.000. Nyanya recorded 6.500 ± 0.100 in October and in March 12.000 ± 0.100 with irregular pattern in between these periods. Wuse site displayed an alternating increase and decrease with a transition from 8.500 ±0.100 to 9.700 ± 0.000. Jabi also displayed an irregular pattern with highest value of 11.500 ± 0.265 in October and 5.550 ± 0.071 in March. This may be due to irregular release of phosphate from sediments or bacteria oxidation of phosphorous compounds and perturbation from human activities through waste disposal. Appendix 27 on page 99 showed that there is no significant difference in the level of phosphate concentration in all sites throughout the research period. Orozo showed a negative correlation with Gidan Mangoro and Jabi sites respectively. Pinto-Coelho (1998) reported that phosphorus, nitrogen and chlorophyll a are widely used to monitor the progress of eutrophication in aquatic ecosystem.

### 5.10 Potassium

Appendix 29 on page 101, all the sites displayed very low values for potassium in the month of January with almost a general decrease from October to January. This may be due to the reduction in the use of the popular NPK fertilizers as the year approached the dry season and hence reduction in farming activities from October to January when cultivation activities are almost brought to a standstill and potassium depleted in effluent flow and plant metabolism. A rapid leap in potassium concentration was again noticed from

February to March in all sites suggesting that potassium might have been introduced by resumption of cultivation activities usually by irrigation along the water bodies. The sharp change in concentrations from February to March can be seen in figures 4.1, 4.5, 4.9, 4.13 and 4.17. Appendix 30 on page 102 showed that there was no significant difference in the concentration of potassium in all sites. The sites correlated positively in all sites except between Jabi and Nyanya.

# CHAPTER SIX

## 6.0 SUMMARY AND CONCLUSION

Physical, Chemical and biochemical parameters were measured in five strategic areas of water channels in Abuja to evaluate the level of eutrophication impact and the physical parameters measured included total dissolved solid and temperature, chemical parameters were concentration of nitrate, phosphate, potassium, conductivity and chemical oxygen demand while biochemical parameters measured were biochemical oxygen demand and algae count.

Temporal and spatial variations were observed during the rainy and dry seasons and there was clear disparity in concentrations of parameters measured due to extensive human activities minimizing or annulling the effects of seasonal changes.

Although biochemical oxygen demands were reasonably high indicating high eutrophication level, and the tendency of being blown into frightening proportion by human activities which are conspicuously visible, the effects of eutrophication was however controlled by both human activities and climatic conditions. Abuja is a town with adequate rainfall during the rainy season and the abnormal phenomenon of climatic changes made rains available on some few occasions during the dry season under which this research work was done. This prompted NIMET to educate farmers in Abuja metropolis not to embark on farming activities but to wait for the proper rainy season to avoid poor agricultural yields. Research in Israel has shown that to combat eutrophication, nutrients have to be removed and fresh water introduced (Shoshana 2012). There is adequate rainfall in Abuja and nutrients removal alongside with debris of dead algae from water channels do

take place through the process of sand removal for moulding of cement blocks and concrete formation and this accounts for the nutrients depletion in surface water bodies in Abuja. Adsorption of plant nutrients do take place on sand particles especially clay soil and to a far lesser extent on sandy soil ranging between 0.002-2mm (Noemi and Jozsef 2010). A casual observer can easily spot some dark/grey portions of sands excavated from soils along some water surface channels in Abuja and hence the removal of sand deposited periodically by moving water current also help to check eutrophication. However, it may be argued that the removal of these sand particles from the bottom of water ways can pose a potential risk of devastating erosion but the water bed of Abuja surface water channels have shown little or no effect and have not been shown to be prone to the problem of erosion throughout the period of this research. This may be attributed to the large extensive concrete network along the water channels which respond very slowly to the abrasion effect resulting from human activities but nevertheless, cautions have to be taken to prevent land degradation in Abuja town.

### 6.1 Recommendations

Based on the findings of this research work, the following recommendations are made.

Periodic assessment of eutrophication levels should be made, recorded and archived for future date references and this should embrace other parameters such as the concentrations of magnesium, calcium, sodium and other trace elements and ions that take part in plant metabolism.

The degree and pattern of rainfall should be monitored in conjunction with eutrophication parameters mentioned above and this should be done simultaneously in a rain forest region of Nigeria and a relatively low rainfall region in the interior Northern Nigeria and the data obtained should be used to access the mitigation of land degradation or Sahara desert encroachment.

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## APPENDICES

APPENDIX 1.PHYTOPLANKTON COMPOSITION IN AWBA RESERVOIR

| *Cyanophyceae* | Total Abundance per $cm^3$ | % Abundance |
|---|---|---|
| *Mycrocystis aeruginosa kutz* | 319000 | 67.7 |
| *Coelosphaerium kuetzingianum Nag* | 35000 | 7.4 |
| *Phormidium Sp. Kutz ex Gom* | 9000 | 1.9 |
| *Chlorophyceae* | | |
| *Pediastrum boryanum Kutz* | 51000 | 10.8 |
| *Botsyococcus braunti Kutz* | 10,000 | 2.1 |
| *Selenastrum bibraianum Kutz* | 1000 | 0.2 |
| *Tetraspora lubrica Kutz* | 1000 | 0.2 |
| *Desmidaceae* | | |
| *Closterium monoliforme Kutz* | 18000 | 3.8 |
| *Cosmarium Punctulatum Kutz* | 13000 | 2.8 |
| *Micrasterias Sp.* | 1000 | 0.2 |
| *Bacilliariophyceae* | | |
| *Cyclotella meneghiniana Kutz* | 3000 | 0.6 |
| *Nitzschia gracilis Kutz* | 4000 | 0.9 |

| | | |
|---|---|---|
| *Navicula rhyncocephala Kutz* | 5000 | 1.1 |
| *Dinophyceae* | | |
| *Peridinium Sp* | 1000 | 0.2 |

