MACROBENTHIC INVERTEBRATES COMPOSITION IN RELATION TO SOME PHYSICO-CHEMICAL CHARACTERISTICS OF MAKWAYE AND KUBANNI RESERVOIRS IN ZARIA, NIGERIA

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DECEMBER, 2015

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BY

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(M.Sc./SCIE/46195/2012-2013)

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

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN BIOLOGY

DEPARTMENT OF BIOLOGICAL SCIENCES,
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DECEMBER, 2015

DECLARATION

I declare that the work in this thesis entitled "**Macrobenthic Invertebrates Composition in Relation to Some Physico-Chemical Characteristics of Makwaye and Kubanni Reservoirs in Zaria, Nigeria**" has been carried out by me in the Department of Biological Sciences, under the supervision of Prof. M. L. Balarabe and Dr. I. M. K. Gadzama. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at any institution.

Alhassan ABDULLAHI BALA	____________________	____________________
	Signature	Date

CERTIFICATION

This thesis titled "**Macrobenthic Invertebrates Composition in Relation to Some Physico-Chemical Characteristics of Makwaye and Kubanni Reservoirs in Zaria, Nigeria**" by Alhassan ABDULLAHI BALA meets the regulations governing the award of the degree of Master of Science (M.Sc.) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. M. L. Balarabe Chairman, Supervisory Committee Department of Biological Sciences, Ahmadu Bello University, Zaria	________________ Signature	____________ Date
DR. I. M. K. Gadzama Member, Supervisory Committee Department of Biological Sciences, Ahmadu Bello University, Zaria	________________ Signature	____________ Date
Prof. A.K. Adamu Head, Department of Biological Sciences Ahmadu Bello University, Zaria	________________ Signature	____________ Date
Prof. Kabir Bala Dean, School of Postgraduate Studies, Ahmadu Bello University, Zaria	________________ Signature	____________ Date

DEDICATION

I dedicate this work to my father and lovely mum, to my family and whosoever may find the information useful.

ACKNOWLEDGEMENTS

I am most grateful to Almighty God for making me who I am and for His guidance, protection, and keeping me in good health and strength throughout this period. Praise Be to Him for His Mercy.

My special and profound gratitude goes to my supervisors, Prof. M.L. Balarabe and Dr. I.M.K. Gadzama for the assistance and guidance they rendered during the course of the study. Indeed, they were instrumental to the success of this work through their close supervision and constructive criticisms. Forever I remain thankful and say God bless you.

I will not fail to acknowledge the technical support I enjoyed from the staff of Hydrobiology and Fishery Laboratory, Department of Biological Sciences, A.B.U., Zaria especially Mal. Abdulkadir Magaji and Mr. W. Steven for always being around during the field survey and laboratory analysis. May the Almighty God bless you all, Amin.

To my kind and lovely dad and mum also, I remain loyal and grateful for giving me the greatest gift of life - education, and for your support and advice all along. May Almighty Allah continue to grant you sound health, more happiness, wisdom and peace of mind and may Paradise be your final destination, Amin.

My entire family members, friends and the brethren all over who stood by me in prayers during the period of the study are highly acknowledged. Your role was invisible but it broke barriers and put everything in place for me. To you all, I say God Bless.

Finally, my most precious and innermost appreciation and thanks go to my closest friend and wife Rahmatu, you are truly a source of blessing and motivation to me. May the Almighty God bless our union forever, Amin.

ABSTRACT

The physico-chemical characteristics, macrobenthic invertebrate diversities and presence of some heavy metals in Makwaye and Kubanni reservoirs, Zaria, Nigeria, were investigated monthly between January to December, 2014. Physico-chemical properties were analyzed according to the standard procedures for examination of water and waste waters. Macrobenthic invertebrates were collected using an Ekman grab. Heavy metal concentrations in water samples and macrobenthic invertebrate samples were analysed using Air/Acetylene Flame Atomic Absorption Spectrophotometer. The results from Makwaye reservoir showed that temperature ranged between 20.13±0.29 – 29.90±0.92 °C, pH (6.12±0.21-7.62±0.12), Electrical conductivity (58.00±1.10 - 87.33±1.45 μS/cm), Total dissolved solids (29.20±0.67 - 41.67±2.33 ppm), Dissolve oxygen (2.02±0.01-7.33±0.38 mg/L), Biological oxygen demand (0.62±0.35 - 2.96±0.03 mg/L), Alkalinity (22.3±0.12 – 38.9±0.16 mg/L), Nitrate (13.50±0.05 - 25.00±0.03 mg/L), Phosphate (0.59±0.01 - 4.40±0.01 mg/L) and Calcium (2.01±0.07 - 4.73±0.47 mg/L) while results from Kubanni reservoir showed temperature ranged from 18.87±0.34– 28.25±0.22°C, pH (6.43±0.01 - 7.49±0.04), Electrical conductivity (60.51±0.01 – 108.00±0.58 μS/cm), Total dissolved solids (30.12±0.77 - 50.33±0.88 ppm), Dissolve oxygen (2.11±0.71 - 5.97±0.27 mg/L), Biological oxygen demand (0.37±0.22 - 2.97±0.01 mg/L), Alkalinity (22.40±0.03 – 43.3±0.15 mg/L), Nitrate (12.00±0.03 - 30.00±0.02 mg/L), Phosphate (0.59±0.01 - 3.00±0.03 mg/L) and Calcium (2.61±0.31 - 5.43±0.87 mg/L). As for the heavy metal concentrations in macrobenthic invertebrate, the results from Makwaye reservoir showed that Fe, Mn, Zn, Cd, Ni and Pb in dry season ranged from 3.30±0.45 - 22.52±3.22 mg/L, 1.31±0.03 - 5.96±0.15 mg/L, 0.25±0.01 – 6.23±1.44 mg/L, below detectable limit (BDL), 0.30±0.01 – 3.61±0.29 mg/L and BDL respectively while for wet season, the concentrations ranged from 6.91±0.84 - 29.07±2.56 mg/L, 0.23±0.04 - 3.21±0.09 mg/L, 0.14±0.01 – 0.82±0.09 mg/L, below detectable limit (BDL), 0.13±0.07 – 0.67±0.06 mg/L and BDL. Results from Kubanni reservoir showed that Fe, Mn, Zn, Cd, Mg and Ni in dry season ranged from 11.33±3.39 – 46.21±5.26 mg/L, 1.19±0.23 – 4.70±0.22 mg/L, 1.67±0.01 – 3.43±0.54 mg/L, 0.09±0.01 - 0.27±0.04 mg/L, 1.11±0.01 – 2.63±0.76 mg/L and BDL respectively while for wet season, the concentrations ranged from 7.36±1.77 – 38.62±2.76 mg/L, 1.13±0.01 – 2.73±0.66 mg/L, 1.62±0.01 – 2.92±0.55 mg/L, 0.11±0.04 - 0.30±0.11 mg/L, 1.11±0.01 – 2.76±0.03 mg/L and BDL respectively. A total of 11,723 macrobenthic invertebrates comprising three phyla, five classes, thirteen families and thirteen species were recorded in Makwaye reservoir dominated by the Phyla Mollusca (52%), Arthropoda (25%) and Annelida (23%) while in Kubanni reservoir, a total of 1868 macrobenthic invertebrates comprising three phyla, five classes, thirteen families and thirteen species were recorded. Benthic community in Kubanni reservoir was also dominated by the Phyla Mollusca (51%), Arthropoda (27%) and Annelida (22%). Shanon-Weiner diversity index of Makwaye reservoir also ranged from 2.04 - 2.42 and 1.70 - 1.97 in Kubanni reservoir. Significant variations ($P \leq 0.05$) were observed in physicochemical parameters, heavy metal concentrations, macrobenthic invertebrate abundance with seasons, with the macrobenthic invertebrate being less abundant in the rains and were more abundant in the dry season and also more abundant in Makwaye reservoir than Kubanni reservoir. Significant influence ($P \leq 0.05$) of physicochemical properties of Makwaye and Kubanni reservoirs on macrobenthic invertebrate composition was observed with BOD, DO, pH and Ca at ($P \leq 0.05$) significantly influencing the presence of macrobenthic invertebrate in Makwaye and Kubanni reservoirs. Makwaye and Kubanni reservoirs have similar macrobenthic invertebrate species. However, species diversity is higher in Makwaye reservoir with *Chironomus* sp having the highest percentage composition in both reservoirs. Various management strategies such as periodic, repetitive limnological measurements should be carried out on the reservoirs to monitor and track the trend of changes of its water quality and quantity, productivity, periodicity and biodiversity.

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LIST OF ABBREVIATIONS AND SYMBOLS

^oC = Degree centigrade

% = Percent

sec = Seconds

cm = Centimetre

mg = Milligram

Kg = Kilogram

ml = Millilitre

dL = Decilitre

L = Litre

Mag = Magnification

DO = Dissolved oxygen

BOD = Biological oxygen demand

BDL = Below Detectable Limit

pH = Potential of hydrogen

EC = Electrical conductivity

TEMP = Temperature

ALK = Alkalinity

Ca = Calcium

NO_3-N= Nitrate nitrogen

PO_4- P= Phosphate phosphorus

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to Study

The abundance of benthic fauna mainly depends on physical and chemical properties of the substratum (Sharma *et al*., 2000). Macrobenthic invertebrate communities are known to respond to changes in the quality of water or habitat (Adeyemo *et al*., 2008). Because of their extended residency period in specific habitats and presence or absence of particular benthic species in a particular environment, these organisms can be used as bio-indicators of specific environment and habitat conditions (Sharma *et al*., 2000).

Macrobenthic community plays significant roles in aquatic ecosystems as primary and secondary consumers in biological assessments. A detailed and perfect knowledge of the bottom fauna is not merely important for the purpose of productivity but is also helpful in seeing the diversity of the habitat (Atobatele *et al*., 2005). Sustaining biological diversity is a priority for nature conservation in terrestrial, maritime, and freshwater environments. Thus, the assessment of biological diversity in freshwaters plays important role as the basis for protection of nature (Brooks *et al*., 2006).

Diversity, distribution and abundance of macrobenthos depend on the characteristics of their environment such as pollution condition, organic matter content, soil texture and sediment. Because they vary in their adjustment to environmental conditions and their tolerance or sensitivity to contamination, the parameters of benthic animals such as their community structure, dominant species, variety and abundance can be utilized to reflect environmental quality (Gao, 2011).

Macrobenthic invertebrates are organisms in the aquatic environment without backbone that live on or inside the deposit at the bottom of a water body. These organisms play important roles in aquatic community, which include mineralization, mixing of sediments, flux of oxygen into sediments, cycling of organic matter and in assessing the quality of inland water. Macrobenthic invertebrate species are differentially sensitive to biotic and abiotic factors in their environment (Adeyemo *et al*., 2008). The distribution of these macroinvertebrates fauna is determined by several factors such as the physical nature of the substratum, depth, and nutritive content, degree of stability and oxygen content of the water body (Sharma *et al*., 2013).

Macrobenthic invertebrates have been used as indicators of environmental conditions especially in evaluating the impacts of specific pollutants in the aquatic environment because of their limited mobility, long life period, sensitivity to changes in their environment and tolerance of some to contamination (Sharma *et al*., 2013; Flores and Zafaralla, 2012; Tampus *et al*., 2012; Superales and Zafaralla, 2008; Barbosa *et al*., 2001). Their community characteristics such as diversity, richness and abundance, are often used as indicators of the degree of pollution of water bodies, to supplement and give more information on physicochemical properties (Flores and Zafaralla, 2012; Edward and Ugwumba, 2011; Superales and Zafaralla, 2008; Arimoro *et al*., 2007).

Macroinvertebrate communities can be described in a variety of ways such as; their species composition, their trophic organization, i.e. the number of species in different trophic groups, and structure and functioning of their food-webs. Understanding the factors that control ecosystem structure and function is necessary if satisfactory conservation and management practices are to be implemented (Allan, 1995). A key to this understanding is an appreciation of the environmental factors that operate at different spatial scales such as geographical regions, catchments, single streams or segments of streams, beaches and microhabitats (Minshall and Robinson, 1998).

The biological composition and richness of most of the earth's major ecosystems are changing as a result of harvesting, habitat destruction, pollution, exotic invasions, and climate change. Stimulated in part by these transformations, theoretical and empirical research in ecology has turned actively to the relationship between biodiversity and environment (Charvet *et al*., 1998).

Living organisms vary at every level of the phylogenetic hierarchy from individual genes through higher taxa, and ecological assemblages vary in composition from guilds or functional groups, through communities, to landscapes (Delong and Brusven, 1998). This variation is of interest in understanding ecosystem functioning since it provides a proxy for variation in traits important to processes such as growth, production, and resource utilization (Delong and Brusven, 1998; Barbour *et al*., 1999).

Conceptually, diversity can be partitioned into variation in identity (composition) and number (or richness) of elements, whether those elements are species, genotypes, or other entities (Odum, 1971). It has long been recognized that the identities of species in a system is strongly influenced by environmental variables, particularly the types of keystone and dominant species, and their ecological roles are determined by prevailing environmental variables (Maiti, 2004). Whether and how changing environmental factors influences biodiversity obviously depend on which taxa are lost and which are gained via invasion (Allan, 1995) Studies in benthic ecology have shown that the abundance and diversity of the existing biocoenosis is a reflection of the prevailing environmental condition (Leveque *et al.*, 2005). Understanding the specific roles of environmental variables in biotic assemblages and community structure has been the primary focus of recent research in ecology.

Macroinvertebrate species exhibit a wide variation of response to disturbances and have been extensively monitored in water bodies to evaluate water quality and complement physico-chemical surveys (Allan, 1995). Seasonal samples of the macroinvertebrate community can indicate the effects of pollutant sources which may not have been detected by either intermittent physico-chemical sampling or continuous monitoring of a restricted range of parameters. The impacts of urban discharges on receiving water are conventionally stated in terms of hydraulic and hydrochemical criteria and the ecological dimension of environmental impact has been overlooked. The distribution of aquatic organisms is the result of interactions among their ecological role, the physical conditions that characterize the habitat, and food availability. Thus, the community structure of macrobenthic invertebrates depends on a number of factors, namely water quality, type of substratum, particle size of sediment, water flow, sediment organic matter availability and oxygen concentration (Cummins, 1995).

Nearly all macrobenthic invertebrates fall into six major groups (Leveque *et al.*, 2005). These are:

1. Flatworms (Planarians) – Small, flat, soft-bodied worms which often have a triangular or arrowhead-shaped head. As a group, these are called Tubellaria.

2. Segmented Worms – This phylum includes aquatic worms and leeches. Some oligochaetes that look like small earthworms one could find in ones garden, although they are usually smaller, thinner, and more delicate. Leeches are larger, flattened, and usually have a suction pad on at least one end of their body.
3. Molluscs – This phylum includes snails and clams/mussels. Clams and mussels belong to the class Pelecypoda. Snails belong to the class Gastropoda. Pollution tolerant snails are identified by their opening spiraling up from the left if one looks at the shell with the tip pointed up. A more pollution sensitive group is the right spiral snail, which are identified by their opening spiraling up from the right if one looks at the shell with the tip pointed up.
4. Crustaceans – These organisms have more than six legs, two pairs of antennae, and an exoskeleton composed of chitin. This combination of characteristics separates crustaceans from other groups. The classes of this phylum according to Leveque *et al*. (2005) are:
    i. Crayfish (Decapoda) that look like small lobsters and have ten legs, with the front two bearing large claws.
    ii. Scuds (Amphipoda) are laterally compressed (body is higher than it is wide), white to pale yellow in color, and good swimmers. They are also called “freshwater shrimp” (although there is no relation); scuds will be on their sides if taken out of the water because of their body shape.
    iii. Sowbugs (Isopoda) look similar to scuds except they are flat (body is wider than it is high) and gray to brown in color.

5. Arachnids - The water mite is the member of this class. They have 8 legs, no antenna, and a round one segment body.
6. Insects – Many have three pairs of "true" legs, and those without legs will usually have fleshy bumps called prolegs.

1.2 Statement of the Research Problem

The biological composition and richness of most of the earth's major aquatic ecosystems are changing as a result of harvesting, habitat destruction, pollution, exotic invasions, and climate change (Charvet *et al*., 1998).

Increase farming activities, dumping of refuse and other anthropogenic activities in the catchment of Makwaye and Kubanni reservoirs is on the increase and could lead to changes in physico-chemical characteristics and biota of the reservoirs.

The rate of water pollution of all types has increased much more as compared to other fields of pollution due to discharge of all sorts of obnoxious matter into it (Akhtar *et al*., 2005). When pollutants such as heavy metals enter water bodies they change water quality, bind to sediment and accumulate in aquatic biota causing anemia, disturbance of physiological functions and mortalities of fish and other aquatic organisms (Post, 1983).

1.3 Justification

Knowledge on macrobenthic invertebrate diversity is of great environmental concern and serves as an indicator to know the extent of pollution of the water bodies and prevent extinction in aquatic environment as a result of pollution (Farkas *et al*., 2001). The interactive effects of changing diversity of aquatic organisms and environmental variability in Makwaye and Kubanni reservoirs are poorly understood but are likely to be important under realistic scenarios of functional diversity changes. This underscores the importance of understanding functional environment interrelationship at the ecosystem level and the variability in abundances of functional groups.

This study evaluated the pollution level of the aquatic ecosystem of Makwaye and Kubanni reservoirs by determining the fauna diversity and heavy metal concentrations in the reservoirs as information on macrobenthic invertebrate diversity has been a useful tool to know the extent of pollution and prevention of species extinction in an aquatic environment as it is strongly influenced by environmental variables (Abolude, 2007; Allan, 1995).

1.4 Aim and Objectives

The aim of this work was to evaluate macrobenthic invertebrate composition and assessment of some physico-chemical characteristics in Makwaye and Kubanni reservoirs, Zaria, Nigeria.

The specific objectives of the study were:

i. To determine the mean monthly and seasonal variations in physico-chemical parameters of Makwaye and Kubanni reservoirs.
ii. To assess the seasonal macrobenthic invertebrate species abundance and diversity of Makwaye and Kubanni reservoirs.
iii. To determine the influence of physico-chemical parameters on the composition of macrobenthic invertebrates in Makwaye and Kubanni reservoirs.
iv. To determine the heavy metal concentrations in some of the macrobenthic invertebrates of Makwaye and Kubanni reservoirs.

1.5 Hypotheses

i. There is no significant difference in the mean monthly and seasonal variations in physico-chemical characteristics between Makwaye and Kubanni reservoirs.

ii. There is no significant difference in seasonal abundance and diversity of macrobenthic invertebrate in Makwaye and Kubanni reservoirs.

iii. There is no significant influence of physico-chemical parameters on macrobenthic invertebrate composition of Makwaye and Kubanni reservoirs.

iv. There is no significant difference in heavy metal concentrations in macrobenthic invertebrates of Makwaye and Kubanni reservoirs.

CHAPTER TWO

3.0 LITERATURE REVIEW

3.1 Macrobenthic Invertebrates in Aquatic Ecosystem

Benthic macro fauna are those organisms that live on or inside the deposit at the bottom of a water body (Idowu and Ugwumba, 2005). In fresh water ecosystem, they include several species of organisms, which cut across different phyla including annelids, coelenterates, molluscs, arthropods and chordates. These organisms play vital roles in the circulation of nutrients in aquatic ecosystems. They constitute the link between the unavailable nutrients in detritus and useful protein materials for fish and shellfish (Sharma *et al*., 2013).

Most benthic organisms feed on debris that settle on the bottom of the water and in turn serve as food for a wide range of fishes (Idowu and Ugwumba, 2005). They also accelerate the breakdown of decaying organic matter into simpler inorganic forms such as phosphates and nitrates (Gallep *et al.,* 1978). All forms of aquatic plants, which are the first link of several food chains existing in aquatic environment, can utilize the nutrients. These organisms therefore form a major link in the food chain as most estuarine and marine fishes, birds and mammals depend directly or indirectly on the benthos for their food supply (Barnes and Hughes, 1988).

Macrobenthic invertebrates in water bodies are of value as long term indicators of water quality and can provide signs of impending water pollution and habitat fragmentation (Ogbeibu and Oribhabor, 2002). Macrobenthic invertebrates show high variability and are able to integrate the effects of short term environmental variations which have been used in characterizing rivers and streams in many parts of the world (George et al., 2009). Adakole and Anunne (2003) reported that organic pollution of Bindare stream caused a decrease in macrobenthic invertebrates' species richness. Environmental modifications or pollution can alter macro invertebrate communities (Waters and Rivers Commission, 2010).

Macroinvertebrate communities can be described in a variety of ways such as (1) their species composition, (2) their trophic organization, i.e. the number of species in different trophic groups, and (3) the structure and functioning of their food-webs, i.e. the patterns of flow of energy and matter through the ecosystem. Understanding the factors that control ecosystem structure and function is necessary if satisfactory conservation and management practices are to be implemented. A key to this understanding is an appreciation of the environmental factors that operate at different spatial scales such as geographical regions, catchments, single streams or segments of streams, reaches and microhabitats (Minshall and Robinson, 1998).

At a broader scale, previous biogeographical events, geology, environmental conditions and associated vegetation are thought to be the main determinants of stream habitat characteristics, and macroinvertebrate assemblages often show correspondence to such large-scale factors across ecoregions or other regional delineations (Heino *et al*., 2003). Other studies have also shown that, on the contrary, catchment scale characteristics such as weather condition, land use and water chemistry are more useful than regional factors in predicting stream macroinvertebrate assemblage structure (Hawkins and Vinson, 2000). On a more local scale, differences in specific habitat characteristics for example riparian conditions, and local biotic interactions have been found to contribute substantially to variations in macroinvertebrates assemblages within a stream. Furthermore, both biotic and abiotic factors at the site where the animals reside are important in defining the niche space of individual species (Minshall and Robinson, 1998). Water temperature, flow and substratum are amongst the most important abiotic factors while food resources, competition and predation are important biotic factors, especially at the microhabitat scale (Lancaster *et al*., 1991).

Habitat heterogeneity is essential for species richness and assemblage structure, and it occurs across both spatial and temporal scales among, along and within streams (Minshall and Robinson, 1998). Physical characteristics such as stream size, width, depth and distance from source, slope, velocity and substratum are important variables that explain most observed variations in species data. Stream size, which generally increases with distance from the source, presumably influences macroinvertebrates through an increase in habitat diversity. Velocity directly affects the size of particles in the substrate and together with slope determines the diversity of microhabitats available for invertebrate colonization (Malmquivst, 2002). Chemical factors that explain most observed variations in species composition in a water body include dissolved oxygen, biological oxygen demand, alkalinity, pH, nitrate, phosphate, sulphate, hardness and nutrients (Harper, 1992).

2.2 Ecological Diversity Indices

It is common practice among ecologists to complete the description of a community by one or two numbers expressing the "diversity" or the "evenness" of the community. For this purpose a bewildering diversity of indices have been proposed and a small subset of those have become popular and are now widely used, often without much statistical consideration or theoretical justification (Carlo *et al*., 1998).