**APPENDIX 2 SUMMARY OF BOD CONCENTRATION (mg/L)**

Appendix 2 shows the results of biochemical oxygen demand in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 38.000 ±0.000 | 26.500 ±0.000 | 21.000 ±1.000 | 13.000 ±1.000 | 7.370 ±0.010 | 18.800 ±0.000 |
| 2 | Gidan mangoro | 9.000 ±0.000 | 31.200 ±0.100 | 12.000 ±0.000 | 11.433 ±0.379 | 5.080±0. 010 | 20.400 ±0.000 |
| 3 | Nyanya | 17.300 ±0.100 | 27.200 ±0.000 | 14.000 ±0.000 | 18.500 ±0.100 | 10.050 ±0.000 | 32.400 ±0.100 |
| 4 | Wuse | 15.000 ±0.000 | 40.300 ±0.100 | 17.000 ±0.000 | 17.000 ±0.000 | 7.007 ±0.116 | 20.5000 ±0.000 |
| 5 | Jabi | 3.100 ±0.000 | 26.500 ±0.000 | 11.000 ±0.000 | 16.200 ±0.100 | 9.120 ±0.010 | 20.200 ±0.000 |

**APPENDIX 3 ANOVA SUMMARY FOR BOD**

Appendix 3 shows the summary of analysis of variance for biochemical oxygen demand within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo b/w Groups | 1720.716 | 5 | 344.143 | 1.027E3 | 0.000 |
| Within Groups | 4.020 | 12 | 0.335 | | |
| Total | 1724.736 | 17 | | | |
| Gidan Mangoro b/w Groups | 1342.789 | 5 | 268.558 | 1.050E4 | 0.000 |
| | 0.307 | 12 | 0.026 | | |
| Within Groups | | | | | |
| Total | 1343.096 | 17 | | | |
| Nyanya b/w Groups | 1050.276 | 5 | 210.055 | 4.201E4 | 0.000 |
| Within Groups | 0 .060 | 12 | 0.005 | | |
| Total | 1050.336 | 17 | | | |
| Wuse b/w Groups | 1867.401 | 5 | 373.480 | 2.211E5 | 0.000 |
| Within Groups | 0.020 | 12 | 0.002 | | |
| Total | 1867.422 | 17 | | | |
| Jabi b/w Groups | 1051.216 | 5 | 210.243 | 1.249E5 | 0.000 |
| Within Groups | 0 .020 | 12 | 0.002 | | |
| Total | 1051.236 | 17 | | | |

**APPENDIX 4 SUMMARY OF BOD CORRELATION**

Appendix 4 shows the Pearson correlation result of biochemical oxygen demand within and between the sites.

| | | Orozo | G.man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.273 | 0.254 | 0.378 | -0.180 |
| | Sig (2-tailed) | | 0.273 | 0.309 | .122 | 0.474 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan | Correlation | 0.273 | 1 | 0.813 | 0.965 | 0.887 |
| mangoro | Sig (2-tailed) | 0.273 | | 0.000 | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.254 | 0.813 | 1 | 0.680 | 0.742 |
| | Sig (2-tailed) | 0.309 | 0.000 | | 0.002 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | 0.378 | 0.965 | 0.680 | 1 | 0.810 |
| | Sig (2-tailed) | 0.122 | 0.000 | 0.002 | | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | -0.180 | 0.887 | 0.742 | 0.810 | 1 |
| | Sig (2-tailed) | 0.474 | 0.000 | 0.000 | 0.000 | |
| | N | 18 | 18 | 18 | 18 | 18 |

**APPENDIX 5 SUMMARY OF NITRATE CONCENTRATION (mg/L)**

Appendix 5 shows the results of nitrate concentrations in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 3.520 ±0.106 | 2.833 ±0.116 | 1.8 ±0.100 | 2.130 ±0.113 | 1.443 ±0.513 | 0.967 ±0.058 |
| 2 | Gidan Mangoro | 0.933 ±0.116 | 1.200 ± 0.100 | 2.510 ±0.173 | 1.500 ±0.100 | 2.620 ±0.072 | 2.773 ±0.379 |
| 3 | Nyanya | 5.500 ±0.173 | 6.767 ±0.577 | 7.700 ±0.100 | 4.133 ±0.577 | 3.600 ±0.100 | 4.300 ±0.173 |
| 4 | Wuse | 4.600 ±0.100 | 4.500 ±0.000 | 6.300 ±0.100 | 6.300 ±0.100 | 3.300 ±0.000 | 1.500 ±0.100 |
| 5 | Jabi | 0.400 ±0.100 | 4.300 ±0.000 | 4.300 ±0.100 | 2.900 ±0.000 | 3.700 ±0.100 | 2.000 ±0.100 |

## APPENDIX 6 ANOVA SUMMARY FOR NITRATE CONCENTRATION

Appendix 6 shows the summary of analysis of variance for nitrate within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 13.078 | 5 | 2.616 | 294.989 | 0.000 |
| Within groups | 0.106 | 12 | 0.009 | | |
| Total | 13.184 | 17 | | | |
| Gidan Man.B/W groups | 9.704 | 5 | 1.941 | 289.181 | 0.000 |
| Within groups | 0.081 | 12 | 0.007 | | |
| Total | 9.784 | 17 | | | |
| Nyanya B/W groups | 39.587 | 5 | 7.917 | 548.123 | 0.000 |
| Within groups | 0.173 | 12 | 0.014 | | |
| Total | 39.760 | 17 | | | |
| Wuse B/W groups | 40.105 | 5 | 8.021 | 1.604E3 | 0.000 |
| Within groups | 0.060 | 12 | 0.005 | | |
| Total | 40.165 | 17 | | | |
| Jabi B/W groups | 34.840 | 5 | 6.968 | 1.045E3 | 0.000 |
| Within groups | 0.080 | 12 | 0.007 | | |
| Total | 34.920 | 17 | | | |

**APPENDIX 7 SUMMARY OF NITRATE CORRELATION**

Appendix 7 shows the Pearson correlation result of nitrate ion within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | -0.931 | 0.375 | 0.416 | -0.344 |
| | Sig(2-tailed) | | 0.000 | 0.125 | 0.086 | 0.163 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | -0.931 | 1 | -0.210 | -0.274 | 0.335 |
| | Sig(2-tailed) | 0.000 | | 0.403 | 0.271 | 0.174 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.375 | -0.210 | 1 | 0.928 | 0.358 |
| | Sig(2-tailed) | 0.125 | 0.403 | | 0.000 | 0.145 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | 0.416 | -0.274 | 0.928 | 1 | 0.100 |
| | Sig(2-tailed) | 0.086 | 0.271 | 0.000 | | 0.693 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | -0.344 | 0.335 | 0.358 | 0.100 | 1 |
| | Sig(2-tailed) | 0.163 | 0.174 | 0.145 | 0.693 | |
| | N | 18 | 18 | 18 | 18 | 18 |

**APPENDIX 8 SUMMARY OF TDS LEVEL**

Appendix 8 shows the results of total dissolved solids in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 1222 ±0.000 | 288.0 ±0.000 | 351.0 ±2.000 | 112.6 ±0.100 | 105.1 ±0.100 | 168.0 ±0.000 |
| 2 | Gidan Mangoro | 861.0 ±0.000 | 205.0 ±1.000 | 397.0 ±0.000 | 157.4 ±0.100 | 148.8 ±0.000 | 94.400 ±0.100 |
| 3 | Nyanya | 676.0 ±0.000 | 198.5 ±0.100 | 194.0 ±0.000 | 127.6 ±0.100 | 136.3 ±0.000 | 175.5 ±0.208 |
| 4 | Wuse | 86.200 ±0.000 | 1.23.0 ±0.000 | 200.0 ±1.000 | 134.4 ±0.000 | 150.1 ±0.100 | 161.0 ±0.000 |
| 5 | Jabi | 846.0 ±0.000 | 283.0 ±0.000 | 292.0 ±1.000 | 151.8 ±0.000 | 253.0 ±0.000 | 278.0 ±1.000 |

**APPENDIX 9 ANOVA SUMMARY FOR TDS**

Appendix 9 shows the summary of analysis of variance for total dissolved solids within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 2730302.865 | 5 | 546060.573 | 815000 | 0.000 |
| Within groups | 8.040 | 12 | 0.670 | | |
| Total | 2730310.905 | 17 | | | |
| Gidan Man.B/W groups | 1253845.200 | 5 | 250769.040 | 1475000 | 0.000 |
| Within groups | 2.040 | 12 | 0.170 | | |
| Total | 1253847.240 | 17 | | | |
| Nyanya B/W groups | 662125.484 | 5 | 132425.097 | 12550000 | 0.000 |
| Within groups | 0.127 | 12 | 0.011 | | |
| Total | 662125.611 | 17 | | | |
| Wuse B/W groups | 21965.385 | 5 | 4393.077 | 26100 | 0.000 |
| Within groups | 2.020 | 12 | 0.168 | | |
| Total | 21967.405 | 17 | | | |
| Jabi B/W groups | 923228.500 | 5 | 184645.700 | 553900 | 0.000 |
| Within groups | 4.000 | 12 | 0.333 | | |
| Total | 923232.500 | 17 | | | |

**APPENDIX 10 SUMMARY OF TDS CORRELATION**

Appendix 10 shows the Pearson correlation result of total dissolved solids within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.976□ □ | 0.993□ □ | -0.626□ □ | 0.983□ □ |
| | Sig(2-tailed) | | 0.000 | 0.000 | 0.005 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 0.976□ □ | 1 | 0.949□ □ | -0.505□ | 0.939□ □ |
| | Sig(2-tailed) | 0.000 | | 0.000 | 0.032 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.993□ □ | 0.949□ □ | 1 | -0.683□ □ | 0.992□ □ |
| | Sig(2-tailed) | 0.000 | 0.000 | | 0.002 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | -0.626□ □ | -0.505□ | -0.683□ □ | 1 | -0.641□ □ |
| | Sig(2-tailed) | 0.005 | 0.032 | 0.002 | | 0.004 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | 0.983□ □ | 0.939□ □ | 0.992□ □ | -0.641□ □ | 1 |
| | Sig(2-tailed) | 0.000 | 0.000 | 0.000 | 0.004 | |
| | N | 18 | 18 | 18 | 18 | 18 |