Diversity indices are mathematical functions that combine richness and evenness in a single measure, although usually not explicitly. There are many others, the most commonly used diversity indices in ecology are Shannon diversity, Simpson diversity, Evenness or equitability index, Mclntosh index (MI), Odum's index, Goodnight and Whitley's index, Kothe's species deficit index, Berger-Parkar dominance index or community dominance index (CDI), Similarity index, Autotrophic index (AI) and Margalef’s diversity indices (Chao, 2004).

2.4 Functions of Reservoirs

Reservoirs are normally constructed for a function which has a fundamental influence upon their morphology and limnology. Reservoirs for a particular function are built as a result of societal demand for drinking water supply, irrigation, hydroelectric power generation, industrial water supply, flood protection, fish production and recreation. With time, however, most reservoirs have had secondary functions superimposed upon them such as navigation, sediment control, insect and water borne disease control, industrial processing and cooling, tourism and urban run-off control (Tundisi and Matsumura-Tundisi, 2003). Other benefits reservoirs offer include conservation and enhancement of local environments and landscapes. Mustapha (2005) discussed how reservoirs could help in the attainment of millennium development goals (MDGs) by 2015 in terms of alleviating poverty, enhance food security. Reservoirs have facilitated industrial, economic and societal growths in many developing countries such as Nigeria. But, for most of these functions, maintenance of good water quality is of utmost importance. Moss (1980) noted that multiple functions in tropical reservoirs may create conditions that facilitate the dispersal of water borne diseases and their vectors thus exacerbating health problems among end users of the reservoirs.

Obstructing the course of rivers by dams to create expanses of lentic water, as well as, excavating canals for the purpose of navigation and irrigation are two human activities that possibly co-originated with agriculture. Today, almost every major river in the world has become equipped with series of high dams, behind which lie major impoundments. Only few river systems all over the world have escaped impoundment (Miranda, 2001).

Reservoirs play important economic, ecological and social roles, by interfering quantitatively and qualitatively with hydrographic networks and producing many changes in water shed and river systems. Reservoir ecosystems are influenced by tributaries, riparian zone and watersheds (Miranda, 2007). The protection, recovery and optimization of operations of reservoirs for multiple uses can only be achieved if there is a sound ecological data, based on long term observations, experimental studies and theoretical approaches.

The impoundment of water through dam construction has strongly interfered with river functioning and hydrogeological cycles thus producing many changes in the cycles and biodiversity of the affected rivers. A reservoir will be biologically more productive than the original river provided the nutrients that accumulate in it are adequately circulated. Miranda (2001) observed that, impoundment of river will generally have negative impact on biodiversity. The impact of reservoir construction on the main river include alterations in the natural flow regimes with subsequent changes in current speed, flow volume, water temperature, oxygen concentration, obstruction of fish breeding and migrations (Dudgeon, 2003).

Dam construction by regulating river flow may also have cascading effects on downstream lakes. Other notable impacts include a reduction in average body sizes of the species that constitute the fish community of the reservoir and this could have an important effect on the fisheries of the reservoir. The virtual disappearance of large bodied species, will not only influence yield, but also fishing methods, fish marketing and commercial value of the fishes. A shift in species composition and abundance, with extreme proliferation of some species and reduction or elimination of others as noticed in Kainji Lake where riverine species were replaced by lacustrine species are some of the other unavoidable effects of impoundment (Dudgeon, 2003). Balogun (1986) reported the reduction in the numbers of Citharinids and the dominance of Cichlids after the closure of Kainji Lake.

Other variables that influence this impact include presence of other reservoirs in the water shed, design and operational characteristics of the reservoir, use of the water shed (e.g. for irrigation, fisheries, urbanization) and the geology of the area. Riverine fish, suffer considerable impacts from damming because their established pathways connected to the reproductive cycles are disrupted. For instance, the construction of Lake Kainji influenced the fish community in the lake as well as in the reservoir downstream as only species able to adjust to lacustrine conditions became dominant (Mustapha, 2006;

Welcomme, 1986). The positive and negative impacts of large dam construction have also been highlighted by Tundisi *et al.* (2002).

Although reservoir are built by man and for man, activities in the catchments area before and after the building of the reservoir affects its subsequent primary function, the downstream river as well as its biodiversity. The problems that could arise are eutrophication due to run-offs from excessive application of fertilizers, siltation from catchments land erosion, and excessive loading of organic and inorganic particles from domestic and industrial effluents. Reservoirs attract human settlement to exploit opportunities such as fisheries, irrigation and recreation offered by the water body (Mustapha, 2006). However, the migration of large numbers of people increase the level of human activities in the water shed and intensifies human pressures upon the reservoir. Typical example is Moro reservoir, in Ilorin, Nigeria, where human activities have greatly modified the water quality and the biodiversity of the reservoir (Mustapha, 2006). Coincident with expanding demand for water quantity should be concerns also over the quality.

2.4 Physico-chemical Parameters of Water Bodies

The study of the physico-chemical properties of water which is a fundamental part of limnology have been used in assessing water quality (Djukic *et al.*, 1994), biological productivity and trophic status (Mustapha, 2003), as well as composition, distribution and abundance of biotic organisms (Mustapha and Omotosho, 2006). Physico-chemical study could help in understanding the structure, function and management of reservoir in relation to its biotic components and production. Physical and chemical features in reservoirs are governed by the prevailing hydrologic and geomorphic processes, while the local geology determines the water chemistry.

Water is known to contain a large number of chemical elements which enter into chemical complexes in aquatic ecosystems (Adakole and Abolude, 2012). The chemical elements found in water are known to have effects on biological processes that lead to interconversion and flow of energy, nutrient cycling, production of organic materials and ultimately production of aquatic resources most especially fishes. Physical factors such as temperature, transparency, water velocity or current have also been known to interplay with the chemical factors in reservoirs to produce a sustainable ecosystem rich in phytoplankton species (the primary producers), zooplanktons and diverse fish populations (Adakole and Abolude, 2012).

2.4.1 Temperature

Temperature, which is dependent on local climate and geomorphic conditions, is an important physical factor that influences the distribution of aquatic organisms. Water temperature comes from solar radiation by direct absorption. Many biological processes in water are triggered by temperature. Temperature preferences vary among species but all species can tolerate slow seasonal changes better than rapid changes. Dominance of various phytoplankton groups have been noted, for example, between 20 – 25°C diatoms predominate and green algae predominate at 35°C (Berman and Steinman,1998). Temperature could affect zooplankton production directly through physiological process as zooplankton metabolism is highly temperature-dependent in addition to the indirect effect via primary production (Bottrell *et al.* 1976). Temperature also influences fish by controlling reproductive cycles, feeding and metabolic rates, swimming performance, growth rates and distribution (Coutant, 1975). Jackson and Ye (2000) reported that temperature could influence fish stock structure through food production. An inverse relationship between temperature and dissolved oxygen also exist. As temperature increases, dissolved oxygen decreases (Jackson and Ye, 2000). Temperature is also known to control metabolism, physiology and behaviour of aquatic organisms.

2.4.2 Dissolved oxygen (DO)

Dissolved oxygen is an essential chemical ion needed for body metabolism of aquatic organisms. It also provides information about the biological and biochemical processes in water. Dissolved oxygen level of 5mg/L or greater has been reported to support healthy growth of most fishes (Hanna, 2003). Brinley (1974) indicated that dissolved oxygen value of 3mg/L is too low to maintain a good fish population in reservoirs. The absence of oxygen in water permits anaerobic decay of organic matter and production of toxic materials and gases such as hydrogen sulphide. Low levels of dissolved oxygen are indicative of serious pollution. Oxygen deficits have been used as indices of trophic status of lakes (Henry, 1992).

2.4.3 Phosphorous

Phosphorous is the least abundant of all the nutrients in water and most limiting in primary production (Schnidler, 1971). The amount found in water is generally not more than 0.1ppm (Renn, 1970) except the water has become polluted from waste water sources or excessive run off from agricultural lands. According to Rast *et al.* (1989), increase in nitrogen or phosphorous, one or other which tend to limit productivity will lead to eutrophication. Nutrients lead to increase in algal growth, and when the algae die and decompose, oxygen is used leading to anoxia, and fish kill. Such eutrophied water has unpleasant taste and odour. Models based on phosphorous loading data have been used in the past to predict the trophic status of reservoirs (Dillon, 1975). Hanson and Leggett (1982) have used total phosphorous concentration to develop predictive models of fish yield and or biomass of lacustrine water bodies.

2.4.4 Hardness

Hardness in water is mainly due to the presence of calcium and magnesium ions (Boyd, 1979). Knowledge of the hardness of water is of importance in industrial water use since it is the chief source of scale and corrosion in heat exchange equipment, boilers, pipelines, etc. From the domestic point, hard water consumes excessive quantity of soap forming curds and depositing a film on hair, fabrics and glassware. The hardness scale of Hanna (2003) categorized water into very soft (0 - 70mg/L), soft (71 - 150mg/L), slightly hard (151 - 250mg/L), moderately hard (251 - 320mg/L), hard (321 - 420mg/L) and very hard (421mg/L and above). Calcium and magnesium ions have been reported to be the major ions used by rotifers, crustaceans, shelled animals for their shell and aquatic macrophytes for chlorophyll formation. Calcium is used by green algae as micronutrients. The distribution of certain algae has been correlated with differing concentrations of calcium (Wetzel, 2001). Only very few group of freshwater animals exist in which distribution of some species has not been related to calcium concentration (Horne and Goldman, 1994).

2.4.5 Alkalinity

Alkalinity or buffering capacity of water is due primarily to the presence of bicarbonate, carbonate and hydroxide ions. Silicates and phosphate may also contribute to the buffering capacity of water. Alkalinity is important for fish and other aquatic life because it buffers pH changes that occur naturally due to photosynthesis. Positive correlations have been established between alkalinity and fish production (Carlander, 1955). The alkalinity of freshwater under natural condition should not be less than 20ppm (USEPA, 1976). Waters with low alkalinity often have pH of 6 to 7.5. Waters with extreme high total alkalinity may have pH values too high for fish production. Waters dominated by bicarbonate ions usually have low or no phenolphthalein alkalinity (Campbell and Wildberger, 2001).

2.4.6 Hydrogen ion concentration (pH)

Hydrogen ion concentration (pH) is an important factor in the physical, chemical and biological systems of natural waters. The pH of water is related to a large number of dissolved substances and is therefore a good indicator of water quality. Species richness tends to decline at either extreme, from broad optimum of 6-8.5 (Kalff, 2003). High acidic and extremely high alkaline waters have been reported to retard growth and reproduction of fishes and can lead to stress. Most natural waters have a pH of 4-9 but commonly above 7 because of alkalinity (APHA, 1998). Tepe *et al.* (2005) reported a range of pH values in Hatay-harbiye spring to be between 5 and 10, with greater frequency of values falling between 6.5 and 9. Changes in water pH can affect aquatic life by changing other aspects of the water chemistry. Waters with pH 6.5- 9 are considered best for fish production (Boyd and Lichtkoppler, 1979), while pH below 3 and above 11 was reported to be lethal to all species of fish (Campbell and Wildberger, 2001). Low pH has also been shown to influence the toxicity of trace metals in water (Kemdirim, 1987) and this could negatively affect fishes and other aquatic life.

2.4.7 Sulphate

Sulphate is the third most abundant ion in freshwater (Renn, 1970). It is not toxic but has to be kept below a certain threshold which USEPA (1976) in accordance with safe drinking water act has established to be 400-600 mg/L of magnesium sulphate and 250-800 mg/L of calcium sulphate (Hach, 2003). Sulphate may either be beneficial or detrimental in domestic water supply. Higher concentration in water can cause unpleasant taste to the water and contribute significantly to the hardness of the water. Sulphate has also been implicated in the eutrophication of reservoirs (Armengol *et al*., 1991).

2.4.8 Total dissolved solids (TDS)

Total dissolved solids (TDS) are a measure of the total concentration of dissolved substances (ions) in natural waters and are closely related to the specific conductance of the water. Total dissolved solids give a good representation of the fertility of the water body. The TDS apparently determine the overall productivity of any aquatic system (Melack, 1976). TDS often influence aquatic biological communities through osmotic diffusion mechanisms, changes in the supply of nutrients and other important materials (Reid and Wood, 1976). Large quantity of TDS can render freshwater unsuitable for domestic and industrial use, as well as for fish production. High TDS in drinking water could cause unpleasant taste, hardness, coloured water, stains, salty taste and may render the water unfit for irrigation. TDS of less than 500ppm is reported as desirable in drinking water (Moore, 1989). TDS has been used to estimate fish production in lakes and reservoirs. Ryder (1965) developed the morpho edaphic index (MEI) as the ratio of total dissolved solids to mean depth to calculate the potential fish yield in lakes. Jenkins (1982) successfully applied it to reservoirs, while Reiger *et al.* (1982), Henderson and Welcomme, (1974) and Adeniji (1991) have all applied this method in African lakes and reservoirs. Relationships between TDS and temperature were used by Schlesinger and Reiger *et al*. (1982) to estimate MEI.

2.4.9 Electrical conductivity (EC)

Conductivity is basically a measurement of the amount of dissolved salts in water and is inversely proportional to resistance. It is the ability of water to conduct electric current. The conductivity of most fresh water is low (Golterman, 1978). The specific conductance of water in bicarbonate dominated reservoirs is closely proportional to the concentration of major cations. In aqueous solution, conductivity is directly proportional to the concentrations of total dissolved solids, the higher the concentration of solids, the greater the conductivity (Hanna, 2003). Conductivity can also be used to obtain the value of hardness of water (Egborge, 1977). Egborge (1977) reported that conductivity contributed to the productivity of water body. Conductivity influences composition, abundance and distribution of biotic organisms (Mustapha, 2006). Electrical conductivity is an index of chemical pollution; it is also useful in identifying various sources of water responsible for flow at a particular time. According to Brook (2002), waters with very high conductivity are not potable.

2.4.10 Nitrate

In the aquatic environment, the most common ionic (reactive) forms of inorganic nitrogen are ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). These ions may be present naturally in aquatic ecosystems as a result of atmospheric deposition, surface runoff, dissolution of nitrogen-rich geological deposits, N_2 fixation by certain prokaryotes (cyanobacteria particularly) and biological degradation of organic matter (Rabalais, 2002). Ammonium tends to be oxidized to nitrate in a two-step process (NH_4^+ to NO_2^- to NO_3^-) by aerobic chemoautotrophic bacteria (Nitrosomonas and Nitrobacter primarily), even if levels of dissolved oxygen decline to a value as low as 1.0 mg O_2/L (Wetzel, 2001). In consequence, concentrations of nitrate in freshwater and marine ecosystems usually are higher than those of ammonium and nitrite (Rabalais, 2002). Nitrate (but also ammonium and nitrite) may however be removed from water by aquatic plants, algae and bacteria which assimilate it as a source of nitrogen (Wetzel, 2001). Furthermore, when concentrations of dissolved oxygen decrease to minimum values, facultative anaerobic bacteria (e.g., *Pseudomonas*, *Micrococcus*, *Bacillus*, *Achromobacter*) can utilize nitrate as a terminal acceptor of electrons, resulting in the ultimate formation of N_2 (Wetzel, 2001).

2.4.11 Biological oxygen demand (BOD)

Biological oxygen demand is not a precise quantitative test, although it is widely used as an indication of the organic quality of water (Clair *et al*., 2003). The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20°C and is often used as a robust surrogate of the degree of organic pollution of water.

Biological oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

Biological oxygen demand is the amount of oxygen required for microbial metabolism of organic compounds in water. This demand occurs over some variable period of time depending on temperature, nutrient concentrations, and the enzymes available to indigenous microbial populations. The amount of oxygen required to completely oxidize the organic compounds to carbon dioxide and water through generations of microbial growth, death, decay, and cannibalism is total biological oxygen demand (total BOD). Total BOD is of more significance to food webs than to water quality. Dissolved oxygen depletion is most likely to become evident during the initial aquatic microbial population explosion in response to a large amount of organic material. If the microbial population deoxygenates the water, however, that lack of oxygen imposes a limit on population growth of aerobic aquatic microbial organisms resulting in a longer term food surplus and oxygen deficit (Clair *et al*., 2003).

2.5 Heavy Metals in Aquatic Ecosystem

Heavy metals are regarded as serious pollutants in the aquatic environment because of their environmental persistence and tendency to concentrate in aquatic organisms. High concentrations of heavy metals in water, sediments, and organisms may result in serious ecological consequences. Most heavy metals released into the environment enter the aquatic phase as a result of direct input, atmospheric deposition and erosion due to rain (Veena *et al*., 1997). Adakole and Abolude (2012) observed that global concern about heavy metals in the environment stems from their persistence, toxicity and bioaccumulation in the trophic chain. Therefore, aquatic animals are often exposed to elevated levels of heavy metals (Abolude, 2009; Farkas *et al*., 2001).

Contamination of aquatic ecosystems by heavy metals has been observed in water, sediment and organisms. Heavy metals may be directly absorbed by organisms but are also transferred from lower to higher trophic levels of the food chain. The high accumulation of heavy metals in these components can result in serious ecological changes. One of the most serious results of their persistence is the biological amplification of metal in the food chain. Metals transferred through aquatic food chains and webs to fish, humans and other animals are of more environmental concern to human health (Farkas *et al*., 2001). Measuring heavy metals in aquatic organisms may be a bioindicator of their impact on organism and ecosystem health, but a true evaluation of the damage inflicted by heavy metals should come from comprehensive biomarker studies. Researches over time have focused on various species and various biomarkers to determine the amount of heavy metal toxicity in aquatic environments (Balarabe *et al*., 2004).

The pollution of the aquatic environment with heavy metals has become a worldwide problem during recent years because they are indestructible and most of them have toxic effects on organisms (MacFarlane and Burchett, 2000). Among environmental pollutants, heavy metals are of particular concern due to their potential toxic effect and ability to bioaccumulate in aquatic ecosystems (Censi *et al*., 2006). The presence of heavy metals in aquatic ecosystems is the result of two main sources of contamination: natural process and or natural occurring deposit and anthropogenic activities. The main sources of heavy metal pollution to life form are invariably the result of anthropogenic activities (Kennish, 1992). In the fresh water environment, heavy metals are potentially accumulated in sediments and marine organisms and subsequently transferred to man through food chain. Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota (Cammusso *et al*., 1995).

Gadzama *et al*. (2013) reported 19 metals that were present in the analysed soft tissues of the three species of bivalves (*Anodonta anatine, Anodonta marginata* and *Anodonta implicate*) studied in Kubanni reservoir. The elements vary in concentrations in the three bivalve species, with some of the elements falling below detection limit. The metals reported were Mn, Na, K, As, La, Sm, U, Sc, Cr, Fe, Co, Zn, Ba, Eu, Lu, Yb, Th, Sb and Rb.

Amman *et al.* (2002) is of the view that anthropogenic activities like mining, final disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates from different industries, such as tannery, steel plants, battery, industries, thermal power plants and the indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture are some of the main causes of metal pollution in the aquatic ecosystem. Although some metals like Cu, Fe, Mn, Ni, Zn and Se are essential micronutrients for life processes in plants and animals, others like Cd, Cr and Pb have no physiological activity and have been proven detrimental beyond certain limit (Abolude, 2007). Trace elements constitute natural component of the earth crust and are not biodegradable, hence persist in the environment. Heavy metals may come from natural sources, leached from rocks and soils according to their geochemical mobility or come from anthropogenic sources as a result of human land occupation and industrial pollution (Abolude *et al.*, 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Makwaye reservoir is located on 11□ 11□ N and 7□ 37□ E. Makwayereservoir is one of the sources of water for communities around Ahmadu Bello University Farm Centre and the water is used for domestic, agricultural and production of valuable fish protein (Fig. 3.1).

Kubanni reservoir is located on 11□ 08□ N and 7□ 39□ E south of Ahmadu Bello University Zaria Samaru campus, with an elevation of 2111 ft above sea level and reservoir area of 57km^2 and mean depth of 6 meters (Fig. 3.2). The reservoir receives runoff and domestic waste waters from within the campus, nearby irrigation farms and Samaru community. The reservoir's two major tributaries are the Kampagi and Samaru stream. Kampagi stream, which originates from a rural settlement, has a seasonal flow whereas Samaru stream that originates from a semi-urban settlement has an all-year round flow due to its sustenance by urban runoffs and seepages (Abolude, 2007).
Kubanni River which empties into the lake is known to play a major role in the disposal of industrial wastes accumulated from industries cited in Zaria (Abolude *et al*., 2009).

3.2 Sample Collection

3.2.1 Study design

Samplings were done covering rainy and dry season in three stations each for the two study areas based on accessibility, nearness to settlement and their suitability for future studies.

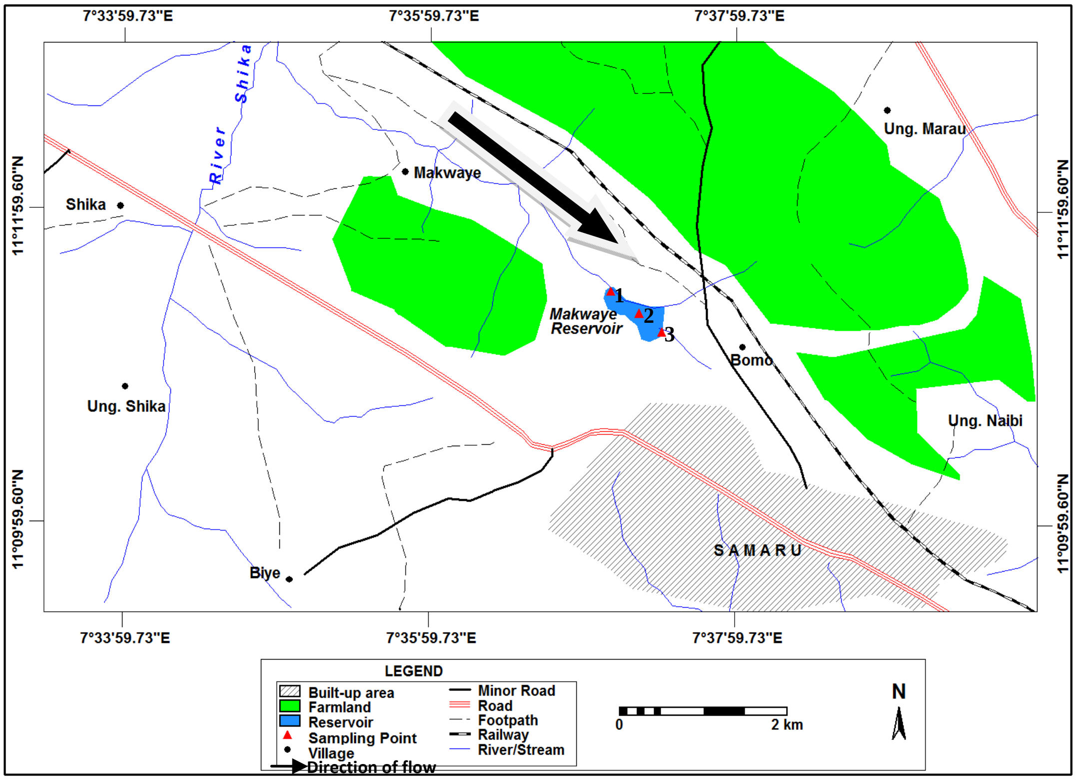

Fig. 3.1: Map of Makwaye reservoir showing three sampling stations

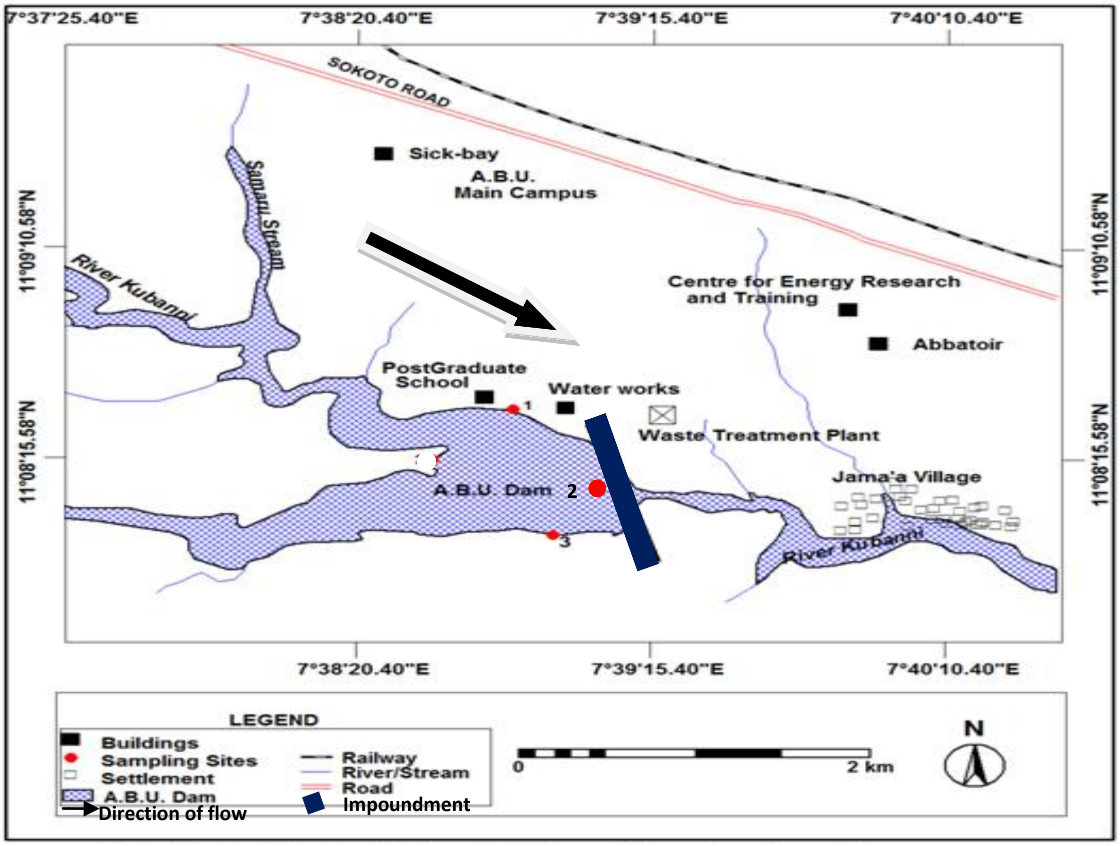

Fig. 3.2: Map of Kubanni reservoir showing three sampling stations

3.2.2 Collection of water samples for physicochemical parameters

In situ determination of surface water temperature (°C), pH, EC and TDS were carried out using HANNA portable pH/EC/TDS/ TEMPERATURE combined water proof tester model HI 98129. Water samples for the determination of dissolved oxygen (DO), and biochemical oxygen demand (BOD) were collected twice in a month between January 2014 to December 2014 in transparent and amber coloured 250ml reagent bottles. The samples was treated on the field according to the procedures described in APHA (2005) and taken to the laboratory for further analysis. Electrical conductivity was measured in µS/cm, temperature in degree Celsius (°C) while total dissolved solids values measured in mg/L were derived by multiplying the conductivity value with a conversion factor of 0.67 (Hanna, 2003).

TDS (in mg/L) = 0.67 x EC (µS/cm).

3.2.3 Collection of benthic samples

Benthic sediment samples were collected between the hours of 8.00a.m and 9.00a.m using an Ekman grab, model number 923, measuring 19cm by 14cm with an area of $0.0266m^2$. The samples were collected twice in a month. Three grab hauls were taken from each station, emptied into pre-labelled polythene bags and taken to the laboratory for sorting and analysis. The collected materials were washed through a 0.5mm mesh sieve. The residue in the sieve for each station was then preserved in 10% formalin solution and kept in labeled plastic containers for further laboratory analysis.

3.3 Laboratory Studies

3.3.1 Dissolved oxygen

Dissolved oxygen was determined by Azide modification of Winkler method according to (APHA, 2005). Water sample for dissolved oxygen was collected in a 100ml plastic water sampling bottle. The bottle was filled to overflow to remove any trapped water bubbles. The sample was then fixed on the field by adding 1ml of manganous sulphate and 1ml of alkali-iodide azide solution. The sample was mixed, a brown flocculate precipitate was formed which was allowed to settle completely. The fixed sample was taken to the laboratory where 1g of sulfamic acid powder was added to the fixed sample and mixed until both reagent and precipitate dissolved. The solution was decanted to 20ml and titrated with 0.025N sodium thiosulphate solution until the brown colour nearly disappeared. 1ml of starch indicator was then added and a blue colour developed. The titration was continued until the sample changed from blue to near colourless. The amount of dissolved oxygen in the sample was determined by the amount of titrant or sodium thiosulphate used.

3.3.2 Biological oxygen demand

This was determined by calculating the difference between dissolved oxygen over a 5-day incubation interval: that is $BOD = DO_1 - DO_5$

Where DO_1= dissolved oxygen value for day one

DO_5=dissolved oxygen value after five days incubation

3.3.3 Total alkalinity

Total alkalinity was measured by titration method according to APHA (2005). 100ml of the water sample collected was transferred into 250 ml flask. 10ml of phenolphthalein indicator was added and mixed. The solution was titrated with 0.020N sulphuric acid solution until the sample changed from pink to colourless. Total alkalinity was calculated to be:

No. of mls of 0.020N sulphuric acid used ×10 = the amount of calcium carbonate mg/l in the sample.

3.3.4 Calcium hardness

Calcium hardness of the water was measured using the Burette titration method as described in APHA (2005). 50ml of the water sample was transferred into a flask, diluted to 100ml with distilled water. 2ml of 0.1M sodium hydroxide solution was added to buffer the sample; one calcium indicator tablet (murexide indicator) was then added. A pink colour was observed. The sample was titrated with EDTA until the pink colour changed to blue. Calcium hardness was calculated as:

No of mls of EDTA used x 0.1 = the amount of calcium hardness (mg/L) in the sample.

3.3.5 Nitrate – nitrogen

Phenoldisulphonic acid method (APHA, 2005) was used to measure nitrate- nitrogen in the water sample. 50mls of the sample was evaporated to dryness and 1ml of phenodisulphonic acid added to the residue. This was left to stand for 10 minutes, before 10ml of distilled water was added to it until the residue was completely dissolved. 5ml of 0.12N potassium hydroxide was added to the solution, this was again diluted with distilled water to 50ml, and a yellow colour was formed. The absorbance was read in a Hach spectrophotometer model DR-EL/2 at 430nm wavelength. The nitrate-nitrogen concentration was determined from a calibration curve. Nitrate-nitrogen was measured in mg/L.

3.3.6 Phosphate

Phosphate was measured using the Deniger's method as described in APHA (2005). 1ml of Deniger's reagent and 5 drops of stannous chloride were added to 100ml of the sample. A blue colour was formed. The absorbance was measured with a Hach spectrophotometer model DR-EL/2 at 690nm wavelength. The phosphate concentration was determined from a calibration curve. The unit of measurement was in mg/L.

3.3.7 Macrobenthic invertebrate

At the laboratory, small portions of sediment samples from each sampling stations were washed in a 0.5 mm sieve to remove debris. Macrobenthic invertebrates were sorted out and were transferred into sample bottles containing 5% formalin. Analysis was carried out on the organisms while identification under dissecting microscope and classification were done using standard methods (Odum, 1971; Pennak, 1978). Thereafter, the orgainisms were grouped into different taxa in each sample.

3.3.8 Shannon index

This is also called Shannon-Weiner index or Shannon-Weaver index. It is most widely used index for measuring biological diversity, which has been developed from the information theory. This index was used to measure diversity of macrobenthic invertebrate in Makwaye and Kubanni reservoirs (Maiti, 2004).

$$H' = \sum_{i=1}^{S} Pi\ln Pi$$

Where,

S = Total number of species.

Pi = *n/N* = proportion of individuals of the total sample belonging to the i^{th} species.

n = Number of individuals *(N)* belonging to the i^{th} species.

N = Total number of individuals of all the species.

This index can be used to calculate the diversity of phytoplankton, zooplankton and macrobenthic invertebrates. This formula assumes an infinite sample, but as long as sample size is large, the bias is likely to be small if *n/N* is used to approximate Pi. The higher the value of H', the greater is the diversity. The maximum value of H' can be more than 1. The decline in the value of H' is taken as an evidence of pollution. According to (Maiti, 2004), a value of this index above 3 will indicate clean water, whereas values fewer than this would indicate pollution.

However, the use of this index should be made with great care, as wrong interpretations can be frequently drawn in the conditions of mild pollution or when the system is under transition from one season to another (Maiti, 2004).

3.3.9 Heavy metals

Some Macrobenthic invertebrates collected were squashed using porcelain pestle and mortar, placed in a crucible and dried at 60°C for 36 hours. The dried samples were now weighed and grounded into powdery form (enough to pass 1mm sieve) using porcelain pestle and mortar, and dissolved by wet chemical digestion in prepared 1 volume to 4 of 62% Perchloric acid and 70% Nitric acid.

Heavy metal concentrations of macrobenthic invertebrates sample were analyzed by subjecting the digested samples to heavy metal analysis using Air/Acetylene Flame Atomic Absorption Spectrophotometer (UNICAM 696 AA Spectrometer).

Water samples were obtained by means of a tube sampler from the water surface in one litre bottles. The analysis of water samples was carried out according to methods describe by APHA (2005). Water samples were preserved by the addition of 1 ml of concentrated nitric acid per liter until the time of analysis. The water samples were filtered through 0.45µl membrane filter. The required volume (100 ml) of the filtrate was collected to measure heavy metals levels in water samples by using Air/Acetylene Flame Atomic Absorption Spectrophotometer (UNICAM 696 AA Spectrometer). This was done by comparing their absorbance with those of standards (solution of known metal concentration). This was carried out at the Multi user laboratory, Ahmadu Bello University, Zaria.

3.4 Data Analysis

Paleontological Statistics Software Package (PAST) V.2.17c (2013) was used to estimate the species diversity in each reservoir using Shannon - Wiener diversity index and to determine the interrelationship of the physico-chemical parameters with the macrobenthic invertebrate composition using Principal Component Analysis.

Analysis of variance (ANOVA) and student t-test at $P \leq 0.05$ were used to determine variations in physico-chemical parameters as well as variations in heavy metal concentrations in the macrobenthic invertebrates. Statistics Analysis System (SAS) version 9.1 (2005) was used.

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-chemical Parameters

The result of the physico-chemical parameters of the two reservoirs analyzed is presented in Table 4.1, 4.2, and 4.3 and monthly fluctuations of each physico-chemical parameters are presented in figures under each parameter.

pH–Potential of hydrogen, is the measure of the concentration of hydrogen ions. It provides the measure of the acidity or alkalinity of a solution. In this study, (Figure 4.1) shows the mean monthly variations in pH at the two reservoirs. The observed pH values ranging from 6.12 and 7.62 in Makwaye reservoir was the lowest and highest in the months of January and July respectively and shows that the reservoir pH ranged from slightly acidic to moderately alkaline (Table 4.1) while pH values ranging from 6.43 and 7.49 were observed in Kubanni reservoir was the lowest and highest in the months of February and September respectively and also shows slight acidic and alkaline in this reservoir (Table 4.2) but also indicate that Kubanni reservoir is slightly less acidic and alkaline than Makwaye reservoir. In the two reservoirs, the pH was close to neutral. Slight acidic and moderately alkaline pH was observed during the dry season and wet season for the two reservoirs and analysis of variance ANOVA ($P \leq 0.05$) shows pH to be significantly higher in the wet seasons than in the dry seasons (Table 4.3), but for most times, the pH was in alkaline medium especially during the rains.

Table 4.1 Mean monthly physico-chemical parameters of Makwaye reservoir

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	P value
pH	6.12 ± 0.21^{c}	6.99 ± 0.07^{ab}	6.20 ± 0.31^{b}	6.92 ± 0.11^{ab}	7.25 ± 0.16^{a}	7.46 ± 0.67^{a}	7.62 ± 0.12^{a}	6.77 ± 0.25^{de}	7.47 ± 0.05^{a}	6.21 ± 0.05^{c}	6.82 ± 0.21^{ab}	7.35 ± 0.19^{a}	0.00
EC(µS/cm)	65.22 ± 2.53^{d}	58.00 ± 1.10^{e}	63.61 ± 2.07^{de}	72.54 ± 2.43^{c}	75.20 ± 2.02^{b}	75.82 ± 0.52^{b}	78.67 ± 4.26^{b}	78.33 ± 1.20^{b}	87.33 ± 1.45^{a}	66.00 ± 2.89^{d}	78.67 ± 0.88^{b}	69.00 ± 1.53^{d}	0.00
TDS(ppm)	32.92 ± 1.21^{d}	29.20 ± 0.67^{d}	30.81 ± 0.69^{d}	36.21 ± 0.15^{c}	37.20 ± 0.43^{b}	37.51 ± 0.27^{b}	38.67 ± 0.88^{b}	37.33 ± 0.88^{b}	41.67 ± 2.33^{a}	38.33 ± 1.20^{c}	39.33 ± 2.65^{ab}	34.50 ± 3.38^{cd}	0.00
TEMP(□ C)	20.92 ± 0.54^{d}	22.12 ± 0.11^{d}	29.90 ± 0.92^{a}	27.23 ± 0.66^{b}	26.75 ± 0.23^{bc}	26.22 ± 0.12^{bc}	24.37 ± 0.12^{c}	24.33 ± 0.19^{c}	25.03 ± 0.22^{bc}	22.43 ± 0.69^{d}	21.90 ± 0.15^{d}	20.13 ± 0.29^{d}	0.00
DO(mg/L)	2.16 ± 0.03^{e}	2.09 ± 0.01^{e}	2.02 ± 0.01^{e}	2.89 ± 0.03^{cd}	3.00 ± 0.04^{c}	3.07 ± 0.02^{c}	3.02 ± 0.02^{c}	2.88 ± 0.25^{d}	7.33 ± 0.38^{a}	3.67 ± 0.06^{b}	2.63 ± 0.04^{d}	2.21 ± 0.06^{e}	0.00
BOD(mg/L)	2.00 ± 0.05^{c}	2.96 ± 0.03^{a}	2.01 ± 0.13^{c}	0.92 ± 0.02^{ef}	0.70 ± 0.01^{f}	0.69 ± 0.03^{f}	0.72 ± 0.04^{f}	0.62 ± 0.35^{f}	1.12 ± 0.53^{e}	1.95 ± 0.18^{d}	2.61 ± 0.18^{b}	2.78 ± 0.08^{ab}	0.00
ALK(mg/L)	35.40 ± 0.09^{b}	38.90 ± 0.16^{a}	36.10 ± 0.81^{ab}	33.90 ± 0.05^{c}	32.10 ± 0.51^{c}	30.60 ± 0.07^{d}	36.30 ± 0.15^{ab}	35.00 ± 0.06^{b}	24.30 ± 0.07^{e}	22.30 ± 0.12^{e}	23.00 ± 0.17^{e}	23.70 ± 0.09^{e}	0.00
NO_3-N(mg/L)	15.00 ± 0.02^{d}	13.50 ± 0.05^{d}	17.00 ± 0.01^{c}	21.00 ± 0.04^{b}	23.00 ± 0.02^{a}	24.00 ± 0.01^{a}	25.00 ± 0.03^{a}	25.00 ± 0.03^{a}	22.00 ± 0.02^{a}	16.00 ± 0.01^{cd}	20.00 ± 0.02^{bc}	20.00 ± 0.01^{bc}	0.03
PO_4- P(mg/L)	3.10 ± 0.03^{c}	2.20 ± 0.00^{e}	0.59 ± 0.01^{f}	2.60 ± 0.02^{c}	2.90 ± 0.04^{c}	3.20 ± 0.02^{c}	3.50 ± 0.02^{b}	2.90 ± 0.02^{d}	4.40 ± 0.01^{a}	3.50 ± 0.02^{b}	0.60 ± 0.01^{f}	0.59 ± 0.01^{f}	0.00
Ca(mg/L)	2.31 ± 0.01^{e}	2.01 ± 0.07^{e}	2.23 ± 0.02^{e}	3.20 ± 0.01^{d}	3.70 ± 0.03^{bc}	3.71 ± 0.06^{bc}	3.80 ± 0.25^{bc}	4.73 ± 0.47^{a}	4.00 ± 1.02^{b}	3.60 ± 0.09^{c}	3.03 ± 0.45^{d}	2.53 ± 0.54^{de}	0.03

Mean values along row with same superscript were not significantly different (P>0.05)

KEY

pH = Potential of hydrogen
EC = Electrical conductivity
TEMP = Temperature
DO = Dissolved oxygen
BOD = Biological oxygen demand
ALK = Alkalinity
Ca = Calcium
NO_3-N = Nitrate nitrogen
PO_4- P = Phosphate phosphorus

Table 4.2: Mean monthly physico-chemical parameters of Kubanni reservoir

	JAN	FEB	MAR	APRIL	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	P Value
pH	7.21±0.03^{b}	6.43±0.01^{c}	7.11±0.07^{b}	7.26±0.21^{b}	7.41±0.25^{a}	7.40±0.02^{a}	7.43±0.10^{a}	6.81±0.13^{bc}	7.49±0.04^{a}	6.57±0.16^{c}	6.97±0.09^{b}	7.11±0.21^{b}	0.00
EC(µS/cm)	74.12±1.12^{d}	67.23±0.99^{e}	60.51±0.01^{f}	75.57±0.05^{c}	76.33±1.27^{c}	79.13±1.16^{c}	98.67±1.76^{b}	108.00±0.58^{a}	99.73±1.20^{b}	62.33±0.88^{f}	75.33±1.76^{c}	77.33±0.88^{c}	0.00
TDS(ppm)	37.02±0.61^{d}	33.15±0.27^{f}	30.12±0.77^{f}	37.65±0.53^{d}	38.17±0.65^{d}	39.46±0.07^{d}	44.67±2.85^{c}	50.33±0.88^{a}	48.67±3.71^{b}	31.17±0.58^{f}	37.67±1.73^{d}	38.67±1.73^{d}	0.00
TEMP(□ C)	18.92±0.01^{f}	19.90±0.91^{ef}	28.25±0.22^{a}	27.34±0.09^{a}	25.65±0.76^{b}	25.32±0.51^{b}	24.70±0.06^{c}	24.10±0.06^{c}	25.03±0.46^{b}	23.13±0.20^{de}	20.77±0.15^{e}	18.87±0.34^{f}	0.00
DO(mg/L)	2.21±0.09^{d}	2.18±0.01^{d}	2.11±0.71^{d}	2.39±0.19^{d}	2.72±0.21^{c}	2.83±0.32^{c}	2.91±0.03^{c}	3.78±0.12^{b}	5.97±0.27^{a}	3.95±0.23^{b}	2.92±0.23^{c}	2.24±0.09^{d}	0.00
BOD(mg/L)	2.07±0.03^{c}	2.09±0.01^{c}	2.10±0.32^{c}	0.97±0.02^{d}	0.81±0.01^{d}	0.80±0.01^{d}	0.79±0.01^{ed}	0.63±0.07^{e}	0.37±0.22^{f}	2.27±0.06^{b}	2.89±0.07^{a}	2.97±0.01^{a}	0.00
ALK(mg/L)	22.80±0.51^{e}	22.40±0.03^{e}	22.90±0.05^{e}	25.20±0.07^{de}	30.10±0.04^{c}	33.10±0.72^{b}	43.30±0.15^{a}	42.30±0.15^{a}	30.00±0.32^{c}	27.30±0.27^{d}	23.70±0.32^{e}	23.10±0.23^{e}	0.00
NO_3^- N(mg/L)	18.00±0.06^{f}	16.00±0.01^{d}	12.00±0.03^{f}	20.00±0.01^{cd}	22.00±0.02b^{c}	25.00±0.01^{b}	28.00±0.04^{a}	30.00±0.02^{a}	26.00±0.01^{a}	14.50±0.01^{e}	17.00±0.01^{d}	19.00±0.01^{cd}	0.00
PO_4^- P(mg/L)	1.90±0.01^{d}	1.26±0.01^{e}	0.59±0.01^{f}	2.30±0.02^{b}	2.70±0.01^{a}	3.00±0.03^{a}	1.60±0.01^{de}	1.40±0.01^{f}	1.60±0.01d^{e}	0.59±0.01^{f}	2.20±0.01^{b}	2.00±0.02^{b}	0.00
Ca(mg/L)	2.89±0.09^{gh}	3.01±0.27^{f}	2.61±0.31^{h}	3.21±0.04^{e}	3.63±0.51^{d}	4.01±0.64^{c}	4.20±0.32^{b}	5.43±0.87^{a}	4.03±0.32^{b}	3.47±0.23^{de}	3.09±0.23^{f}	3.10±0.26^{e}	0.00

Mean values along row with same superscript were not significantly different (P>0.05)

KEY

pH = Potential of hydrogen
EC = Electrical conductivity
TEMP = Temperature
DO = Dissolved oxygen
BOD = Biological oxygen demand
ALK = Alkalinity
Ca = Calcium
NO_3-N = Nitrate nitrogen
PO_4- P = Phosphate phosphorus

Table 4.3 Seasonal variations of physico-chemical parameters in Makwaye and Kubanni reservoirs

	MAKWAYE		KUBANNI	
	WS	DS	WS	DS
pH	7.25±0.15^{a}	6.62±0.19^{b}	7.30±0.12^{a}	6.90±0.11^{b}
EC(µS/cm)	77.98±1.99^{a}	66.75±2.15^{b}	89.57±1.71^{a}	69.48±5.15^{b}
TDS(ppm)	38.10±1.32^{a}	34.18±0.85^{b}	43.16±2.96^{a}	34.63±2.57^{b}
TEMP(□ C)	25.66±0.15^{a}	22.90±0.41^{b}	25.36±0.19^{a}	21.64±0.63^{b}
DO(mg/L)	3.70±0.74^{a}	2.46±0.22^{b}	3.43±0.46^{a}	2.60±0.27^{b}
BOD(mg/L)	0.80±0.19^{b}	2.39±0.15^{a}	0.73±0.09^{b}	2.40±0.12^{a}
ALKALINITY(mg/L)	32.0±0.19^{a}	29.9±0.07^{b}	34.0±0.24^{a}	23.7±0.15^{b}
NITRATE(mg/L)	23.33±0.02^{a}	16.92±0.01^{b}	25.17±0.01^{a}	16.08±0.01^{b}
PHOSPHATE(mg/L)	3.25±0.62^{a}	1.76±0.05^{b}	2.10±0.01^{a}	1.42±0.03^{b}
CALCIUM(mg/L)	3.86±0.38^{a}	2.62±0.29^{b}	4.09±0.36^{a}	3.03±0.28^{b}