| | |
|---|---|
| | 18 |

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

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

**APPENDIX 11 SUMMARY OF COD CONCENTRATIONS (mg/L)**

Appendix 11 shows the results of chemical oxygen demand in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 80.000 ±0.000 | 80.000 ±0.000 | 38.400 ±0.100 | 17.500 ±0.173 | 17.400 ±0.100 | 40.200 ±0.100 |
| 2 | Gidan Mangoro | 16.000 ±0.000 | 32.000 ±1.000 | 25.600 ±0.000 | 16.000 ±1.000 | 16.800 ±0.100 | 50.000 ±0.000 |
| 3 | Nyanya | 32.000 ±0.000 | 48.000 ±0.000 | 32.667 ±1.528 | 24.000 ±0.000 | 24.300 ±0.100 | 50.400 ±0.173 |
| 4 | Wuse | 32.000 ±0.000 | 86.000 ±0.000 | 28.000 ±1.000 | 19.167 ±0.116 | 19.733 ±0.153 | 35.300 ±0.000 |
| 5 | Jabi | 8.000 ±1.000 | 50.500 ±0.100 | 19.200 ±0.000 | 20.800 ±0.000 | 19.600 ±0.100 | 40.000 ±1.000 |

**APPENDIX 12 SUMMARY OF COD ANOVA**

Appendix 12 shows the summary of analysis of variance for chemical oxygen demand within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 12097.705 | 5 | 2419.541 | 242000 | 0.000 |
| Within groups | 0.120 | 12 | 0.010 | | |
| Total | 12097.825 | 17 | | | |
| Gidan Man.B/W groups | 2690.320 | 5 | 538.064 | 1606 | 0.000 |
| Within groups | 4.020 | 12 | 0.335 | | |
| Total | 2694.340 | 17 | | | |
| Nyanya B/W groups | 1967.349 | 5 | 393.470 | 994.727 | 0.000 |
| Within groups | 4.747 | 12 | 0.396 | | |
| Total | 1972.096 | 17 | | | |
| Wuse B/W groups | 9376.547 | 5 | 1875.309 | 10850 | 0.000 |
| Within groups | 2.073 | 12 | 0.173 | | |
| Total | 9378.620 | 17 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Jabi B/W groups | 3701.265 | 5 | 740.253 | 2199 | 0.000 |
| Within groups | 4.040 | 12 | 0.337 | | |
| Total | 3705.305 | 17 | | | |

**APPENDIX 13 SUMMARY OF COD CORRELATION**

Appendix 13 shows the Pearson correlation result of chemical oxygen demand within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.145 | 0.546□ | 0.725□ □ | 0.235 |
| | Sig(2-tailed) | | 0.566 | 0.019 | 0.001 | 0.349 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 145 | 1 | .894□ □ | .384 | .737□ □ |
| | Sig(2-tailed) | 0.566 | | 0.000 | 0.115 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.546□ | 0.894□ □ | 1 | 0.718□ □ | 0.809□ □ |
| | Sig(2-tailed) | 0.019 | 0.000 | | 0.001 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | 0.725□ □ | 0.384 | 0.718□ □ | 1 | 0.780□ □ |
| | Sig(2-tailed) | 0.001 | 0.115 | 0.001 | | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Jabi | Correlation | 0.235 | 0.737□ □ | 0.809□ □ | 0.780□ □ | 1 |
| | Sig(2-tailed) | 0.349 | 0.000 | 0.000 | 0.000 | |
| | N | 18 | 18 | 18 | 18 | 18 |

□ □Correlation is significant at the 0.01 level (2-tailed)

□ Correlation is significant at the 0.05 level (2-tailed)

**APPENDIX 14 SUMMARY OF CONDUCTIVITY LEVEL (µS/cm)**

Appendix 14 shows the results of conductivity in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 2460 ±2.645 | 597.7 ±0.577 | 723.0 ±1.000 | 232.0 ±1.000 | 221.0 ±2.646 | 382.0 ±1.000 |
| 2 | Gidan Mangoro | 179.0 ±0.000 | 425.0 ±1.000 | 814.0 ±0.000 | 312.0 ±1.000 | 313.0 ±1.000 | 216.7 ±1.528 |
| 3 | Nyanya | 141.4 ±0.000 | 412.0 ±0.000 | 401.0 ±1.000 | 259.0 ±0.000 | 285.0 ±1.000 | 399.0 ±1.000 |
| 4 | Wuse | 179.1 ±0.000 | 257.0 ±0.000 | 415.0 ±1.000 | 272.0 ±0.000 | 315.0 ±1.000 | 364.0 ±0.000 |
| 5 | Jabi | 175.6 ±0.000 | 581.0 ±0.000 | 595.0 ±1.000 | 309.0 ±0.000 | 523.0 ±1.000 | 629.0 ±0.000 |

**APPENDIX 15 SUMMARY OF CONDUCTIVITY ANOVA**

Appendix 15 shows the summary of analysis of variance for conductivity within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 683116.944 | 5 | 136623.389 | 47290 | 0.000 |
| Within groups | 34.667 | 12 | 2.889 | | |
| Total | 683151.611 | 17 | | | |
| Gidan Man.B/W groups | 5359919.611 | 5 | 1071983.922 | 1206000 | 0.000 |
| Within groups | 10.667 | 12 | 0.889 | | |
| Total | 5359930.278 | 17 | | | |
| Nyanya B/W groups | 2887894.000 | 5 | 577578.800 | 1155000 | 0.000 |
| Within groups | 6.000 | 12 | 0.500 | | |
| Total | 2887900.000 | 17 | | | |
| Wuse B/W groups | 5427282.000 | 5 | 1085456.400 | 3256000 | 0.000 |

| | | | | | |
|---|---|---|---|---|---|
| Within groups | 4.000 | 12 | 0.333 | | |
| Total | 5427286.000 | 17 | | | |
| Jabi B/W groups | 3970094.500 | 5 | 794018.900 | 2382000 | 0.000 |
| Within groups | 4.000 | 12 | 0.333 | | |
| Total | 3970098.500 | 17 | | | |