Mean values along row with same superscript were not significantly different ($P>0.05$)

KEY

WS = Wet season
DS = Dry season
pH = Potential of hydrogen
EC = Electrical conductivity
TEMP = Temperature
DO = Dissolved oxygen
BOD = Biological oxygen demand

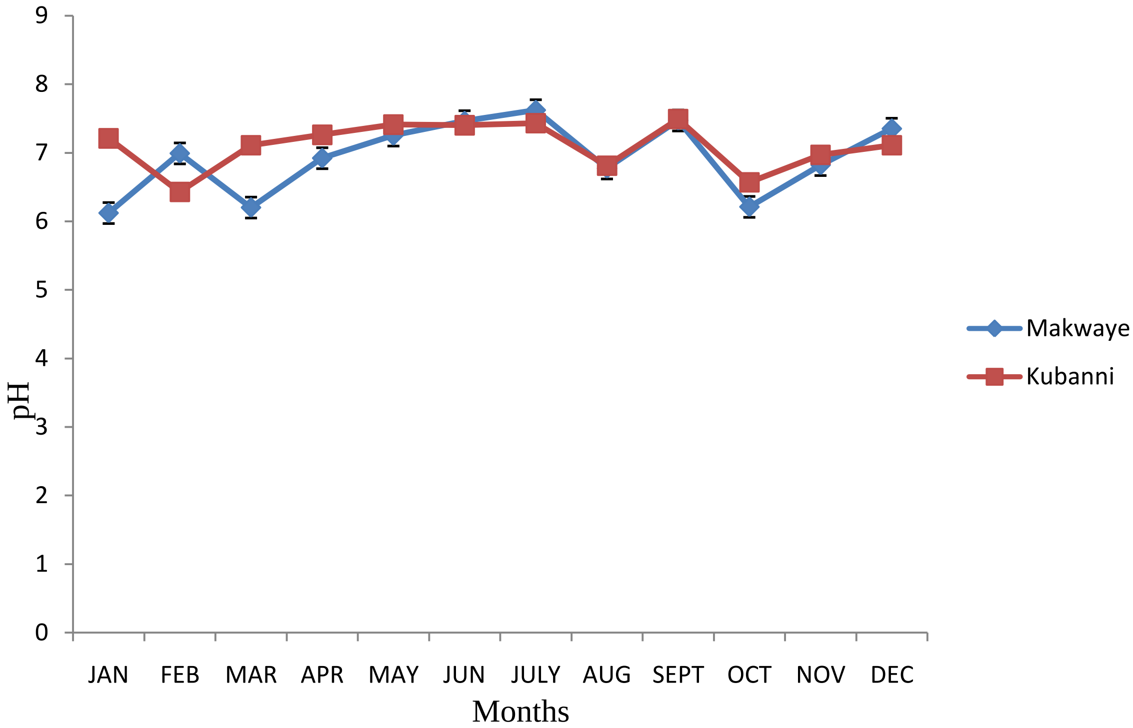

Fig 4.1: The mean monthly variation in the pH of Makwaye and Kubanni reservoirs

But comparing seasons between the two reservoirs, ANOVA shows that there was no significant difference in the pH values of wet seasons of the two reservoirs and there was no significant difference in the dry seasons of the two reservoirs with the pH values of the dry season been slightly acidic and pH values of the wet season been moderately alkaline (Table 4.3).

These values are within maximum permissible limit prescribed by WHO (1993) and similar findings were also reported by Sharma *et al*. (2013).

The monthly mean variation in the Electrical conductivity of Makwaye and Kubanni reservoirs is presented in Figure 4.2. The electrical conductivity in Makwaye reservoir varied from the lowest value of 58.0 μS/cm in the month of February, 2014 to the highest of 87.33 μS/cm in the month of September 2014 while in Kubanni reservoir, the electrical conductivity varied from the lowest value of 60.51 μS/cm in the month of March to the highest value of 108 μS/cm in the month of August.

ANOVA ($P \leq 0.05$) shows conductivity to be significantly higher in the wet season than in the dry season both within the reservoir but electrical conductivity shows significant difference when compared in the wet seasons of the two reservoirs but shows not significantly different in the dry seasons of the two reservoirs.

The total dissolved solids (TDS) of the two reservoirs followed the same pattern with conductivity (Fig 4.3).

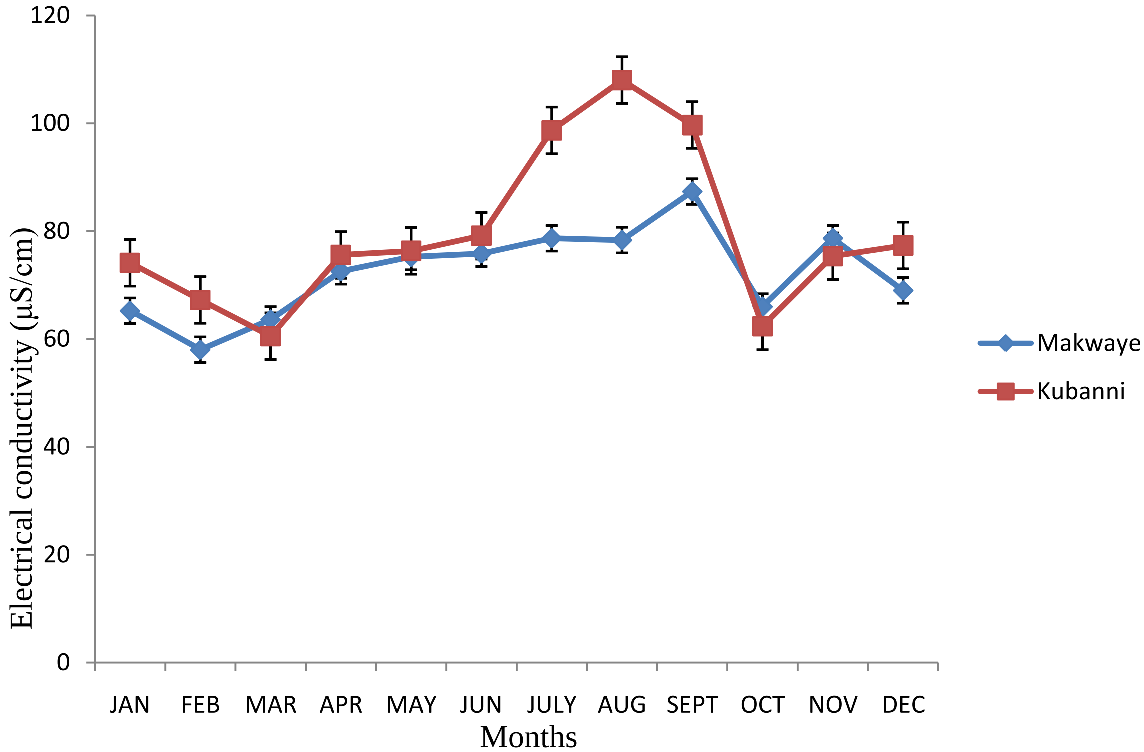

Fig 4.2: The mean monthly variation in the electrical conductivity of Makwaye and Kubanni reservoirs

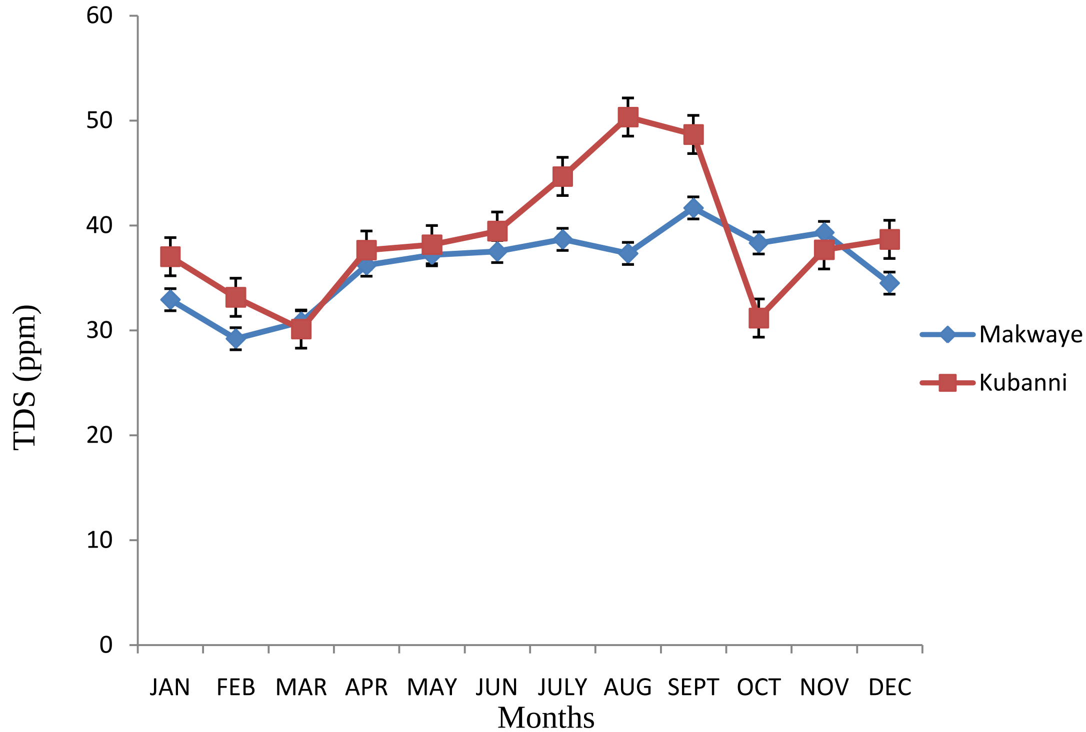

Fig 4.3: The mean monthly variation in the Total Dissolve Solids of Makwaye and Kubanni reservoirs

Figure 4.3 shows the monthly mean variations in the total dissolved solids in the two reservoirs. The range of the TDS in Makwaye reservoir was from the lowest value of 29.20 mg/L recorded in the month of February 2014, to the highest value of 41.67 mg/L recorded in September 2014 while in Kubanni reservoir was from lowest value of 30.12 mg/L recorded in the month of March 2014, to the highest value of 50.33 mg/L recorded in August 2014. Total dissolved solids were observed to be higher in wet season than in the dry season.

At $P \leq 0.05$, analysis of variance shows a significant difference among the seasons both within and between the reservoirs. The wet season TDS values were significantly higher than the dry season.

The monthly mean variations in the surface water temperature of the two reservoirs are presented in Figure 4.4. The temperature range was between 20.13°C and 29.92°C in Makwaye reservoir and 18.87°C to 28.25°C in Kubanni reservoir. Low temperature of 20.13°C was obtained in the month of December 2014 in Makwaye reservoir while 18.87°C in Kubanni reservoir was also obtained in December 2014, while high temperature value of 29.90°C was obtained in Makwaye reservoir during the month of March 2014 and 28.25°C in Kubanni reservoir obtained also in March 2014.

Analysis of variance at 0.05 probability level ($P \leq 0.05$) shows a significant difference in the seasonal temperature within the reservoirs. Early dry season temperatures were lower than the wet season. No significant difference was seen between the temperatures of the same seasons between the two reservoirs.

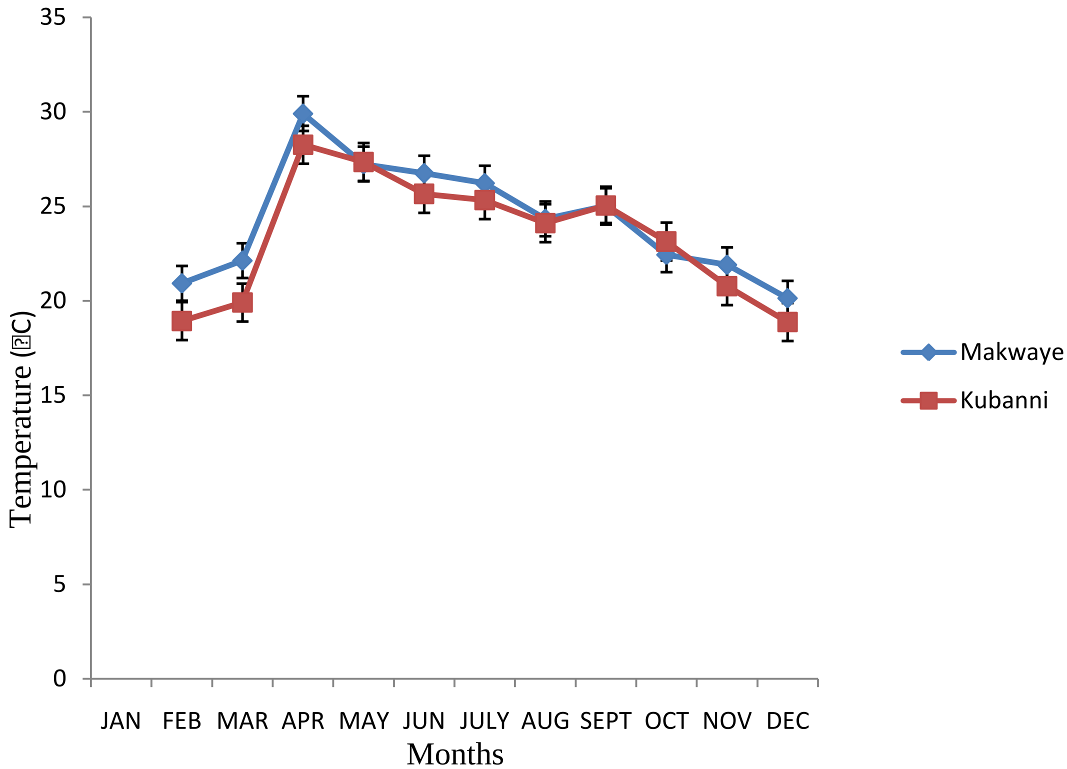

Fig 4.4: The mean monthly variation in the surface water temperature of Makwaye and Kubanni reservoirs

The fluctuations in the concentration of dissolved oxygen are presented in Figure 4.5. Dissolved oxygen fluctuated between monthly mean of 2.02 mg/L in March 2014 and 7.33 mg/L in September 2014 at Makwaye reservoir while the fluctuation in Kubanni reservoir is between 2.11mg/L in March 2014 and 5.97 mg/L in September 2014 also. ANOVA showed significant difference ($P \leq 0.05$) among the months, seasons within each reservoir and showed no significance between the same seasons in different reservoirs. Dissolved oxygen was significantly higher in the wet season than in the dry season.

The monthly mean variations in the biological oxygen demand (BOD) of the two reservoirs are shown in Figure 4.6. Biological oxygen demand values varied between 0.62 mg/L in August and 2.96 mg/L in February 2014 at Makwaye reservoir while in Kubanni reservoir, the BOD value varied between 0.37 mg/L in September as the lowest value and 2.97 mg/L in December 2014 as the highest value.

ANOVA test at ($P \leq 0.05$) shows a significant difference between the seasons within the reservoirs and between the same seasons between the reservoirs.

Biological oxygen demand was significantly higher in the dry season than in the wet season. It was highest in the month of February and lowest in the month of August in Makwaye reservoir and higher in the month of December in Kubanni reservoir and lowest in the month of September in Kubanni reservoir.

Alkalinity varied between monthly mean of 22.3mg/L and 38.9mg/L for Makwaye reservoir and 22.4mg/L and 43.3mg/L for Kubanni reservoir (Figure 4.7). Highest value of 3.89mg/L for Makwaye reservoir was obtained in February, 2014 and the lowest value

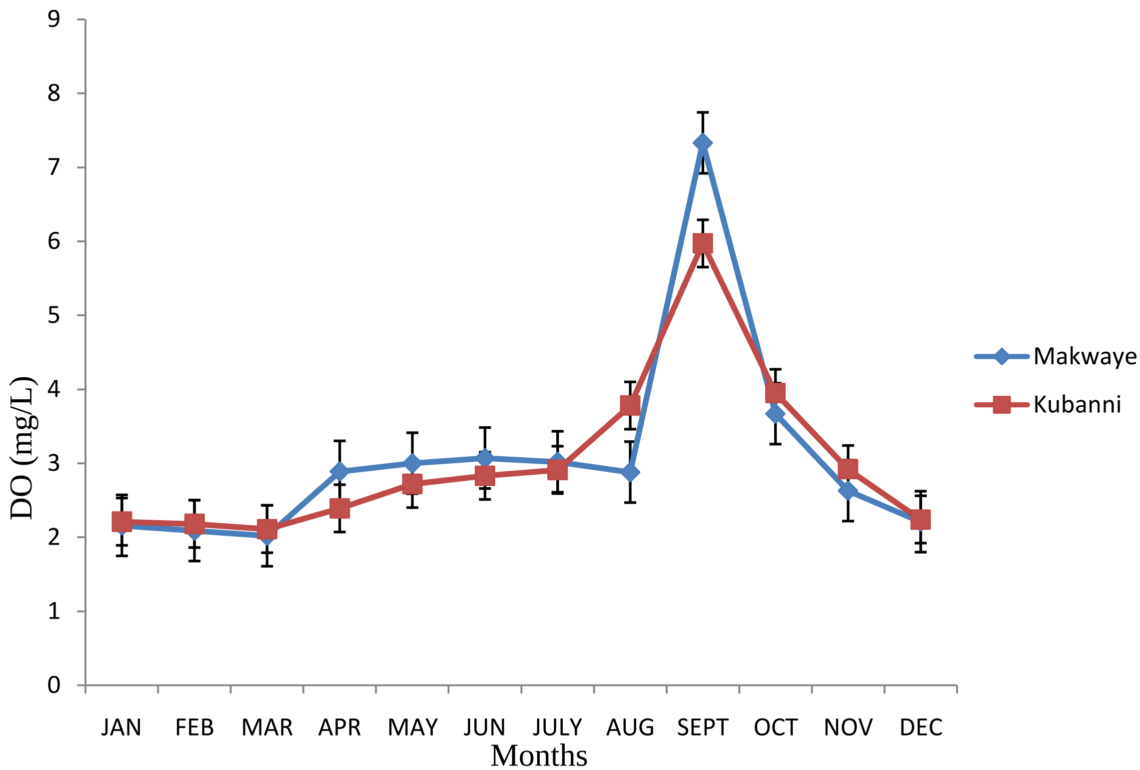

Fig 4.5: The mean monthly variation in the Dissolve Oxygen of Makwaye and Kubanni reservoirs

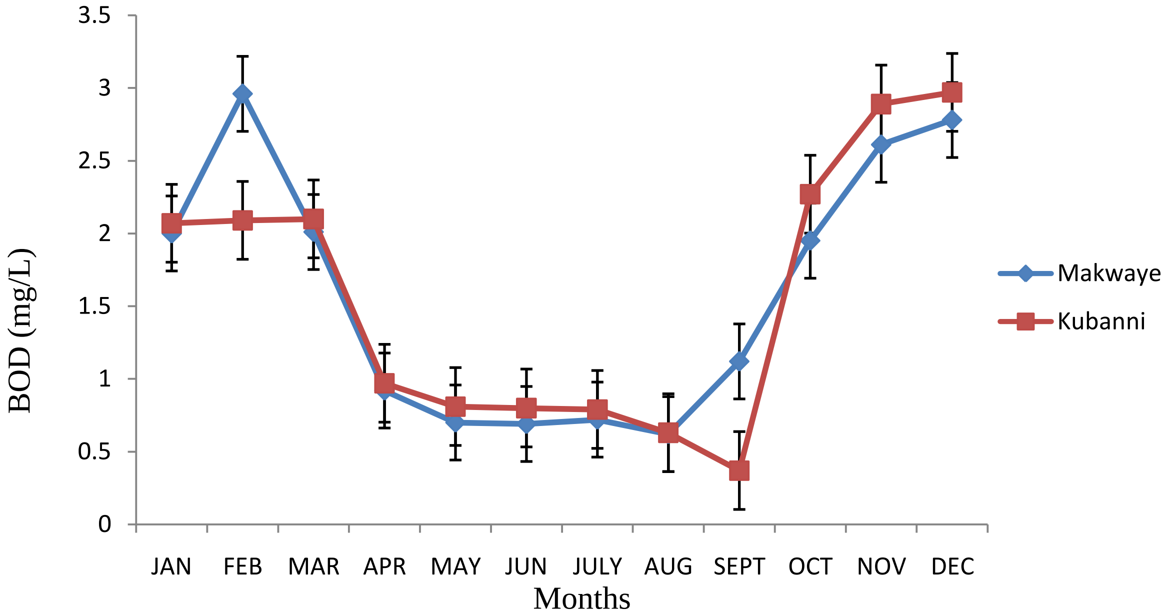

Fig 4.6: The mean monthly variation in the Biological Oxygen Demand of Makwaye and Kubanni reservoirs

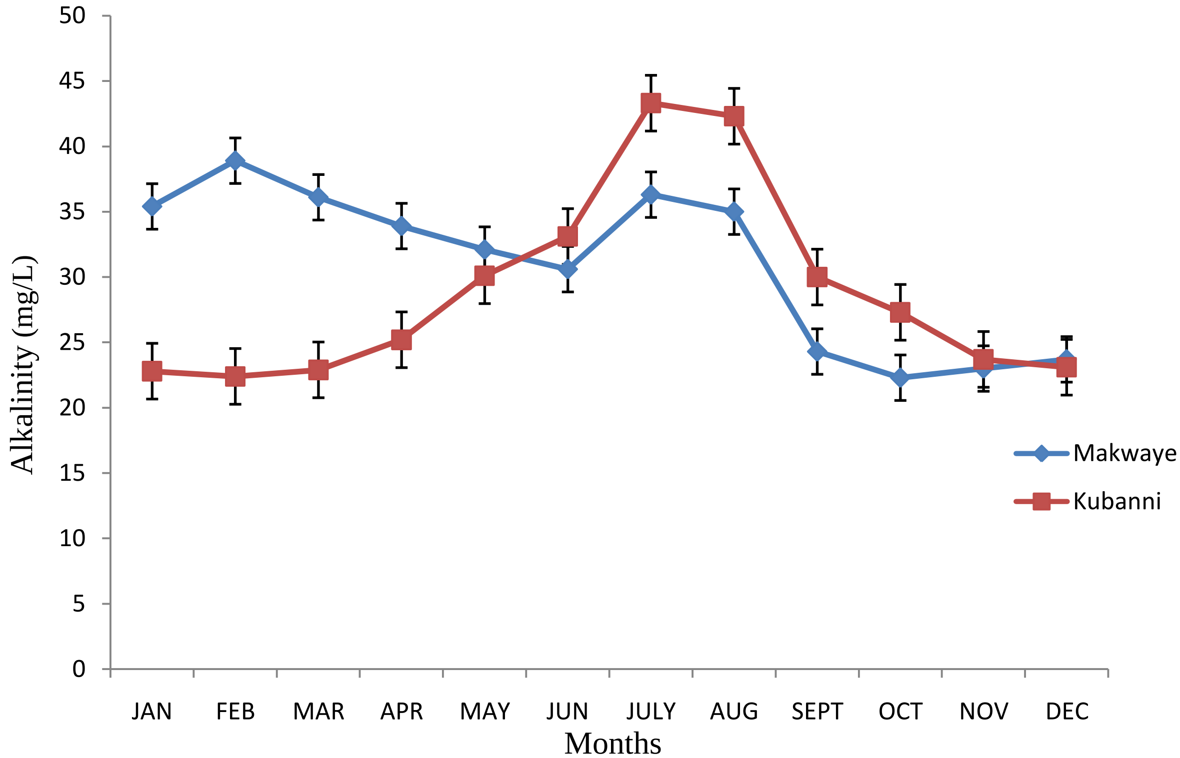

Fig 4.7: The mean monthly variation in Alkalinity of Makwaye and Kubanni reservoirs

in October, 2014 while the highest value of 4.33mg/L for Kubanni reservoir was obtained also in July, 2014 and the lowest value of 2.24 mg/L were obtained in February, 2014. ANOVA ($P \leq 0.05$) revealed significant difference existed between the seasons with the wet season values higher than the dry season but no significant different for dry season between the two reservoir.

The concentration of nitrate in Makwaye reservoir was found to be in the range of 13.50mg/L to 25.00mg/L while that of Kubanni reservoir was found to be in the range of 12.00mg/L to 30.00mg/L. Minimum nitrate concentration was recorded in the month of February and maximum was also recorded in the month of July in Makwaye reservoir while in Kubanni reservoir, minimum nitrate concentration was observe in the month of March and maximum concentration in the month of August, 2014 (Fig. 4.8). Analysis of variance at ($P \leq 0.05$) shows that significant difference exists between the seasons for each reservoir but there was no significant difference in same seasons between the two reservoirs. The nitrate concentration was significantly higher in the rainy season than in the dry season.

The values of phosphate fluctuated between 0.59 mg/L to 4.4 mg/L. The maximum phosphate was recorded in the month of September and minimum was also recorded in the month of March for Makwaye reservoir while the values fluctuated between 0.59mg/L to 3.00mg/L in kubanni reservoir with the maximum phosphate been recorded in the month of June and minimum in the month of March and October, 2015 (Fig. 4.9). The increased use of fertilizers, use of detergents and domestic sewage greatly contribute

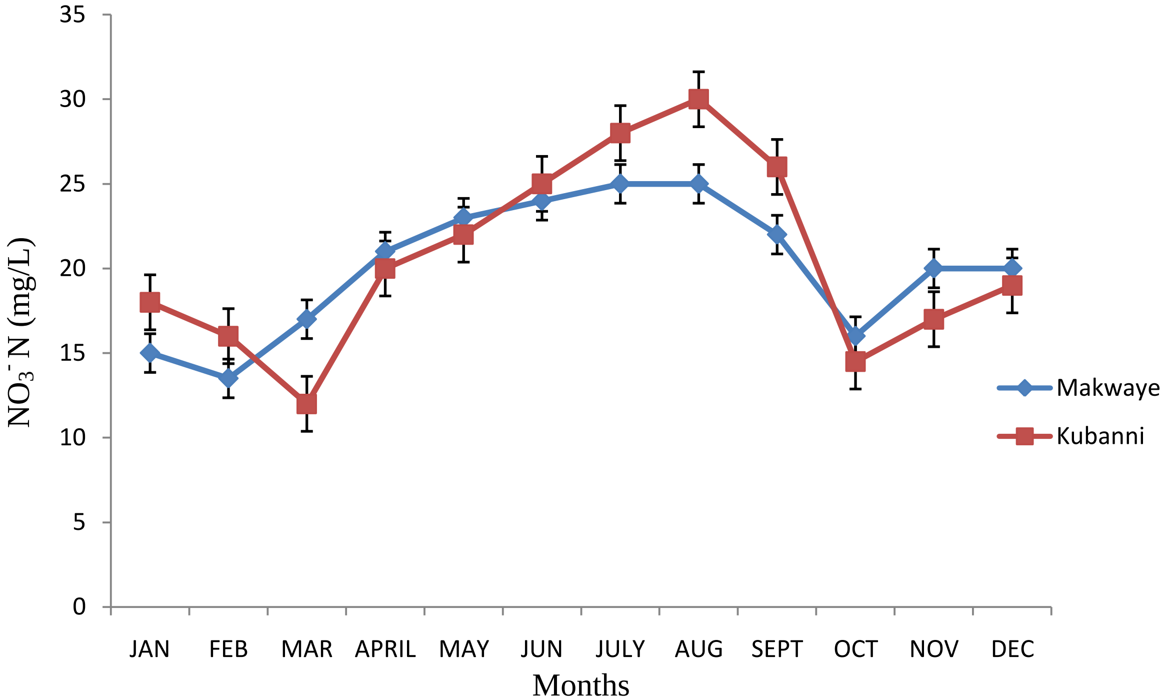

Fig 4.8: The mean monthly variation in Nitrate of Makwaye and Kubanni reservoirs

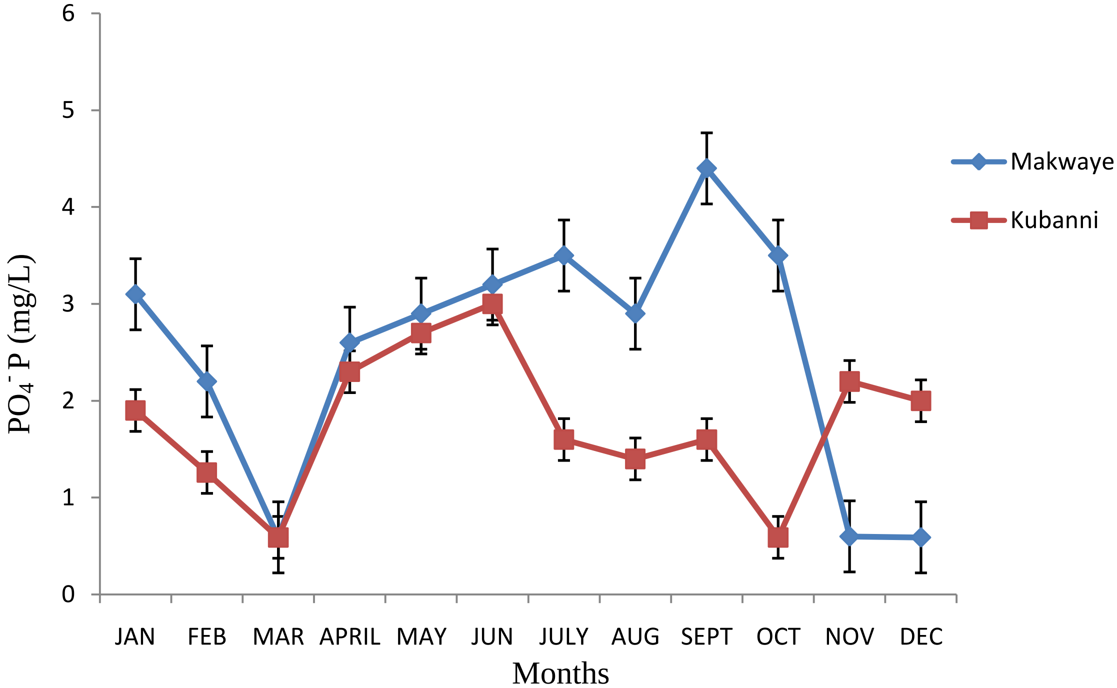

Fig 4.9: The mean monthly variation in Phosphate of Makwaye and Kubanni reservoirs

to the heavy loading of phosphorus in the water. ANOVA shows a significant difference at ($P \leq 0.05$) in the seasonal concentrations of phosphate in the reservoirs each.
The wet season had significantly higher phosphate concentration than the dry season in each reservoir. No significant difference in phosphate concentration among the two reservoirs in dry season but there was significant difference in wet seasons of the two reservoirs.

In this study, the highest calcium hardness concentration in Makwaye reservoir was recorded to be 4.73 mg/L obtained in August and the lowest concentration was 2.01 mg/L obtained in February while the highest recorded in Kubanni reservoir was 5.43mg/L in August and the lowest was 2.61mg/L in the month of March 2014 (Fig. 4.10).

Analysis of variance at 0.05 probability level shows significant difference in seasonal concentrations in the calcium hardness of the reservoirs each. The wet season values were significantly higher than the dry season. However there was no significant difference in calcium concentration in same seasons between the two reservoirs.

Also, Principal Component Analysis shows the interrelationship between physicochemical parameters and macrobenthic invertebrate in Makwaye reservoir (Fig. 4.11). The same apply to Kubanni reservoir as shown in Fig. 4.12. In Makwaye reservoir, PCA showed that the first two components accounted for 86.6% of the total variation observed in the PCA. The whole of the macrobenthic invertebrate were positively correlated with BOD, DO, pH and Ca but negatively correlated with EC, TDS, Temperature, Alkalinity, NO_3^- N and PO_4^- P.

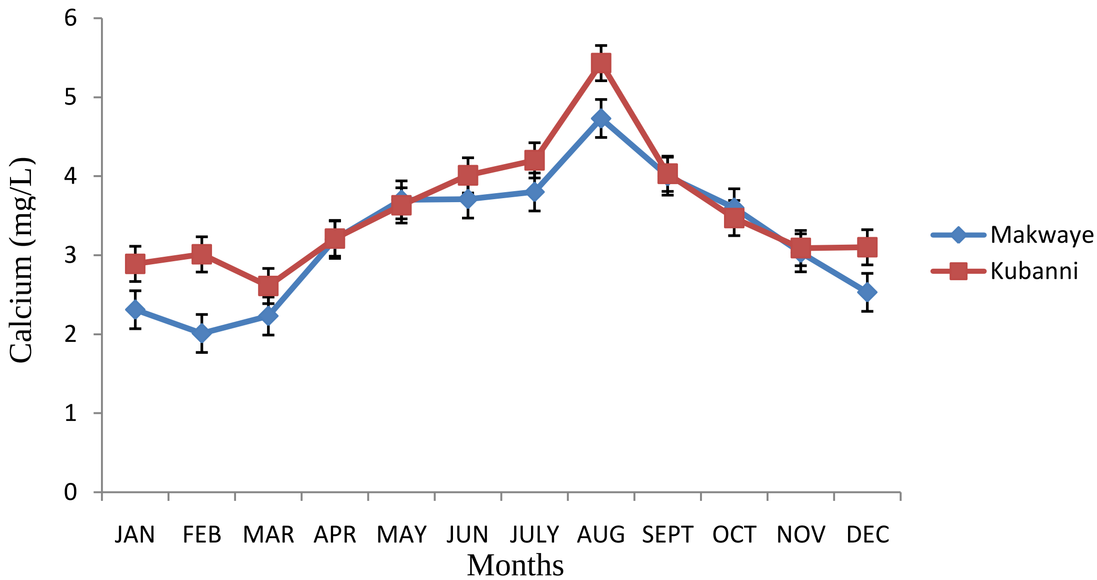

Fig. 4.10: The mean monthly variation in Calcium of Makwaye and Kubanni reservoirs

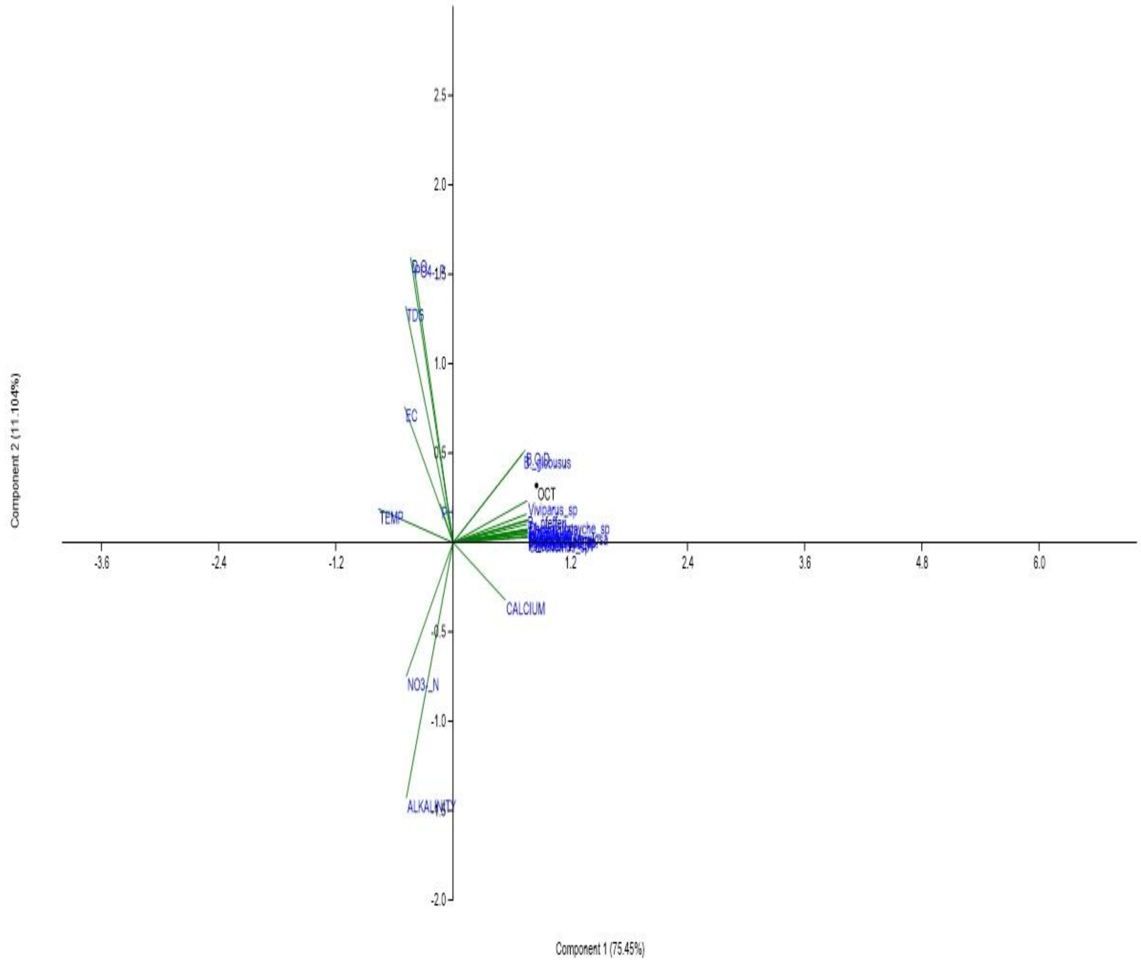

Fig 4.11: Principal component analysis (PCA) biplot for physico-chemical parameters and macrobenthic invertebrates in Makwaye reservoir.

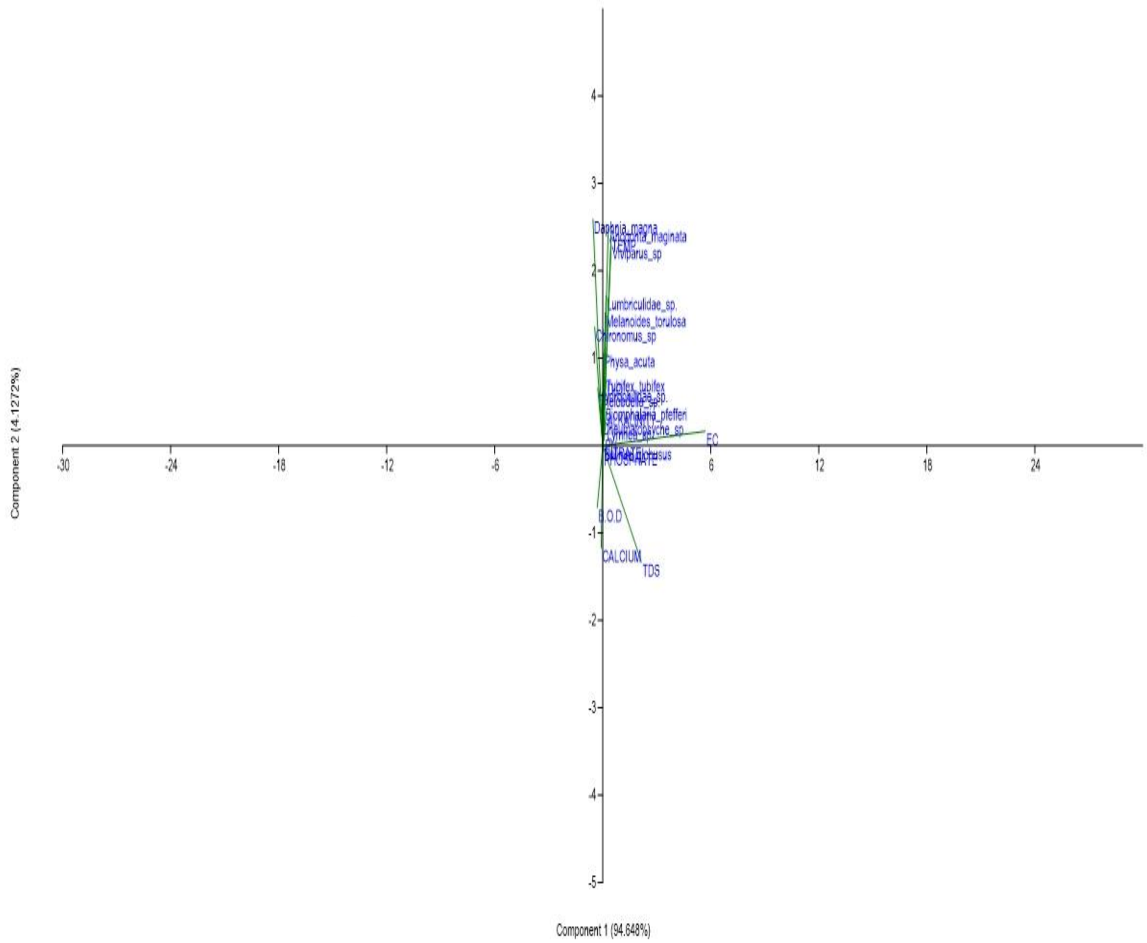

Fig 4.12: Principal component analysis (PCA) biplot for physicochemical parameters and macrobenthic invertebrates in Kubanni reservoir

In Kubanni reservoir, PCA showed that the first two components accounted for 98.8% of the total variation observed in the PCA. The whole of the macrobenthic invertebrate with the exception of *Chironomus* sp were positively correlated with all the physicochemical parameters. *Chironomus* sp were negatively correlated with all the physicochemical parameters.

Cluster analysis shows the relationship in the physicochemical parameter between the three sampling stations in Makwaye reservoir (Fig. 4.13) and also in Kubanni reservoir (Fig. 4.14).

4.2 Macrobenthic Invertebrates Abundance and Diversity

A summary of seasonal collection of macrobenthic invertebrates from Makwaye and Kubanni reservoirs are presented in Table 4.4 and Table 4.5 respectively. A total of 11,723 macrobenthic invertebrate comprising three phyla, five classes, thirteen families and thirteen species were recorded. Figure 4.15 shows that the benthic community in Makwaye reservoir was dominated by the Phyla Mollusca (52%), Arthropoda (25%) and Annelida (23%) while in Kubanni reservoir, a total of 1868 macrobenthic invertebrate comprising three phyla, five classes, thirteen families and thirteen species were recorded. Figure 4.16 shows that the benthic community in Kubanni reservoir was dominated by the Phyla Mollusca (51%), Arthropoda (27%) and Annelida (22%).

Some of the dominant individuals in the two reservoirs include *Viviparus* sp (Plate I), *Melanoides* sp (Plate II), *Bulinus* sp (Plate III) *and Anodonta* sp (Plate IV) all in phylum mollusca.