**APPENDIX 16 SUMMARY OF CONDUCTIVITY CORRELATION**

Appendix 16 shows the Pearson correlation of conductivity result within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | -0.068 | -0.234 | -0.312 | -0.221 |
| | Sig(2-tailed) | | 0.787 | 0.351 | 0.207 | 0.378 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan | Correlation | 0.068 | 1 | 0.947□ □ | 0.951□ □ | 0.932□ □ |
| Mangoro | Sig(2-tailed) | 0.787 | | 0.000 | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | -0.234 | 0.947□ □ | 1 | 0.990□ □ | 0.992□ □ |
| | Sig(2-tailed) | 0.351 | 0.000 | | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | -0.312 | 0.951□ □ | 0.990□ □ | 1 | 0.982□ □ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sig(2-tailed) | 0.207 | 0.000 | 0.000 | | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | -0.221 | 0.932□ □ | 0.992□ □ | 0.982□ □ | 1 |
| | Sig(2-tailed) | 0.378 | 0.000 | 0.000 | 0.000 | |
| | N | 18 | 18 | 18 | 18 | 18 |

□ □Correlation is significant at the 0.01 level (2-tailed)

□ Correlation is significant at the 0.05 level (2-tailed)

**APPENDIX 17 SUMMARY OF TEMPERATURE LEVEL IN DEGREE CELCIUS**

Appendix 17 shows the results of temperature in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 26.003 ±0.006 | 28.000 ±1.000 | 25.333 ±0.577 | 23.800 ±0.100 | 25.167 ±0.06 | 29.500 ±0.100 |
| 2 | Gidan Mangoro | 26.733 ±0.550 | 26.250 ±0.180 | 25.000 ±0.100 | 23.800 ±0.100 | 25.600 ±0.200 | 29.700 ±0.100 |
| 3 | Nyanya | 26.803 ±0.015 | 26.000 ±0.200 | 21.233 ±0.251 | 23.700 ±0.100 | 25.300 ±0.100 | 29.600 ±0.265 |
| 4 | Wuse | 26.233 ±1.069 | 26.367 ±0.321 | 25.200 ±0.100 | 23.700 ±0.100 | 25.400 ±0.100 | 29.200 ±0.100 |
| 5 | Jabi | 26.700 | 28.016 | 24.700 | 23.900 | 25.200 | 29.600 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | ±0.200 | ±0.153 | ±0.100 | ±0.100 | ±0.100 | ±0.100 |

**APPENDIX 18 SUMMARY OF TEMPERATURE ANOVA**

Appendix 18 shows the summary of analysis of variance for temperature within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 65.061 | 5 | 13.012 | 57.546 | 0.000 |
| Within groups | 2.713 | 12 | 0.226 | | |
| Total | 67.774 | 17 | | | |
| Gidan Man.B/W groups | 60.284 | 5 | 12.057 | 178.253 | 0.000 |
| Within groups | 0.812 | 12 | 0.068 | | |
| Total | 61.096 | 17 | | | |
| Nyanya B/W groups | 120.663 | 5 | 24.133 | 748.042 | 0.000 |

| | | | | | |
|---|---|---|---|---|---|
| Within groups | 0.387 | 12 | 0.032 | | |
| Total | 121.050 | 17 | | | |
| Wuse B/W groups | 50.152 | 5 | 10.030 | 46.774 | 0.000 |
| Within groups | 2.573 | 12 | 0.214 | | |
| Total | 52.725 | 17 | | | |
| Jabi B/W groups | 70.531 | 5 | 14.106 | 1055.000 | 0.000 |
| Within groups | 0.160 | 12 | 0.013 | | |
| Total | 70.691 | 17 | | | |

**APPENDIX 19 SUMMARY OF TEMPERATURE CORRELATION RESULT**

Appendix 19 shows the Pearson correlation result of temperature within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.888□ □ | 0.739□ □ | 0.914□ □ | 0.960□ □ |
| | Sig(2-tailed) | | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 0.888□ □ | 1 | 0.858□ □ | 0.984□ □ | 0.918□ □ |
| | Sig(2-tailed) | 0.000 | | 0.000 | 0.000 | 0.000 |
| | | 18 | 18 | 18 | 18 | 18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | N | | | | | |
| Nyanya | Correlation | 0.739 | 0.858 | 1 | 0.798 | 0.858 |
| | Sig(2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | 0.914□ □ | 0.984□ □ | 0.798□ □ | 1 | 0.914□ □ |
| | Sig(2-tailed) | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | 0.960□ □ | 0.918□ □ | 0.853□ □ | 0.914□ □ | 1 |
| | Sig(2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 18 | 18 | 18 | 18 | 18 |

□ □Correlation is significant at the 0.01 level (2-tailed)

**APPENDIX 20 SUMMARY OF ALGAE COUNT PER $cm^3$**

Appendix 20 shows the results of algae count in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 74.000 | 666.0 | 444.0 | 592.0 | 111.0 | 296.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | ±1.000 | ±86.556 | ±6.083 | ±10.149 | ±3.606 | ±7.937 |
| 2 | Gidan Mangoro | 592.0 ±10.149 | 333.0 ±17.521 | 814.0 ±11.790 | 407.0 ±6.245 | 74.000 ± 3.606 | 518.0 ±2.646 |
| 3 | Nyanya | 407.0 ±2.000 | 111.0 ±1.000 | 148.0 ±2.000 | 148.0 ±20.298 | 185.0 ±5.568 | 296.0 ±8.660 |
| 4 | Wuse | 814.0 ±2.000 | 74.00 ±3.606 | 222.0 ±3.606 | 444.0 ±5.292 | 481.0 ±2.645 | 185.0 ±6.245 |
| 5 | Jabi | 185.0 ±6.245 | 592.0 ±10.535 | 740.0 ±9.165 | 222.0 ±6.928 | 259.0 ±15.589 | 147.0 ±0.000 |

**APPENDIX 21 ALGAE COUNT ANOVA SUMMARY**

Appendix 21 shows the summary of analysis of variance for algae count within and between the sites of research.

| | Sum of squares | Mean | F | Sig |
|---|---|---|---|---|

| | | DF | Squares | | |
|---|---|---|---|---|---|
| Orozo B/W groups | 906962.500 | 5 | 181392.500 | 141.180 | 0.000 |
| Within groups | 15418.000 | 12 | 1284.833 | | |
| Total | 922380.500 | 17 | | | |
| Gidan Man.B/W groups | 941872.000 | 5 | 188374.400 | 1859 | 0.000 |
| Within groups | 1216.000 | 12 | 101.333 | | |
| Total | 943088.000 | 17 | | | |
| Nyanya B/W groups | 192344.500 | 5 | 38468.900 | 437.976 | 0.000 |
| Within groups | 1054.000 | 12 | 87.833 | | |
| Total | 193398.500 | 17 | | | |
| Wuse B/W groups | 1002108.000 | 5 | 200421.600 | 11560 | 0.000 |
| Within groups | 208.000 | 12 | 17.333 | | |
| Total | 1002316.000 | 17 | | | |
| Jabi B/W groups | 863359.765 | 5 | 172671.953 | 1809 | 0.000 |
| Within groups | 1050.000 | 12 | 95.455 | | |
| Total | 864409.765 | 17 | | | |

**APPENDIX 22 SUMMARY OF ALGAE COUNT CORRELATION**

Appendix 22 shows the Pearson correlation of algae count within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.105 | -0.749□ | -0.086 | 0.525□ |
| | Sig(2-tailed) | | 0.680 | 0.000 | 0.735 | 0.025 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 0.105 | 1 | 0.243 | -0.296 | 0.375 |
| | Sig(2-tailed) | 0.680 | | 0.331 | 0.234 | 0.125 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | -0.749□ □ | 0.243 | 1 | 0.224 | -0.629□ □ |
| | Sig(2-tailed) | 0.000 | 0.331 | | 0.371 | 0.005 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | -.086 | -.296 | .224 | 1 | -.090 |
| | Sig(2-tailed) | 0.735 | 0.234 | 0.371 | | 0.722 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | 0.525□ | 0.375 | -0.629□ □ | -0.090 | 1 |
| | Sig(2-tailed) | 0.025 | 0.125 | 0.005 | 0.722 | |
| | N | 18 | 18 | 18 | 18 | 18 |

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

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

**APPENDIX 23 SUMMARY OF pH LEVEL**

Appendix 23 shows the results of pH level in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 3.027 ±0.010 | 3.530 ±0.010 | 3.537 ±0.021 | 4.040 ±0.040 | 4.430 ±0.044 | 6.450 ±0.156 |
| 2 | Gidan Mangoro | 3.060 ±0.010 | 3.580 ±0.010 | 3.490 ±0.010 | 3.910 ±0.010 | 3.090 ±0.030 | 6.450 ±0.046 |
| 3 | Nyanya | 3.117 ±0.012 | 3.730 ±0.044 | 3.820 ±0.017 | 5.940 ±0.010 | 5.810 ±0.010 | 5.670 ±0.010 |
| 4 | Wuse | 3.080 ±0.026 | 5.540 ±0.010 | 3.710 ±0.026 | 5.750 ±0.017 | 6.040 ±0.027 | 6.340 ±0.027 |
| 5 | Jabi | 3.110 ±0.010 | 3.500 ±0.010 | 3.480 ±0.010 | 3.877 ±0.012 | 4.500 ±0.100 | 4.773 ±0.020 |

**APPENDIX 24 SUMMARY OF pH ANOVA**

Appendix 24 shows the summary of analysis of variance for pH level within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 22.202 | 5 | 4.440 | 932.658 | 0.000 |
| Within groups | 0.057 | 12 | 0.005 | | |
| Total | 22.260 | 17 | | | |
| Gidan Mangoro B/W groups | 24.388 | 5 | 4.878 | 8608 | 0.000 |
| Within groups | 0.007 | 12 | 0.001 | | |
| Total | 24.395 | 17 | | | |
| Nyanya B/W groups | 23.792 | 5 | 4.758 | 10840 | 0.000 |
| Within groups | 0.005 | 12 | 0.000 | | |
| Total | 23.797 | 17 | | | |
| Wuse B/W groups | 27.140 | 5 | 5.428 | 10180 | 0.000 |
| Within groups | 0.006 | 12 | 0.001 | | |
| Total | 27.146 | 17 | | | |
| Jabi B/W groups | 6.238 | 5 | 1.248 | 688.910 | 0.000 |
| Within groups | 0.022 | 12 | 0.002 | | |
| Total | 6.260 | 17 | | | |