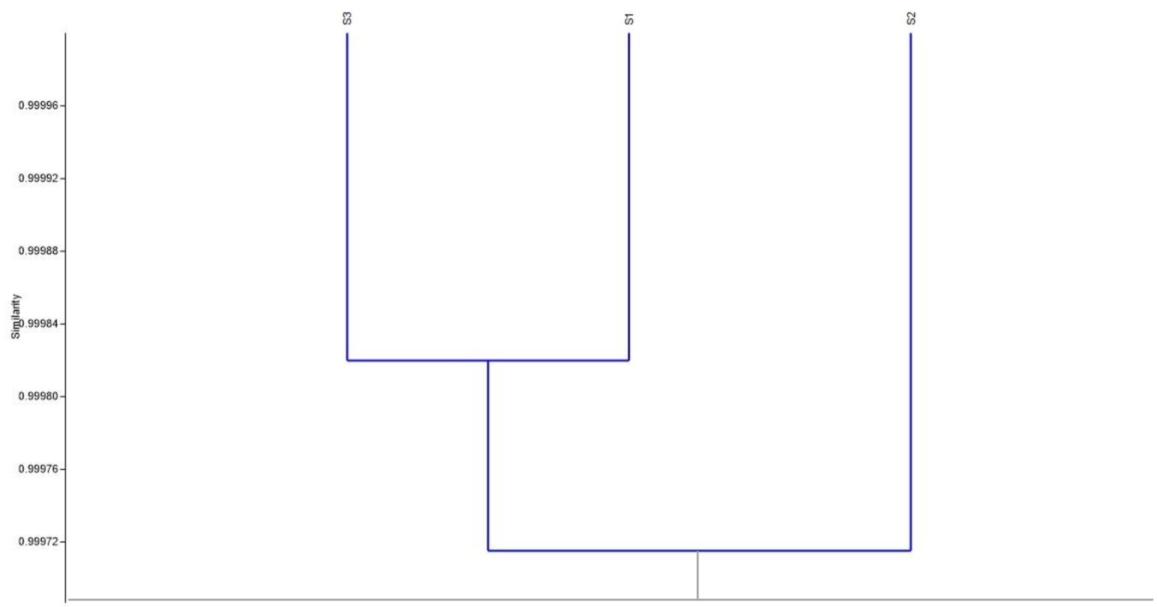

Fig. 4.13: Cluster analysis of relationship between the sampling stations relative to physicochemical parameters in Makwaye reservoir

S1 = Station 1, S2 = Station 2, S3 = Station 3

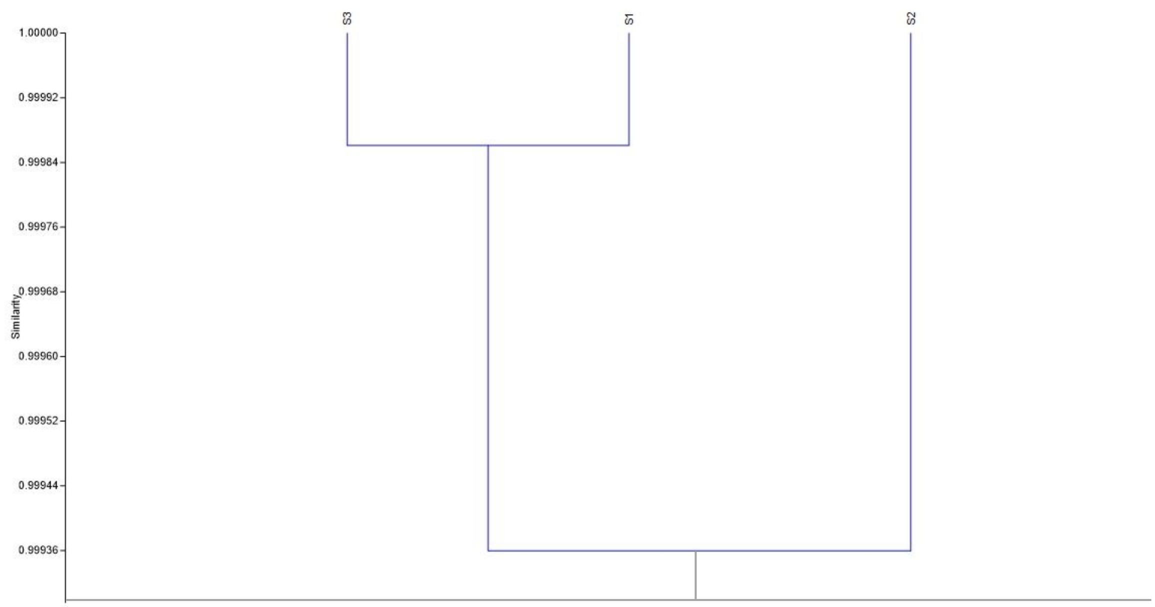

Fig. 4.14: Cluster analysis of relationship between the sampling stations relative to physicochemical parameters in Kubanni reservoir

S1 = Station 1, S2 = Station 2, S3 = Station 3

Table 4.4 Summary of seasonal collection frequency of Macrobenthic invertebrate from Makwaye reservoir

	WS	DS	TOTAL	%
PHYLUM ANNELIDA				
Class-Oligochaete				
Tubifex sp	132	849	981	
Lumbriculid sp	159	811	970	
Class-Hirudinea				
Helobdella sp	66	630	696	
			2647	**23**
PHYLUM MOLLUSCA				
Class-Gastropoda				
Viviparus sp	460	1315	1775	
Melanoides sp	175	756	931	
Biomphalaria sp	87	515	602	
Physa sp	104	652	756	
Lymnea sp	93	625	718	
Bulinus sp	38	125	163	
Class-Bivalvia				
Anodonta sp	202	975	1177	
			6122	**52**
PHYLUM ARTHROPODA				
Class-Insecta				
Chironomus sp	515	1491	2006	
Hydrophilus sp	0	159	159	
Cheumatopsyche sp	0	789	789	
			2954	**25**
TOTAL			**11723**	

KEY
WS = Wet season
DS = Dry season

Table 4.5 Summary of seasonal collection frequency of Macrobenthic invertebrate from Kubanni reservoir

	WS	DS	TOTAL	%
PHYLUM ANNELIDA				
Class-Oligochaete				
Tubifex sp	104	32	136	
Lumbriculid sp	170	71	241	
Class-Hirudinea				
Helobdella sp	16	11	27	
			404	**22**
PHYLUM MOLLUSCA				
Class-Gastropoda				
Viviparus sp	252	131	383	
Melanoides sp	126	48	174	
Biomphalaria sp	22	0	22	
Physa sp	32	5	37	
Lymnea sp	33	0	33	
Bulinus sp	0	0	0	
Class-Bivalvia				
Anodonta sp	219	82	301	
			950	**51**
PHYLUM ARTHROPODA				
Class-Insecta				
Chironomus sp	164	258	422	
Hydrophilus sp	22	65	87	
Cheumatopsyche sp	0	5	5	
			514	**27**
TOTAL			**1868**	

KEY
WS = Wet season
DS = Dry season

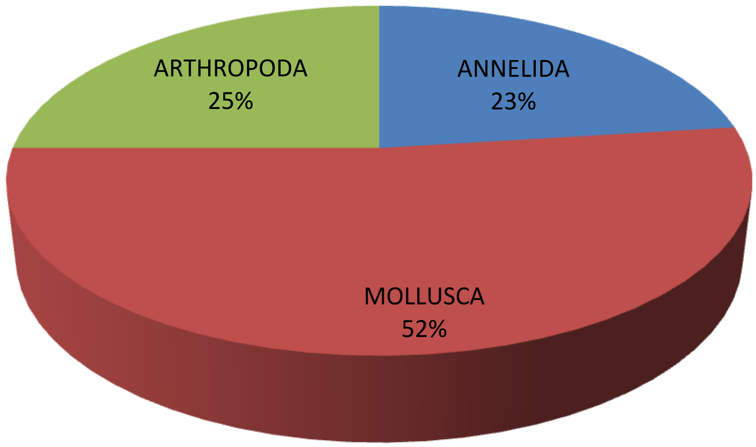

Fig. 4.15: Overall percentage abundance of benthic macrofauna in Makwaye reservoir

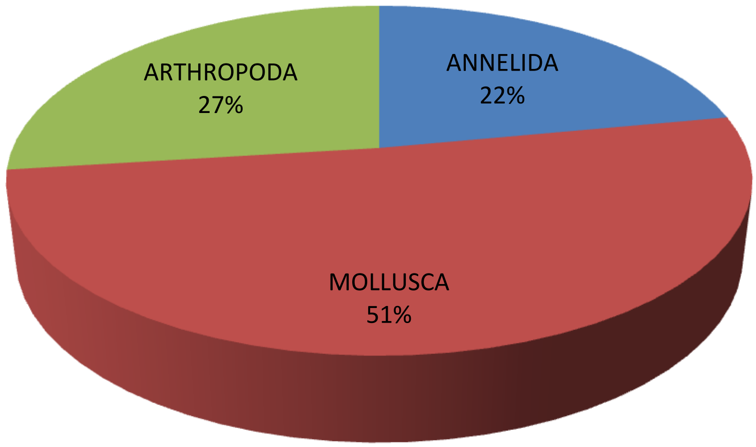

Fig. 4.16: Overall percentage abundance of benthic macrofauna in Kubanni reservoir

Plate I: *Viviparus* sp Mg = ×10

Common name: River snail

Plate II: *Melanoides* sp Mg = ×10

Common name: Rimmed snail

Plate III: *Bulinus* sp Mg = ×10

Common name: Globular Cowry

Plate IV: *Anodonta* sp Mg = ×10

Common name: Mussel

While some of the individuals in phylum arthropoda include *Chironomus* sp (Plate V), *Hydrophilus* sp (Plate VI) and *Cheumatopsyche* sp (Plate VII) and lastly is the dominant individual in the phylum annelid which is *Lumbriculid* sp (Plate VIII).

More macrobenthic invertebrate were recorded in the dry season than in the wet season in Makwaye reservoir while more individuals were recorded in wet season than dry season in Kubanni reservoir.

The Shannon – Weiner diversity index of macrobenthic invertebrates in the study areas in wet and dry season of Makwaye and Kubanni reservoirs are presented in Table 4.6. For Makwaye reservoir, Shannon-Wiener Index (Hs) was 2.04 in wet season and 2.42 in dry season while in Kubanni reservoir, Shannon – Weiner diversity index was 1.97 in wet season and 1.70 in dry season.

4.3 Heavy Metals

The mean seasonal concentrations of heavy metal in macrobenthic invertebrate of the two reservoirs are presented on Table 4.7.

In this study the observed values for Fe in Makwaye reservoir for dry season ranged between 3.30 - 22.52 mg/L while for wet season the value ranged from 6.91 - 29.07 mg/L. So also the values for Fe in kubanni reservoir ranged from 11.33 - 46.21 mg/L in dry season and 7.36 - 38.62 mg/L in wet season. *Lumbriculid* sp and *Cheumatopsyche* sp recorded the highest concentration of Fe. However there was significant variation of Fe concentration in the whole macrobenthic invertebrate for both seasons.

Plate V: *Chironomus* sp Mg = ×20

Common name: Midge fly larva

Plate VI: *Hydrophilus* sp Mg = ×10

Common name: Water beetle

Plate VII: *Cheumatopsyche* sp Mg = ×20

Common name: Caddis fly larva

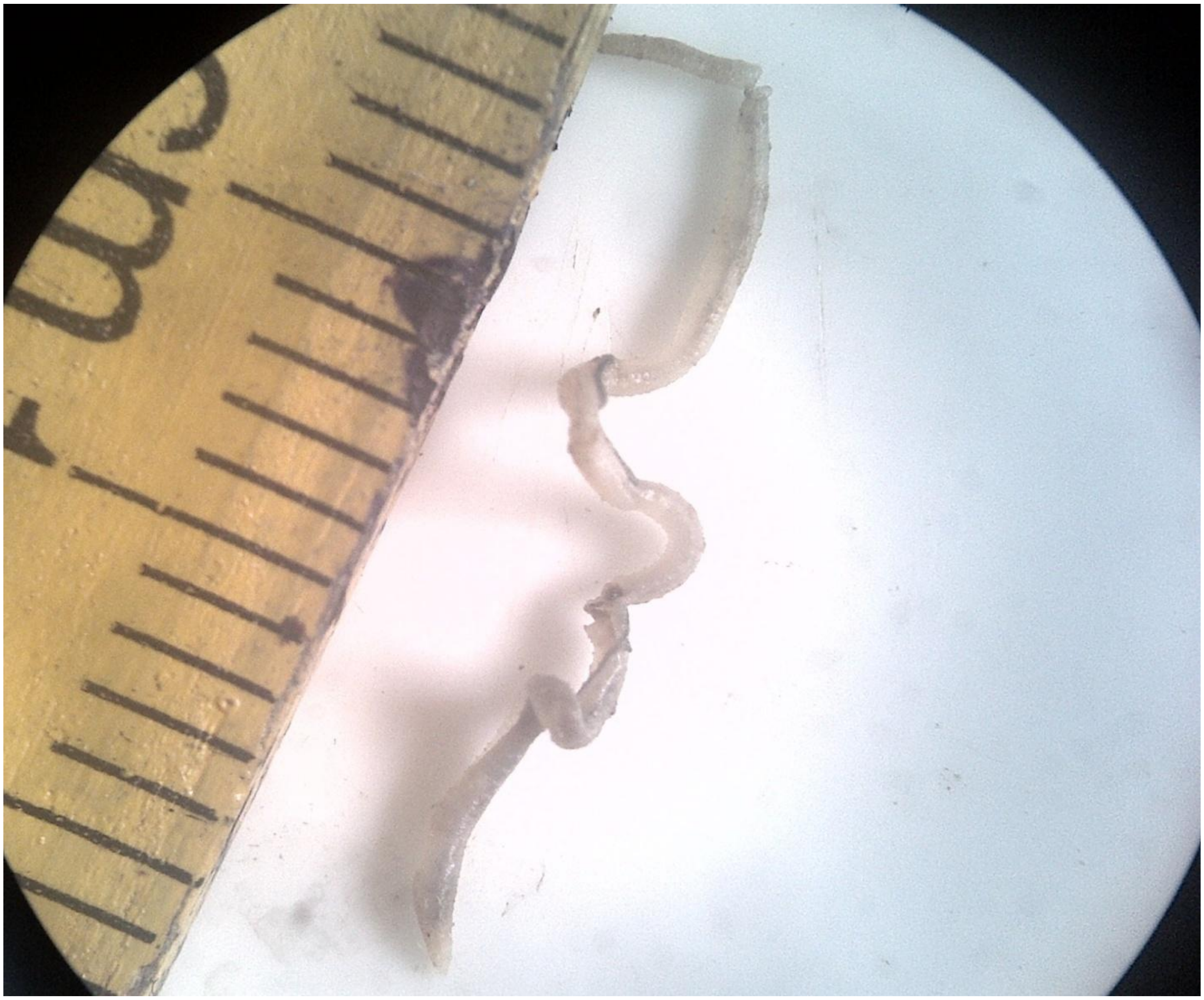

Plate VIII: *Lumbriculid* sp Mg = ×20

Common name: Aquatic worm

Table 4.6: Seasonal variation in Shannon – Weiner diversity Index of Macrobenthic invertebrates in Makwaye and Kubanni reservoir (January, 2014 – December, 2014)

	MAKWAYE		**KUBANNI**	
	WET	**DRY**	**WET**	**DRY**
Shannon_H	2.04	2.42	1.97	1.70

Table 4.7: Mean seasonal concentration of heavy metals in macrobenthic invertebrate of Makwaye and Kubanni reservoirs

	MAKWAYE											
	DRY						WET					
	Fe	**Mn**	**Zn**	**Cd**	**Ni**	**Pb**	**Fe**	**Mn**	**Zn**	**Cd**	**Ni**	**Pb**
***Lumbriculid* sp**	21.32±4.56^{a}	5.96±0.15^{a}	6.23±1.44^{a}	BDL	3.61±0.29^{a}	BDL	29.07±2.56^{a}	3.21±0.09^{a}	0.82±0.09^{a}	BDL	0.67±0.06^{a}	BDL
***Viviparus* sp**	11.6±2.09^{b}	2.21±0.12^{c}	3.67±0.75^{c}	BDL	2.92±0.05^{b}	BDL	15.13±2.66^{b}	1.42±0.01^{b}	0.59±0.04^{d}	BDL	0.32±0.01^{c}	BDL
***Melanoides* sp**	10.2±2.07^{c}	2.33±0.74^{c}	4.71±0.01^{b}	BDL	2.71±0.08^{b}	BDL	12.6±2.01^{d}	1.21±0.02^{d}	0.71±0.01^{b}	BDL	0.39±0.01^{b}	BDL
***Anodonta* sp**	12.1±3.12^{b}	2.22±0.36^{c}	3.91±0.24^{c}	BDL	2.99±0.03^{b}	BDL	14.31±1.09^{c}	1.11±0.01^{e}	0.54±0.01^{d}	BDL	0.33±0.03^{bc}	BDL
***Biomphalaria* sp**	6.2±1.27^{de}	1.31±0.03^{f}	1.43±0.04^{d}	BDL	1.81±0.01^{d}	BDL	8.3±0.92^{e}	0.23±0.04^{g}	0.21±0.06^{e}	BDL	0.17±0.05^{d}	BDL
***Physa* sp**	8.3±1.56^{d}	1.92±0.01^{d}	1.49±0.06^{d}	BDL	2.53±0.04^{c}	BDL	9.72±0.67^{f}	0.81±0.01^{f}	0.29±0.02^{e}	BDL	0.31±0.01^{c}	BDL
***Lymnea* sp**	5.7±0.22^{e}	1.33±0.02^{ef}	1.31±0.09^{e}	BDL	1.22±0.03^{e}	BDL	6.91±0.84^{g}	0.26±0.01^{g}	0.14±0.01^{f}	BDL	0.13±0.07^{d}	BDL
***Bulinus* sp**	8.7±1.87^{d}	2.41±0.01^{c}	4.75±0.19^{b}	BDL	2.62±0.06^{bc}	BDL	15.72±2.22^{b}	1.35±0.05^{c}	0.69±0.06^{c}	BDL	0.35±0.04^{b}	BDL
***Hydrophilus* sp**	3.3±0.45^{f}	1.34±0.01^{e}	0.25±0.01^{g}	BDL	0.30±0.01^{f}	BDL	-	-	-	-	-	-
***Cheumatopsyche* sp**	22.52±3.22^{a}	4.66±0.16^{b}	0.84±0.06^{f}	BDL	0.56±0.03^{f}	BDL	-	-	-	-	-	-
MEAN	**10.98±2.03**	**2.56±0.17**	**2.85±0.27**	**-**	**2.12±0.06**	**-**	**13.98±1.61**	**1.30±0.03**	**0.51±0.03**	**-**	**0.32±0.02**	**-**
P value	**0.001**	**0.0001**	**0.0001**		**0.0001**		**0.0001**	**0.0001**	**0.0001**		**0.0001**	

	KUBANNI											
	DRY						WET					
	Fe	**Mn**	**Zn**	**Cd**	**Ni**	**Pb**	**Fe**	**Mn**	**Zn**	**Cd**	**Ni**	**Pb**
***Lumbriculid* sp**	46.21±5.26^{a}	4.70±0.22^{a}	3.29±0.14^{b}	0.27±0.04^{a}	2.63±0.76^{a}	BDL	38.62±2.76^{a}	2.73±0.66^{a}	2.92±0.55^{a}	0.30±0.11^{a}	2.76±0.03^{b}	BDL
***Viviparus* sp**	22.32±2.22^{bc}	3.21±0.65^{b}	2.07±0.99^{ef}	0.14±0.01^{cd}	2.12±0.04^{d}	BDL	17.56±4.01^{c}	1.76±0.05^{b}	2.07±0.05^{d}	0.22±0.01^{b}	2.61±0.73^{c}	BDL
***Melanoides* sp**	20.76±3.56^{c}	3.98±1.32^{b}	2.12±0.65^{e}	0.17±0.03^{c}	2.32±0.01^{c}	BDL	17.31±1.98^{c}	1.57±0.01^{c}	2.14±0.74^{c}	0.19±0.01^{c}	2.81±0.03^{a}	BDL
***Anodonta* sp**	26.79±2.34^{b}	3.69±0.67^{b}	3.01±0.87^{c}	0.18±0.02^{c}	2.4±0.13^{b}	BDL	18.91±3.22^{b}	1.46±0.45^{d}	2.15±0.11^{c}	0.20±0.06^{b}	2.16±0.34^{e}	BDL
***Biomphalaria* sp**	17.61±3.66^{e}	1.92±0.13^{d}	2.02±0.34^{f}	0.11±0.01^{f}	1.29±0.15^{f}	BDL	14.39±2.34^{d}	1.17±0.01^{e}	2.01±0.33^{d}	0.13±0.01^{cd}	2.61±0.45^{c}	BDL
***Physa* sp**	18.74±1.65^{de}	3.22±0.34^{b}	2.41±0.83^{d}	0.16±0.01^{e}	2.39±0.09^{c}	BDL	14.99±1.45^{d}	1.42±0.01^{d}	2.17±0.54^{c}	0.16±0.09^{c}	2.80±0.66^{a}	BDL
***Lymnea* sp**	13.28±1.11^{f}	1.19±0.23^{d}	1.92±0.45^{g}	0.09±0.01^{g}	1.11±0.01^{g}	BDL	10.51±1.03^{e}	1.13±0.01^{f}	1.62±0.01^{f}	0.11±0.04^{d}	1.16±0.05^{f}	BDL
***Bulinus* sp**	19.31±1.87^{d}	3.22±0.01^{b}	3.43±0.54^{a}	0.21±0.04^{b}	2.43±0.07^{b}	BDL	17.72±2.67^{c}	1.75±0.03^{b}	2.84±0.06^{b}	0.25±0.01^{b}	1.11±0.01^{g}	BDL
***Hydrophilus* sp**	11.33±3.39^{g}	2.34±0.43^{c}	1.67±0.01^{g}	0.13±0.04^{d}	1.63±0.01^{e}	BDL	7.36±1.77^{f}	1.13±0.01^{f}	1.75±0.03^{e}	0.16±0.02^{c}	2.53±0.05^{d}	BDL
***Cheumatopsyche* sp**	40.05±5.79^{a}	4.37±0.22^{a}	3.12±0.07^{bc}	0.25±0.01^{a}	2.33±0.08^{c}	BDL	-	-	-	-	-	-
MEAN	**23.65±3.07**	**3.19±0.41**	**2.50±0.40**	**0.18±0.03**	**2.06±0.12**	**-**	**17.48±2.35**	**1.56±0.03**	**2.17±0.03**	**0.18±0.04**	**2.29±0.02**	**-**
P value	**0.0001**	**0.0001**	**0.0001**	**0.0087**	**0.0001**		**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	

Means ±S.E with different superscripts along the same column were significantly different (P≤0.05)
BDL = Below Detectable Limit

Mn concentration in macrobenthic invertebrate of Makwaye reservoir ranged from 1.31 - 5.96 mg/L in dry season and 0.23 - 3.21 mg/L in wet season. For Kubanni reservoir the values range from 1.19 - 4.70 mg/L in dry season and 1.13 - 2.73 mg/L in wet season.

The Zn concentration in macrobenthic invertebrate of Makwaye reservoir range from 0.25 - 6.23 mg/L in dry season and 0.14 - 0.82 mg/L in wet season while in Kubanni reservoir the values range from 1.67 - 3.43 mg/L in dry season and 1.62 - 2.92 mg/L in wet season.

Cd concentration was found to be below detectable limit in Makwaye reservoir in both seasons but the concentration ranges from 0.25 - 0.27 mg/L in Kubanni reservoir during the dry season and 0.11 - 0.30 mg/L in wet season.

Ni concentration also show variation within the macrobenthic invertebrate with values ranging from 0.30 - 3.61 mg/L in Makwaye reservoir during the dry season and 0.13 - 0.67 mg/L in wet season. In Kubanni reservoir, values ranged from 1.11 - 2.63 mg/L were recorded in the dry season and 1.11 - 2.81 mg/L in wet season.

Lead concentrations were found to be below detectable limit in the two reservoirs for both dry and wet season.

The concentrations of heavy metals are all higher in the dry season and Analysis of Variance ANOVA at $P \leq 0.05$ shows significant difference in concentration of heavy metals between the macrobenthic invertebrates. For concentration of heavy metals in water samples from the two reservoirs, comparing seasons in the two reservoirs, ANOVA shows that there was significant difference in the concentrations of the heavy metals in dry and wet seasons of the two reservoirs with high concentrations in the dry season (Table 4.8).

Table 4.8: Seasonal variation of heavy metal concentrations in Makwaye and Kubanni reservoirs

	MAKWAYE		**KUBANNI**	
	WS	**DS**	**WS**	**DS**
Fe	123.86±56.50^{b}	150.91±67.09^{a}	28.16±1.91^{b}	86.84±7.32^{a}
Mn	2.97±0.64^{b}	10.76±1.43^{a}	4.43±1.64^{b}	9.13±3.43^{a}
Zn	15.61±7.53^{b}	17.66±4.36^{a}	1.56±0.24^{b}	8.65±1.94^{a}
Cd	BDL	BDL	0.07±0.02^{b}	0.25±0.06^{a}
Ni	1.38±0.19^{b}	2.45±0.27^{a}	2.09±0.35^{b}	2.46±0.58^{a}
Pb	0.03±0.01^{b}	0.24±0.05^{a}	0.09±0.01^{b}	0.67±0.07^{a}

Mean values along row with the same superscript were significantly different ($P \leq 0.05$)

KEY

WS = Wet season

DS = Dry season

BDL = Below Detectable Limit

However, the relationship between heavy metal concentrations in water samples and macrobenthic invertebrate in the two reservoirs for each heavy metal is shown in Fig. 4.17 and Fig. 4.18. In Makwaye and Kubanni reservoirs, t-test showed that there was significant variation in Fe concentration in water sample and macrobenthic invertebrates with p value of 0.00096 and 0.00491. So also, the same apply to Zn concentration with p values of 0.02975 and 0.02647 in Makwaye and Kubanni reservoirs respectively. Mn, and Ni concentrations in water sample and macrobenthic invertebrate in the two reservoirs showed no significant different with p values of 0.41543 and 0.24857 for Mn and Ni in Makwaye and Kubanni reservoirs while for Cd in Kubanni reservoir, the p value was 0.70886 which is not significant and the concentration was below detectable limit in both water sample and macrobenthic invertebrates in Makwaye reservoir.