**APPENDIX 25 SUMMARY OF pH CORRELATION**

Appendix 25 shows the Pearson correlation of pH level within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.905□ □ | 0.694□ □ | 0.720□ □ | 0.909□ □ |
| | Sig(2-tailed) | | 0.000 | 0.001 | 0.001 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 0.905□ □ | 1 | 0.447 | 0.529□ | 0.658□ □ |
| | Sig(2-tailed) | 0.000 | | 0.063 | 0.024 | 0.003 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.694□ □ | 0.447 | 1 | 0.831□ □ | 0.858□ □ |
| | Sig(2-tailed) | 0.001 | 0.063 | | 0.000 | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Wuse | Correlation | 0.720□ □ | 0.529□ | 0.831□ □ | 1 | 0.836□ □ |
| | Sig(2-tailed) | 0.001 | 0.024 | 0.000 | | 0.000 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | 0.909□ □ | .658□ □ | 0.858□ □ | 0.836□ □ | 1 |
| | Sig(2-tailed) | 0.000 | 0.003 | 0.000 | 0.000 | |
| | N | 18 | 18 | 18 | 18 | 18 |

□ □Correlation is significant at the 0.01 level (2-tailed)

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

**APPENDIX 26 SUMMARY OF PHOSPHATE CONCENTRATION (mg/L)**

Appendix 26 shows the results of phosphate in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 3.600 ±0.000 | 8.900 ±0.100 | 8.700 ±0.000 | 10.700 ±0.100 | 9.800 ±0.000 | 13.300 ±0.100 |
| 2 | Gidan Mangoro | 7.600 ±0.100 | 6.100 ±0.000 | 5.300 ±0.100 | 7.300 ±0.000 | 6.200 ±0.100 | 7.200 ±0.000 |
| 3 | Nyanya | 6.500 ±0.100 | 6.500 ±0.000 | 7.867 ±0.116 | 9.700 ±0.100 | 7.133 ±0.058 | 12.000 ±0.100 |
| 4 | Wuse | 8.500 ±0.100 | 5.900 ±0.000 | 9.500 ±0.100 | 9.500 ±0.000 | 8.400 ±0.100 | 9.700 ±0.000 |
| 5 | Jabi | 11.500 ±0.265 | 9.000 ±0.000 | 4.600 ±0.100 | 7.400 ±0.100 | 5.200 ±0.000 | 5.550 ±0.071 |

**APPENDIX 27 PHOSPHATE ANOVA SUMMARY**

Appendix 27 shows the summary of analysis of variance for phosphate within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 153.340 | 5 | 30.668 | 6134 | 0.000 |
| Within groups | 0.060 | 12 | 0.005 | | |
| Total | 153.400 | 17 | | | |
| Gidan Man.B/W groups | 11.845 | 5 | 2.369 | 473.800 | 0.000 |
| Within groups | 0.060 | 12 | 0.005 | | |
| Total | 11.905 | 17 | | | |
| Nyanya B/W groups | 71.032 | 5 | 14.206 | 1827 | 0.000 |
| Within groups | 0.093 | 12 | 0.008 | | |
| Total | 71.125 | 17 | | | |
| Wuse B/W groups | 30.505 | 5 | 6.101 | 1220 | 0.000 |
| Within groups | 0.060 | 12 | 0.005 | | |
| Total | 30.565 | 17 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Jabi B/W groups | 102.844 | 5 | 20.569 | 1223 | 0.000 |
| Within groups | 0.185 | 12 | 0.017 | | |
| Total | 103.029 | 17 | | | |

**APPENDIX 28 SUMMARY OF PHOSPHATE CORRELATION**

Appendix 28 shows the Pearson correlation of phosphate concentration within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | -0.107 | 0.787□ □ | 0.292 | -0.732□ □ |
| | Sig(2-tailed) | | 0.672 | 0.000 | 0.240 | 0.001 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | -0.107 | 1 | 0.342 | 0.229 | 0.565□ □ |
| | Sig(2-tailed) | 0.672 | | 0.165 | 0.361 | 0.015 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Nyanya | Correlation | 0.787□ □ | 0.342 | 1 | 0.657□ □ | -0.467 |
| | Sig(2-tailed) | 0.000 | 0.165 | | 0.003 | 0.051 |
| | N | 18 | 18 | 18 | 18 | 18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wuse | Correlation | 0.292 | 0.229 | 0.657□ □ | 1 | -0.468 |
| | Sig(2-tailed) | 0.240 | 0.361 | 0.003 | | 0.050 |
| | N | 18 | 18 | 18 | 18 | 18 |
| Jabi | Correlation | -0.732□ □ | 0.565□ | -0.467 | -0.468 | 1 |
| | Sig(2-tailed) | 0.001 | 0.015 | 0.051 | 0.050 | |
| | N | 18 | 18 | 18 | 18 | 18 |

□ □Correlation is significant at the 0.01 level (2-tailed)

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

**APPENDIX 29 SUMMARY OF POTASSIUM CONCENTRATION (mg/L)**

Appendix 29 shows the results of potassium in the various sites during the study period.

| S/NO | SITES | OCT | NOV | DEC | JAN | FEB | MAR |
|---|---|---|---|---|---|---|---|
| 1 | Orozo | 4.880 ±0.000 | 3.880 ±0.000 | 5.200 ±0.000 | 0.270 ±0.010 | 6.200 ±0.010 | 6.100 ±0.000 |
| 2 | Gidan Mangoro | 6.340 ±0.010 | 5.340 ±0.010 | 6.270 ±0.000 | 0.230 ±0.010 | 5.110 ±0.010 | 5.200 ±0.000 |
| 3 | Nyanya | 10.980 ±0.000 | 9.980 ±0.000 | 10.230 ±0.010 | 0.370 ±0.010 | 7.300 ±0.000 | 7.200 ±0.010 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | Wuse | 1.220 ±0.000 | 9.980 ±0.000 | 1.120 ±0.010 | 0.077 ±0.098 | 8.800 ±0.000 | 8.400 ±0.010 |
| 5 | Jabi | 1.220 ±0.010 | 0.220 ±0.000 | 1.150 ±0.000 | 0.350 ±0.010 | 5.900 ±0.000 | 6.000 ±0.100 |

**APPENDIX 30 POTASSIUM ANOVA SUMMARY**

Appendix 30 shows the summary of analysis of variance for potassium within and between the sites of research.

| | Sum of squares | DF | Mean Squares | F | Sig |
|---|---|---|---|---|---|
| Orozo B/W groups | 72.975 | 5 | 14.595 | 437800 | 0.000 |
| Within groups | 0.000 | 12 | 0.000 | | |
| Total | 72.975 | 17 | | | |
| Gidan Mangoro B/W groups | 77.847 | 5 | 15.569 | 233500 | 0.000 |

| | | | | | |
|---|---|---|---|---|---|
| Within groups | 0.001 | 12 | 0.000 | | |
| Total | 77.848 | 17 | | | |
| Nyanya B/W groups | 229.480 | 5 | 45.896 | 917900 | 0.000 |
| Within groups | 0.001 | 12 | 0.000 | | |
| Total | 229.481 | 17 | | | |
| Wuse B/W groups | 313.066 | 5 | 62.613 | 38200 | 0.000 |
| Within groups | 0.020 | 12 | 0.002 | | |
| Total | 313.086 | 17 | | | |
| Jabi B/W groups | 111.263 | 5 | 22.253 | 13090 | 0.000 |
| Within groups | 0.020 | 12 | 0.002 | | |
| Total | 111.283 | 17 | | | |

**APPENDIX 31 SUMMARY OF POTASSIUM CORRELATION**

Appendix 31 shows the Pearson correlation of potassium concentration within and between the sites.

| | | Orozo | Gidan Man | Nyanya | Wuse | Jabi |
|---|---|---|---|---|---|---|
| Orozo | Correlation | 1 | 0.866□ □ | 0.721□ □ | 0.505□ | 0.681□ □ |
| | Sig(2-tailed) | | 0.000 | 0.001 | 0.032 | 0.002 |
| | N | | 18 | 18 | 18 | 18 |
| Gidan Mangoro | Correlation | 0.866□ □ | 1 | 0.969□ □ | 0.311 | 0.228 |
| | Sig(2- | 0.000 | | 0.000 | 0.209 | 0.362 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | tailed) | 18 | 18 | 18 | 18 | 18 |
| | N | | | | | |
| Nyanya | Correlation | 0.721□ □ | 0.969□ □ | 1 | 0.246 | -0.003 |
| | Sig(2- | 0.001 | 0.000 | | 0.325 | 0.990 |
| | tailed) | 18 | 18 | 18 | 18 | 18 |
| | N | | | | | |
| Wuse | Correlation | 0.505□ | 0.311 | 0.246 | 1 | 0.548□ |
| | Sig(2- | 0.032 | 0.209 | 0.325 | | 0.018 |
| | tailed) | 18 | 18 | 18 | 18 | 18 |
| | N | | | | | |
| Jabi | Correlation | 0.681□ □ | 0.228 | -0.003 | 0.548□ | 1 |
| | Sig(2- | 0.002 | 0.362 | 0.990 | 0.018 | |
| | tailed) | 18 | 18 | 18 | 18 | 18 |
| | N | | | | | |

□ □Correlation is significant at the 0.01 level (2-tailed)

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

**APPENDIX 32 SUMMARIES OF TOTAL AVERAGE PARAMETERS**

Appendix 32 shows mean values (October-March) of all parameters within the research period

| Parameter | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 |
|---|---|---|---|---|---|
| Nitrate | 2.12 | 1.92 | 5.33 | 4.42 | 2.93 |
| Phosphate | 9.17 | 6.62 | 8.28 | 8.58 | 7.21 |
| Potassium | 4.42 | 4.75 | 7.68 | 4.93 | 2.47 |
| COD | 45.58 | 26.07 | 35.23 | 36.7 | 26.35 |
| BOD | 20.78 | 14.85 | 19.91 | 19.47 | 14.35 |
| TDS | 374.45 | 310.60 | 251.32 | 142.45 | 350.63 |
| Conductivity | 769.28 | 376.62 | 316.23 | 300.35 | 468.77 |
| Temperature | 26.3 | 26.18 | 25.44 | 26.02 | 26.35 |
| Algae | 363.83 | 456.33 | 215.83 | 370 | 357.50 |
| pH | 4.17 | 3.93 | 4.68 | 5.08 | 3.87 |