Pb concentrations in macrobenthic invertebrates from the two reservoirs were both below detectable limit but detected in the water sample from the two reservoirs.

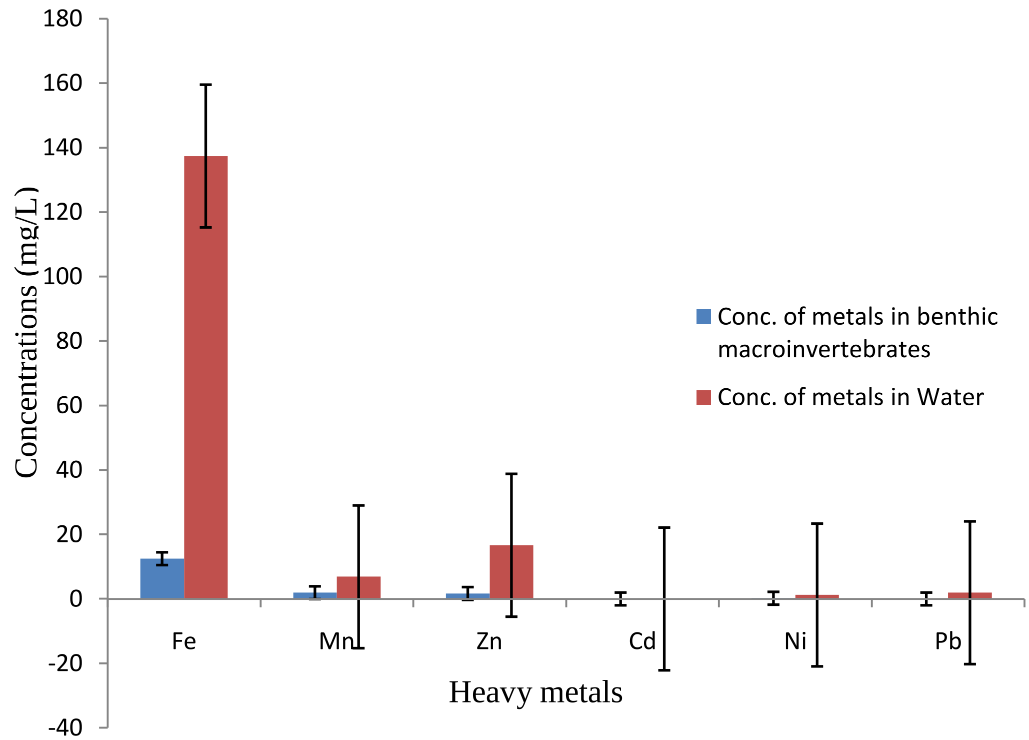

Fig. 4.17: Relationship between heavy metal concentrations in water sample and macrobenthic invertebrate in Makwaye reservoir

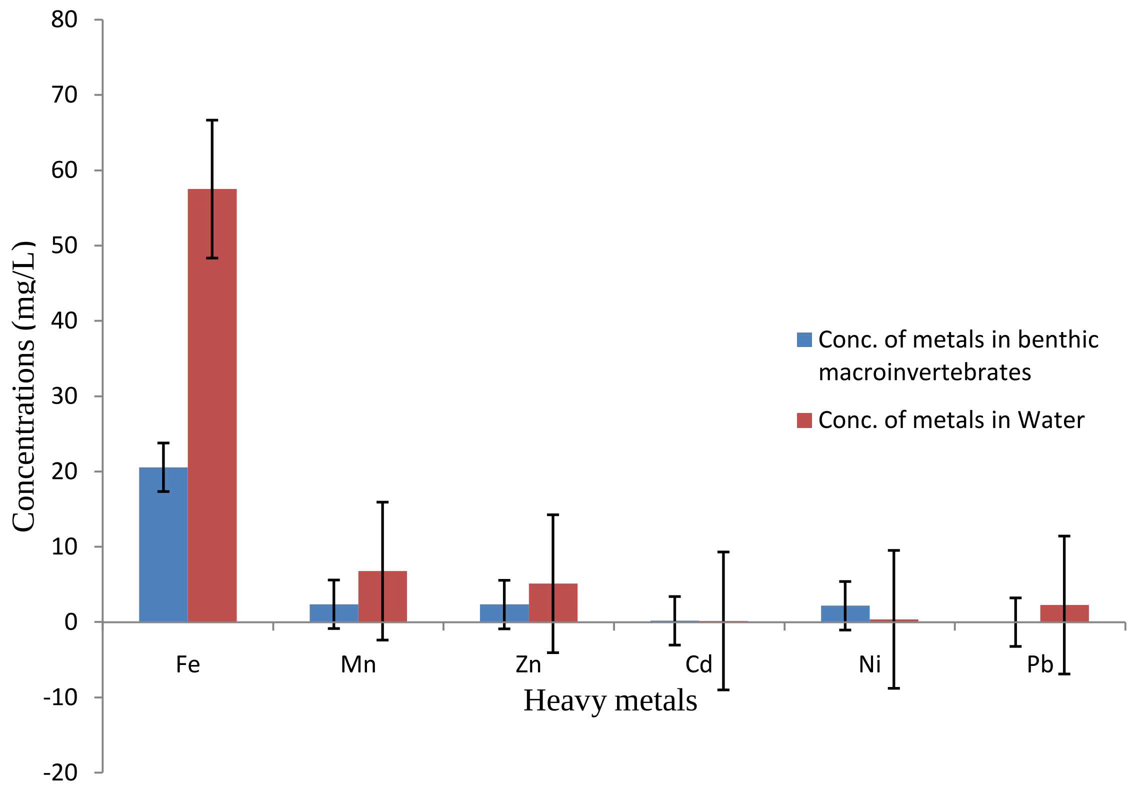

Fig. 4.18: Relationship between heavy metal concentrations in water sample and macrobenthic invertebrate in Kubanni reservoir

CHAPTER FIVE

5.0 DISCUSSION

Ecological dynamics of Makwaye and Kubanni reservoirs was associated with rainfall, wind and solar radiation. These driving forces determine the intensity of different processes operating in reservoir ecosystem as pointed out by Chalar and Tundisi (1999). Other factors like reservoir hydrology and nutrients influence the population dynamics of the reservoir. This type of observation has been reported by Mallin (1994). The physical factors studied in this research interacted with the chemical factors to produce energy flow, nutrient cycling, and organic materials, all of which contributed significantly in producing a viable, sustainable reservoir ecosystem rich in diverse macrobenthic invertebrates. The water budget of the reservoir was governed by direct rainfall, evapo-transpiration and water withdrawal for municipal, domestic and Agricultural uses.

The fluctuations in the pH in the two reservoirs indicate the buffering capacity of total alkalinity. The slight acidic pH 6.12 in Makwaye reservoir and pH 6.43 in Kubanni reservoir recorded during the dry seasons may be due to high concentration of carbon dioxide produced from decomposition of organic materials. Egborge (1977) and Elliot (1986) reported similar observation in Asejire reservoir. Other factors that might have led to the low pH include higher input of allochtonous and autochtonous organic materials into the reservoirs and higher temperature which speeds up the decay process. Lower pH values in the dry season have also been reported for other reservoirs in Nigeria (Kolo, 1999). For a larger part of the study, the surface water pH was in the neutral or moderate alkaline medium which was recorded mostly during the wet season. The reason for this could be higher water volume, with greater water retention, low decomposition and good buffering capacity of total alkalinity. Kolo (1999) and Mustapha (2006) have all reported alkaline pH in various Nigerian lakes and reservoirs during the wet season. Overall, the mean pH range of Makwaye reservoir (6.12 – 7.62) and Kubanni reservoir (6.43 – 7.49) was good and could have allowed for the survival of macrobenthic invertebrate in the reservoir. Tepe *et al.* (2005) reported that most natural waters have pH values between 5 to 10, with greater frequency of values falling between 6.5 to 9 and sustain biota.

Electrical conductivity was another important parameter used in measuring the water quality (Moore, 1989) of the reservoirs. The conductivity of Makwaye and Kubanni reservoirs were low and their mean range could be compared to other reservoirs in Nigeria. Low conductivity of Nigerian rivers and reservoirs has been reported by Imevbore (1975). The low conductivity might be responsible for the very soft nature of the water. Increased concentration of cations such as calcium, magnesium and sulphate during the rains might be responsible for the higher conductivity of the water at that period. Imevbore (1975), Adeniji (1991) and Kemdirim (2005) have all noted higher conductivity of water in the rains. High conductivity of the water in the wet season could be attributed to influx of nutrients from the rocks, watershed, surface run-offs and dissolved solids. Slight variation of conductivity observed between the two reservoirs could be due to utilization of the ions by flora and fauna. Kubanni reservoir which had the highest conductivity could be linked to high flood water which contains a lot of suspended and dissolved materials. Conductivity progressively decreased with time with lower value obtained in the dry season. The reason for this could be the utilization of most of these dissolved salts by planktons and macrophytes. According to Amarinsinghe and Vijverberg (2002), water conductivity usually decreases as a result of phytoplankton uptake of nutrients resulting in their bloom. Vincent *et al.* (1986) recorded minimal nutrient concentration during the dry season in lake Bahia, Bolivia. The short water residence time in the dry season could be another reason why nutrients did not remain long enough in the reservoir.

The mean ranged of conductivity 80.40 μS/cm – 178.80 μS/cm have been reported to support high diverse and abundant biotic organisms. Water with very high conductivity has been found to decrease species number (Dumont, 1999). The range of electrical conductivity in this reservoir will also permit fishing with electricity (Electrofishing). Elecrofishing becomes difficult in waters with higher electrical conductivity above 550 μS/cm (Miranda, 2007). Low conductivity in Makwaye reservoir relative to Kubanni reservoir could be due to the hydrology of the flow regime in which nutrients contained from the head water has either settled or being utilized before getting to the station. Moore (1989) has reported this observation in Lake Superior, Duluth, U.S.A. Effect of human activities which put pressure and added organic and inorganic substances into station thereby causing ionic imbalance may also cause the low conductivity.

Total dissolved solids had a positive correlation with electrical conductivity. The higher the electrical conductivity, the higher the total dissolved solids. Higher values of total dissolved solids during the rainy season may be attributed to run-off from sediments and catchments water shed into the reservoir. Araoye (1997) made similar observation in Asa reservoir. The settling of the dissolved solids coupled with the uptake of the major ions may be adduced for the lower values of total dissolved solids seen in the dry season. High inflow of dissolved materials in to Kubanni reservoir due to its nature could have accounted for the significant high TDS in the reservoir especially in the rains. The range of total dissolved solids fell within tolerable limit for drinking water as the TDS did not exceed 500mg/L. High TDS in drinking water has been known to cause unpleasant taste, hardness, stains, salty tastes and coloured water, such water might not be suitable for irrigation. High TDS could also have impact on benthic ecology. According to Rawson and Moore (1994), TDS in excess of 15,000 mg/L were unsuitable for freshwater organisms.

The surface water temperature of Makwaye and Kubanni reservoirs which ranged from 20.13ºC to 29.90ºC and 18.87ºC to 28.25ºC was similar and compared well with the ranges reported for the surface water temperature of most Nigerian reservoirs such as Upper Ogun (Adebisi, 1981), Shiroro (Kolo, 1999). Lower surface temperatures were observed during the three months of early dry season, while higher temperatures were recorded during the early months of wet season. Similar observations have been reported by Khan and Ejike (1984) in Jos reservoirs and Balarabe (1989) in Makwaye Reservoir. The lower temperature in December may be attributed to the cool dry north east trade winds popularly called harmattan. The low water temperature could also be attributed to low sunshine duration and low incident radiation. The temperature range of 20.13ºC to 29.90ºC and 18.87ºC to 28.25ºC obtained was normal for metabolic activities of aquatic organisms most especially the plankton and macrobenthic invertebrate in the reservoirs. The high temperature and low temperature could also be due to changes in air temperatures and relative humidity as a result of rains and harmattan (Olaniyan, 1975).

The concentration of dissolved oxygen recorded in Makwaye and Kubanni reservoir were similar to the range observed in other reservoirs such as Shiroro (Kolo, 1999), Awba (Yakubu, 2004) and Moro (Mustapha, 2006). Higher dissolved oxygen values obtained during the rainy season could be as a result of low temperature, higher phytoplankton activities which produce autochthonous oxygen and the mixing of water due to high water velocity. Petrovic (1981) reported that wind induced mixing enriches dissolved oxygen content of waters with atmospheric oxygen. Imvebore (1975) and Adeniji (1991) had earlier reported high concentration of oxygen during the rainy season in Kainji and Jebba lakes respectively, while Tepe and Mutlu (2005) linked increase in dissolved oxygen concentration in Hatay Harbiye reservoir in Turkey to high run-offs occurring during the rainy season. The highest concentration of dissolved oxygen noted in Makwaye reservoir could be attributed to its transitional zone status between riverine and lentic ecosystem sections of the reservoir and strong wind diffusion. Human activities, high rate of decomposition and less wind action in Kubanni reservoir might be accountable for the low dissolved oxygen concentration recorded in the reservoir. Low dissolved oxygen concentration recorded in the dry season in Makwaye reservoir relative to Kubanni reservoir may be due to higher temperature, high rate of decomposition and high consumption of the dissolved oxygen through respiration by aquatic organisms such as the fishes, phytoplankton, zooplankton and macrobenthic invertebrate. Also the low dissolved oxygen could be due to dendritic nature of the reservoir (Kalff, 2003) and the absence of high water velocity. Brook (1995) similarly recorded low dissolved oxygen concentration in the dry season in a tropical reservoir of Ethiopia, while Wetzel (2001) reported that zooplanktons and fishes contribute to a severe reduction in oxygen concentration in reservoirs and lakes during the dry season. Generally, the mean range of dissolved oxygen in Makwaye and Kubanni reservoirs are 2.02 - 7.33 mg/L and 2.11 - 5.97 mg/L was good and this may account for the high rate of survival of biotic organisms. According to Boyd (1979), dissolved oxygen concentration of 3 to 12 mg/L will promote the growth and survival of fishes and macrobenthic invertebrate in reservoirs and ponds, but they may become stressed if the concentration is less than 5 mg/L, while APHA (2005) explained that dissolved oxygen concentration of above 5 mg/L is suitable for the support of diverse biota.

The mean range of biochemical oxygen demand (0.62 - 2.96 mg/L and 0.37 - 2.97 mg/L) respectively in Makwaye and Kubanni reservoir showed the reservoir to be less polluted compared to other reservoirs in Nigeria. The low BOD values are indications of very little or no discharge of industrial effluents into the upstream of the reservoirs. High BOD has been linked to pollution (Tepe and Mutlu, 2005). Higher biochemical oxygen demand concentration was found in the dry season with the highest value been recorded in Kubanni reservoir. This probably could be due to high rate of decomposition, intense human activities of fishing and water use, sewage and agricultural run-off from the catchments area into the reservoir. Though the range of biochemical oxygen demand fell within permissible level for drinking and macrobenthic invertebrate production, APHA (2005) however, recommended that B.O.D levels should be less than 2 mg/L in drinking water. The low level of biochemical oxygen demand obtained in the rainy season could be as a result of the effects of run-offs which brought in large amount of allothonous organic matter and caused the resuspension of autochthonous materials.

Organic decomposition brought about by high temperature in the dry season could be the reason for the significant difference noted between the dry and wet season values of biochemical oxygen demand. The probable reason for the high amount of BOD recorded in Kubanni reservoir could be due to impact of human activities which caused the release of organic materials into the reservoir thereby prompting high rate of decomposition.

The total alkalinity of Makwaye and Kubanni reservoir is a reflection of its carbonate and bicarbonate profiles with likelihood of silicates and phosphates contributing to it. Campbell and Wildberger (2001) reported that phenolphthalein alkalinity is usually high in waters dominated by bicarbonates ions. Higher values obtained during the wet season could be due to the release of bicarbonates ions by sediments and rocks (Wetzel, 2001). The mean range of total alkalinity (22.3 - 38.9 mg/L and 22.4 - 43.3 mg/L) compared favourably well with the range given for lakes and reservoirs by U.S.E.P.A (1976). The total alkalinity value could have had an impact in the productivity of the reservoir. According to Carlander (1955), positive correlation exists between alkalinity and macrobenthic invertebrate production, while it is believed that total alkalinity above 40 mg/L is indicative of high productivity (Sugunan, 1995). Alkalinity was a buffer for pH changes caused by photosynthesis thus helping to stabilize the pH in the reservoir. The higher concentration of total alkalinity in July in Kubanni reservoir could be due to the presence of carbonates and bicarbonates ions. The higher total alkalinity in Kubanni reservoir than Makwaye reservoir supports the limnological theory that carbonates and bicarbonates contribute to the total alkalinity of reservoirs (Wetzel, 2001).

The variation in nitrate concentration reflects the effects of human activities on various sections of the reservoir. Nitrate was found to have effects on the chemical properties and macrobenthic invertebrate composition and abundance in the reservoir. Makwaye and Kubanni reservoirs recorded the highest mean concentration of nitrate at 25.00 mg/L and 30.00 mg/L respectively in the month of August. This could have come from nitro-phosphate fertilizer run-off from nearby farm lands. The time corresponds to the peak of agricultural activities around the reservoir location. Carignan *et al.* (2000) linked changes in lakes water quality and structural biodiversity to intensified land use practices within their catchments. High nitrate concentration at Kubanni reservoir can be associated with nutrient of the reservoir caused by human influences. Carpenter *et al.* (1998) reported that nonpoint source nutrients inputs from the water shed are the leading cause of eutrophication and water quality problems.

Lower inputs of nitro-phosphate fertilizers and dilution of water must have been responsible for the tolerable limit and low concentration of nitrate recorded in Makwaye reservoir and also in other months. There was also decrease in nitrate concentration in the dry season. Akpan *et al*. (1993) had also reported lower nitrate concentration in the dry season in some eastern Nigeria rivers.

Anthropogenic activities from the municipal use of the water in some parts of the reservoirs, and non-point source of nitrate from nitro phosphate fertilizers leaching into the water body may be the reason for the similarity between the two reservoirs.

Like nitrogen, phosphate concentration was higher in Makwaye and Kubanni reservoir during the rainy season. This could also be attributed to the leaching and inflow of nitro-phosphate (NPK) fertilizers commonly used by farmers from near farm lands into the water body. Nitrate and phosphate has been linked to eutrophication. Nitrate and phosphate are the principal production-limiting nutrients in freshwaters; their excessive loading can adversely affect receiving waters.

Like nitrate, phosphate stimulates phytoplankton growth. Higher algal productivity has been reported to stimulate the release of phosphorous from sediments (Scheffer, 2004). The range of phosphate at the two reservoir is within the limit for most fresh waters, and fell within the range recorded in Jebba lake (Adeniji, 1991) and Shiroro reservoir (Kolo, 1999). Allochtonous sources of phosphate from fertilizer application on farmlands and the use of phosphate detergents for washing may account for the close relationship between the two reservoirs.

The chemical denudation due to dilution from heavy rains coupled with reservoir circulation might have contributed to the availability of calcium. Weathering of soil and rock, run-offs from surrounding watershed and high rainfall could be the sources of these ions. The high concentration of calcium ions during the rainy season could be due to the rainfall which carried most of these salts to the reservoir. This phenomenon has been reported by Lesack and Melack (1991). This probably explains why Kubanni reservoir had the highest concentration of calcium ions. The lower values obtained during the dry season may have occurred as a result of the uptake of the ions by planktons. Calcium is used by shell animals and zooplanktons to build their shell. The presence of calcium ions in significant amount in the reservoir contributed to the productivity and biotic composition of the planktons and subsequently to the abundance of macrobenthic invertebrate. According to Campbell and Wildberger (2001), waters with calcium levels of 10 mg/L are usually oligotrophic and support sparse animal and plant life while waters with calcium levels of above 25 mg/L are eutrophic and support diverse plant and animal life. Inputs from head water and tributaries which contain a high amount of calcium must have been a major factor for the high concentration of calcium observed in Kubanni reservoir. The utilization of this nutrient by zooplankton and macrobenthic invertebrates in Makwaye reservoir may be the reason why lower concentration was recorded in this reservoir. The significant difference recorded in the concentration of calcium ion within the twelve months of study may be due to high rainfall and utilization of the ion by the aquatic organisms.

Positive correlation that exists between the macrobenthic invertebrate and some physicochemical parameters in both reservoirs can be as a result of their importance in body physiology and survival of these organisms. The benthic fauna of the study areas was dominated by molluscs. The low numerical abundance and diversity are largely due to physical variability of the study area, sampling methodology, and the prevailing ecological conditions, including the state of contamination from anthropogenic sources of the study areas at the time of study. However, the abundance of macrobenthic invertebrate was recorded to be higher in the dry season in Makwaye reservoir but lower or no significant different in Kubanni reservoir. This can be due to dredging activity that was going on at the reservoir in the dry season during the study. Dredging of reservoir can lead to physical disturbance of aquatic environment leading to decrease in abundance and diversity.

The monthly variation in the density of macro-invertebrates as observed from the study could be due to the variation in the physicochemical factors which also indicates the presence of dissolved organic matter in the two reservoirs. The population density of living organisms in aquatic environment usually varies with the variation of environmental parameters.

The presence of pollution-tolerant macroinertebrate such as *Chironomus* sp which recorded the highest abundance, *Lymnaea* sp and *Bulinus* sp could be attributed to the effect of domestic and industrial wastes in the river. DO and BOD values recorded in the present study may have favour the presence of these pollution indicator species. The adaptations of *Chironomus* sp include possession of pigment hemoglobin which gives it a high affinity for oxygen (Mason, 1991), hence their tolerance of low DO. These are characteristic species in water showing some degree of change due to anthropogenic activities in the river. Their high presence is a common feature of organically polluted water bodies (Atobatele *et al*., 2005; Chindah *et al*., 1999). Studies on Ogunpa River were on physico-chemical parameters and macro-invertebrates fauna (Adeyemo *et al.*, 2008; Atobatele *et al*., 2005). Similar results were also reported by (George *et al*., 2009).

In Makwaye reservoir, they were more diversity of macrobenthic invertebrate, as the Shanon-Weiner diversity index is higher in both dry and wet season. A value of this index above three indicates clean water, whereas values fewer than this would indicate pollution (Maiti, 2004) and the higher the value, the greater the diversity. Although the range of this index in Makwaye reservoir was from 2.04 to 2.42 which indicate that the reservoir is mildly polluted. The lowest value in wet season can be due to increase in volume of water and methods of sampling and also the high value in dry season can also be due to decrease in volume of water and the methods of sampling. This result is in line with the study of (Nkwoji and Edokpayi, 2013).

In Kubanni reservoir, the result recorded was different with that of Makwaye reservoir. The Shanon-Weiner diversity index in dry season was the lowest while the highest value was recorded in wet season. This can be due to the effect of dredging going on at the time of the study. So also the result was in line with work of (Robinson *et al*., 2005; Newel *et al*., 2004).

Macrobenthic invertebrate and water samples from the two reservoirs in this study contained wide range of metals at different concentrations. These concentrations of heavy metals in macrobenthic invertebrate and the reservoir are primarily controlled by bedrock and overburden of the catchment. The significant variation in metal concentrations in the macrobenthic invertebrates suggests that the different metals accumulate in different patterns and concentrations in the body of the macrobenthic invertebrates. The different forms (colloidal, particulate, and dissolved forms) that metals exist in water have predisposed macrobenthic invertebrates to continuous metal intake.

High concentration of heavy metals recorded in the dry season can be as a result of decrease dilution due to lack of rain, increase exposure to the metals and activities in the catchment areas. However Cd and Pb were below detectable limit in dry and wet season in macrobenthic invertebrates at Makwaye reservoir and Pb was also below detectable limit in both seasons at Kubanni reservoir. But for water samples, only Cd was below detectable limit in Makwaye reservoir but detected in Kubanni reservoir. So also Pb was detected in water samples from the two reservoirs. This can be due to a difference in the catchment of the two reservoirs (Shuman *et al*., 1997)

Fe recorded the highest values in the two reservoirs and this can be due to smaller sized particles which remain suspended in the water column longer than larger particles, enhancing suspended metal concentrations. This is in line with the work of (Shuman *et al*., 1997).

The low levels of Cd and Pb may be attributed to less industrial and mining operations in the catchment of the reservoir which is considered the main source of Cd in the environment (Iguisi *et al*., 2001).

The most important reason for Zn pollution in the two reservoirs can be as a result of high human activity such as discharge of sewage, sludge and use of fertilizers. However, Zn is an essential element for plants and is taken up actively by roots (Khan *et al*., 2000).

The higher concentration of heavy metals in *Lumbriculid* sp can be attributed to its body anatomy and physiology in response to concentration of the metals. Though the variation in concentrations of the metals in the species of macrobenthic invertebrate in this study may be due to differences in physiological ability to maintain internal metal concentrations or could be from species-specific capacity to regulate or accumulate trace metals (Reinfelder *et al*., 2013).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

There is significant difference in mean monthly and seasonal variation in physicochemical characteristics of Makwaye and Kubanni reservoirs. The physical and chemical properties of Makwaye and Kubanni reservoirs at the time of this study showed the surface water quality to be moderately polluted. The determinants used in arriving at these classes of classifications such as dissolved oxygen, nitrate, phosphate, biological oxygen demand, conductivity, total dissolved solids and pH were found in the range acceptable for drinking water and aquatic organism production, irrigation and recreation (Hach, 2003).

There is significant difference in species composition and diversity of the two reservoirs.

The high abundance of pollution tolerant macrobenthic invertebrate in the two reservoirs indicate the level of pollution with Makwaye reservoir having more abundance of organisms and the pollution tolerant organisms. Makwaye and Kubanni reservoirs dynamics shows seasonality in their hydrology, productivity and periodicity with high macrobenthic invertebrate abundance in the dry season, with the water quality remaining moderately polluted at both seasons.

There is influence of physical and chemical properties of Makwaye and Kubanni reservoir on the changes in composition and diversity of the macrobenthic invertebrate. There is Positive correlation between the macrobenthic invertebrate and some physicochemical parameters in both reservoirs. Physicochemical properties such as BOD, DO, pH and Ca have significant influence on the presence of macrobenthic invertebrate in Makwaye and Kubanni reservoir

There is significant difference in heavy metal concentrations of the macrobenthic invertebrates.

The study has established that 6 different types of metal contaminants; Fe, Mn, Zn, Cd, Ni and Pb exist in macrobenthic invertebrate and water samples from the two reservoirs in various levels of concentrations.

Finally, Makwaye and Kubanni reservoir are subjected to rapid fluctuations in water level. These fluctuations could negatively impact the macrobenthic invertebrates of the two reservoirs as well as its primary productivity. These two reservoirs show similarities in macrobenthic invertebrate diversity. However the sudden difference in abundance during the dry season in Kubanni reservoir could be as a result of dredging activity which leads to physical disturbance of the benthic region of the reservoir at the time of this study.

6.2 Recommendations

Based on findings in this study, the following are recommended:-

i. Information obtained from reservoirs such as prognostication on reservoir pollution level, impacts of watershed uses, eutrophication and ecological interactions between various variables operating in a reservoir should be used as an important tool in the management, operation and conservation of the reservoir and its resources.

ii. Pre and post impoundment studies should be carried out before and after the reservoir construction. This will help in assessing the physico-chemical and biotic conditions of the river prior to impoundment.

iii. Emphasis should be place on water quality, quantity, eutrophication, aquatic fauna diversity and control of invasive species as part of reservoir management.

iv. Periodic, repetitive limnological measurements should be carried out on the reservoir to monitor and track the trend of changes of its water quality and quantity, productivity, periodicity and biodiversity. This becomes especially important in view of the effect of human pressures and activities on the reservoir.

v. Changes caused by the dredging of Kubanni reservoir to water quality and fauna diversity should also be tracked and monitor by periodic repetitive measurements of the physico-chemical and biotic characteristics of the reservoir to see the restoration face of this reservoir after dredging (post dredging effect). This will help in determining the reaction to alteration in living conditions and track changes in species composition and abundance.

vi. Enforcement of strict regulations to control fishing, irrigation activities close to the reservoirs will help in minimizing or control of pollution and loss of fauna in the reservoir.

vii. Excessive water withdrawal should not be permitted and watershed abuses should be stopped.

viii. Basic and applied multi-disciplinary and integrated management-driven limnological research towards the optimization of multiple use of the reservoir for water supply, fish production and recreation should be carried out.

ix. Further study on Makwaye and Kubanni reservoir should incorporate other physical and chemical factors that are not necessarily linked to organic production or pollution level as a result of anthropogenic activities, but are essential as indicators of pollution and are important in the composition, distribution and abundance of aquatic organisms as well as in the normal functioning of the reservoir ecosystem.

x. Attention should also be focused on the aging process of the reservoirs and its effect on composition and abundance of species.

xi. The biology of aquatic macrophytes and the benthos should be undertaken to elucidate their effects or contribution to water quality, fish production and general productivity of the reservoir.

REFERENCES

Abolude, D.S. (2007). *Water quality and metal concentration in sediments and fish from Ahmadu Bello University Reservoir, Zaria using Neutron Activation Analysis and Atomic Absorption Spectrophotometer*. Unpublished PhD. Thesis, Department of Biological Sciences, ABU, Zaria. Pp 7-30.

Abolude D.S., Davis, O.A. and Avong, D.W. (2009). Level of heavy metals in fresh water crab (*Cardisomaguahumi*) obtained from Ahmadu Bello University Reservoir, Zaria Nigeria. *International Journal of Animal and Veterinary Advances*, **1**(2): 54-58.

Adakole, J.A. and Anunne, P.A. (2003). Benthic macro invertebrates as indicators of environmental quality of an urban stream, Zaria, Nigerian. *Journal of Aquacultural Science*, **18**(2): 85-92.

Adakole, J.A. and Abolude, D.S. (2012). Pollution status of Kubanni lake through metal concentration in water and sediment columns, Zaria, Nigeria. *Research Journal of Environmental and Earth Sciences,* **4**(4): 24-27.

Adebisi, A.A. (1981). The physico-chemical properties and hydrology of a tropical seasonal river- upper Ogun river. *Hydrobiologia*, **79**: 157-165.

Adeniji, H.A. (1991). *Limnology and biological production in the pelagic zone of Jebba lake, Nigeria*. Ph.D thesis. University of Ibadan, Ibadan, Nigeria. 278 pp.

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

Akpan, R., Ekom, A. and Offem, J. (1993). Seasonal variation in water quality of the Cross River, Nigeria. *Revue d'Hydrobiolgie Tropicale*, **25** (1): 23-33.

Allan, D.J. (1995). *Stream ecology: structure and function of running waters.* London, Weinheim, New York, Tokyo, Melbourne, Madras, Chapman and Hall, 388 pp.

Amarinsinghe, P.B. and Vijverberg, J. (2002). Primary production in a tropical reservoir in Sri Lanka. *Hydrobiologia,* **487**: 85-93.

Amman, A.A., Michalka, B. and Schramel, P. (2002). Speciation of heavy metals in environmental water by ion chromatography coupled to ICP-MS. *Biochemistry*, **372**:448-452.

APHA (American Public Health Association), (1998). *Standard methods for the examination of water and waste water*. 20th edition. American Public Health Association Inc., New York. 1193 pp.

APHA (American Public Health Association), (2005). *Standard methods for the examination of water and waste water*. 2nd edition. American Public Health Association Inc., New York. 1193pp.

Araoye, P.A. (1997). *Bio-ecology of a mochokid, Synodontis schall (Bloch and Scchneider 1801) in Asa dam, Ilorin, Nigeria*. Ph.D Thesis, University of Ibadan, Ibadan, Nigeria. 201 pp.

Arimoro, F.O., Ikomi, R. B. and Efemuna, E. (2007). Macroinvertebrate community patterns and diversity in relation to water quality status of River Ase, Niger Delta, Nigeria. *Journal of Fisheries and Aquatic Science*, **2**(5): 337-344.

Armengol, J., Riera, J.L. and Morgui, J.A. (1991). Major ionic composition in the Spanish Reservoirs. *Verhandlungen Internationale Vereinigung für Theoretische und Angewandte Limnologie*, **24**: 1363-1366.

Atobatele, O.E, Morenikeji, O.A, and Ugwumba, O.A. (2005). Spatial variation in physical and chemical parameters of macrobenthic invertebrate fauna of River Ogunpa, Ibadan. *The Zoologist*, **3**: 58–67.

Balarabe, M. L. (1989). *Limnology and zooplankton distribution of Makwaye (Ahmadu Bello University Farm) reservoir, Samaru Zaria, Nigeria*. M. Sc. Thesis, Ahmadu Bello University, Zaria. 164 pp.

Balarabe, M.L., Balogun, J.K. and Igberaese, P.M. (2004). Some aspects of the limnology of Makwaye (Ahmadu Bello University Farm) reservoir, Samaru, Zaria. *Journal of Biosciences.* Pp 851-858

Balogun, J.K. (1986). Fish distribution in Kainji lake, Nigeria. *Journal of Fish Biology*, **29**: 489-498.

Barbosa, F.A.R., Callisto, M. and Galdean, N. (2001). The diversity of macrobenthic invertebrates as an indicator of water quality and ecosystem health: A case study for Brazil. *Aquatic Ecosystem Health and Management*, **4**(1): 51-59.

Barbour, M.T., Gerritsen, J., Snyder, B.D. and Stribling, J.B. (1999). *Rapid Bioassessment Protocols for use in streams and wadeable rivers*. periphyton, macrobenthic invertebrates and fish, Second edition. Pp. 99-202.

Barnes, R.D. and Hughes, S. (1988). *An Introduction to Marine Ecology*. 2nd Edition. Blackwell Scientific Publications, UK. 351 pp.

Berman, T. and Steinman, B. (1998). Phytoplankton development and turbulent mixing in Lake Kinneret. *Journal of Plankton Research*, **20**: 709-726.

Bottrell, H.H., Duncan, A., Gliwicz, Z.M., Grygiererek, E., Herzig, A., Hillbricht-Ilkowska, A., Kurasawa, H., Larson, P. and Weglenska, T. (1976). A review of some problems in zooplankton studies. *Norwegian Journal of Zoology,* **24**: 419-456.

Boyd, C.E. (1979). *Water quality in warm water fish ponds*. Craftmaster Printers Inc. Auburn, Alabama, USA. 353 pp.

Boyd, C.E. and Lichtkoppler, F. (1979). Water quality management in pond fish culture. *Research and Development series,* **22**(1): 22-30.

Brinley, F.J. (1974). *Biological studies of house document* 266, 78th congress. 1st session part 11 supplement. Pp. 1275-1353.

Brook, L. (1995). Seasonal limnological studies on lake Alemaya: a tropical African lake, Ethiopia. *Archive fur Hydrobiologie/Supplement*, **107**: 263-285.

Brook, L. (2002). Contrasting effects of human activities on aquatic habitats and biodiversity of two Ethiopian lakes. *Ethiopian Journal of Natural Resources,* **4** (1):127- 148.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D. and Rodrigues, A.S.L. (2006). Global biodiversity conservation priorities. *Science*, **13**(5): 58–61.

Cammusso, M., Vigano L. and Baistrini, R. (1995). Bioaccumulation of trace metals in rainbow trout. *Ecotoxicology Environment Safety*, **31**:133-141.

Campbell, G. and Wildberger, S. (2001). *The monitor's handbook. A Reference Guide for Natural Water Monitoring*. LaMotte Company, Chestertown, Maryland, USA. 63pp.

Carignan, R., Arcy, P. and Lamonangne, S. (2000). Comparative impacts of fire and forest harvesting on water quality in boreal shield lakes. *Canadian Journal of Fish and Aquatic Sciences*, **57**(2): 105-117.

Carlander, K.D. (1955). The standing crops of fish in lakes. *Canadian Journal of Fish and Aquatic Sciences*, **12**(4): 543-570.

Carlo H.R., Peter M.J. and Karline S. (1998). Indices of diversity and evenness. Netherlands Institute of Ecology Centre for Estuarine and Coastal Ecology. *Oceanis*, **24**: 62-69.

Carpenter, S.R., Caranco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H. (1998). Non point pollution of surface waters with phosphorous and nitrogen. *Ecological Applications*, **8**: 559-568.

Censi, P., Spoto, S. E., Saiano, F., Sprovieri, M. and Mazzola, S. (2006). Heavy metals in coastal water system. A case study from the North Western Gulf of Thailand. *Chemosphere,* **64**:1167-1176.

Chalar, G. and Tundisi, J.G. (1999). Main processes in the water column determined by wind and rainfall at Lobo (Broa) reservoir. Implications for phosphorous cycling. In: Tundisi, J.G and Straskraba, M. (Ed). *Theoretical Reservoir Ecology and its Applications*. Backhuys Publishers, Brazilian Academy of Science. pp.477-491.

Chao, A. (2004). Species richness estimation. In Balakrishnan, N. Read, C. B. and Vidakovic, B. (Ed) *Encyclopedia of Statistical Sciences*. A comprehensive review of the statistical methods for estimating richness. New York: Wiley. Pp. 136-141

Charvet, S., Kosmala, A. and Statzner, B. (1998). Biomonitoring through biological traits of macrobenthic invertebrates. *Archiv fur Hydrobiologie*, **142**(4): 415-432.

Chindah, A.H., Hart, A.I. and Atuzie, B. (1999). A preliminary investigation on the effects of municipal waste discharge on the macrofauna associated with macrophytes in a small freshwater stream in Nigeria. *African Journal of Applied Zoology*, **2**:29–33.

Clair, N., Perry, L. M., and Gene, F. P. (2003). *Chemistry for Environmental Engineering and Science* (5th ed.). New York, McGraw-Hill. Pp. 124-226.

Coutant, C.C. (1975). Response of bass to natural and artificial temperature regimes. In: Stroud, R.H. and Clepper, H. (Ed) *Black Bass Biology and Management*. Sport Fishing Institute, Washington, D.C. Pp. 272-285.

Cummins, K. W. (1995). Invertebrates. In: Calow, P. and. Petts, G. E (Ed) *The Rivers Handbook*. Blackwell Scientific,Oxford. pp. 234–250.

Delong, M.D. and Brusven, M.A. (1998). Macroinvertebrate community structure along the longitudinal gradient of an agriculturally impacted stream. *Environmental Management*, **22**(3): 445-457.

Dillon, P.J. (1975). The phosphorous budget of Cameron Lake, Ontario: the importance of flushing rate to the degree of eutrophy of lakes limnology. *Oceanography*, **19**: 767-773.

Djukic, N., Maletin, S., Pujin, V., Ivanc, A. and Milajonovic, B. (1994). Ecological assessment of water quality of Tisze by physico-chemical and biological parameters. *Tisca Szeged,* **28**(1): 37-40.

Dudgeon, D. (2003). The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia*, **50**: 295-314.

Dumont, H.J. (1999). The species richness of reservoir plankton and the effect of reservoirs on plankton dispersal (with particular emphasis on rotifers and cladocerans). In: Tundisi, J.G. and Straskraba, M. (Ed). *Theoretical Reservoir Ecology and its Applications*. Backhuys Publishers, Brazilian Academy of Science, Pp. 477-491.

Edward, J. B. and Ugwumba, A. A. (2011). Macroinvertebrate fauna of a tropical Southern Reservoir, Ekiti State, Nigeria. *Continental Journal of Biological Sciences*, **4** (1): 30-40.

Egborge, A.B.M. (1977). *The hydrology and plankton of Lake Asejire, Nigeria.* Ph.D Thesis. University of Ibadan, Ibadan, Nigeria. Pp. 120-173.

Elliot, O.O. (1986). *Some Aspects of the Biology of fishes of Asejire Reservoir*. Ph.D Thesis, University of Ibadan, Nigeria. 301 pp.

Farkas, A., Salanki, J., Specziar, A. and Varanka I. (2001). Metal pollution as health indicator of lake ecosystems. *International Journal of Occupational Medical Environmental Health*, **14** (2): 163-170.

Flores, M. J. L. and Zaffaralla, M. T. (2012). Macroinvertebrate composition, diversity and richness in relation to the water quality status of Mananga River, Cebu, Philippines. *Philippine Science Letter*, **5**(2): 103-113.

Gadzama, I. M. K., Muhammad, R., Dariya, S. and Tabita, G. S., (2013). Comparative Metal Analysis of the Soft Tissues of Three Species of Anodonta (Class: Bivalvia) From Kubanni lake in Zaria, Nigeria. *Journal of Environmental Science, Toxicology and Food Technology*, **6**(3): 18-23.

Gallep, G.W., Kitchell J.F. and Bartell, S.M. (1978). Phosphorus release from Lake Sediments as affected by chironomid. *Inland Waters Journal of The International Society of Limnology*, **20**: 458-465.

Gao, F. (2011). Ecological characteristics of macrobenthic communities in the Chaohu lake basin and their relationship with environmental factors. *Inland Waters Journal of The International Society of Limnology*, **7**(2): 458-465.

George, A.D., Abowei, J.F., and Daka, E.R. (2009). Benthic macro invertebrate fauna and physico-chemical parameters in Okpoka creek sediments, Niger Delta. *Nigeria International Journal of Animal and Veterinary Advances*, **1**(2): 59-65

Golterman, H.L. (1978). *Physiological Limnology*. Elsevier, Amsterdam. 489 pp.

Hach, A. (2003). *Water analysis handbook* (Fourth edition), Hach Chemical Company, Loveland, Colorado USA. Volume 2, 1268 pp.

Hanna (2003). *The Hanna Catalog*. Hanna Instruments Inc. Woonsocket RI, USA.

Hanson, J.M. and Leggett, W.C. (1982). Empirical prediction of fish biomass and yield. *Canadian Journal of Aquatic Sciences,* **39**(2): 257-263.

Harper, A. (1992). *Eutrophication of freshwaters, Principles, Problems and Restoration*. Chapman and Hall, London. Pp.127-223.

Hawkins, C.P. and Vinson, M.R. (2000). Weak correspondence between landscape classifications and stream invertebrate assemblages. Implications for bioassessment. *Journal of the North American Benthological Society*, **19**: 501-517.

Heino, J., Muotka, T. and Paavola, R. (2003). Determinants of macroinvertebrate diversity in headwater streams. *Regional and Local Influences,* **7**(3): 501-517.

Henderson, H.F. and Welcomme, R.L. (1974). *The relationship of morpho-edaphic index and numbers of fishermen in African inland fisheries*. CIFA Occasional Paper, FAO, Rome. Paper 1. 19 pp.

Henry, R. (1992). The oxygen deficit in Jurumirim reservoir (Paranapanema River, Sao Paulo, Brazil). *Japanese Journal of Limnology*, **53**: 379-384.

Horne, A.J. and Goldman, C.R. (1994). *Limnology*. McGraw-Hill, Inc. New York. 576pp.

Idowu, E.O. and Ugwumba, A. A. (2005). Physical, chemical and benthic faunal characteristics in a Southern Nigeria Reservoir. *The Zoologist*, **3**: 15-25.

Iguisi, E.O., Funtua I.I. and Obamuwe, O.O. (2001). A Preliminary study of heavy metal concentrations in the surface water of the Kubanni reservoir, Zaria, *Nigerian Journal of Earth Sciences,* **1**(2): 26 – 34.

Imevbore, A.M.A. (1975). The chemistry of Lake Kainji Waters- August 1968 to September 1969. In: Imevbore, A.M.A and Adegoke, O.S. (Ed) *The ecology of Lake Kainji- the transition from river to lake*. University of Ife Press, Nigeria. pp. 146-148.

Jackson, D.C. and Ye, Q. (2000). Riverine fish stock and regional agronomic responses to hydrological and climatic regimes in the Upper Yazoo River Basin. In: Cowx, I.G. (Ed) *Management and Ecology of River Fisheries*. Blackwell Scientific Publications, London. pp. 242-257.

Jenkins, R.M. (1982). The morpho edaphic index and reservoir fish production. *Transactions of the American Fisheries Society,* **11**(2): 133-140.

Kalff, J. (2003). *Limnology: Inland water ecosystems*. Prentice Hall Upper Saddle River, New Jersey. 592 pp.

Kemdirim, E.C. (1987). *Limnology and Trace elements studies in an upland and lowland impoundments in Plateau State, Nigeria*. Ph.D Thesis. University of Jos, Jos, Nigeria. 418 pp.

Kemdirim, E.C. (2005). Studies on the hydrochemistry of Kangimi reservoir, Kaduna, Nigeria. *African Journal of Ecology*, **43**: 7-13.

Kennish, M. J. (1992). *Ecology of Estuaries*: *Anthropogenic Effects*. CRC, Press, Boca Raton, 494pp.

Khan, A.G., Kuek, T.M., Chaudhry, C.S. and Hayes, W.J. (2000). Role of plants, mycorrhizae and phytochelators in heavy metal contaminated land remediation. *Chemosphere*, **41**: 197-207.

Khan, M.A. and Ejike, C. (1984). Limnology and plankton periodicity of Jos Plateau Water Reservoir, Nigeria, West Africa. *Hydrobiologia,* **114**: 189-199.

Kolo, R.J. (1999). The assessment of physico-chemical parameters of Shiroro Lake and its major tributaries. In: Eyo, A.A. (Ed) *Proceeding of the Annual Conference of the Fisheries Society of Nigeria*, Pp.260-268.

Lancaster, J., Hildrew, A.G. and Townsend, C.R. (1991). Invertebrates predation on patchy and mobile prey in streams. *Journal of Animal Ecology*, **60**: 625-641.

Lesack, L.F.W. and Melack, J.M. (1991). The deposition, composition and potential sources of major ionic solutes in rain of the central Amazon basin. *Water Resources Research*, **27**:2953-2977.

Leveque, C., Balian, E. V. and Martens, K. (2005). An assessment of animal species diversity in continental water. *Hydrobiologia*, **542**:39-67.

MacFarlane, G. R. and Burchett, M. D. (2000). Cellular distribution of copper, lead and Zinc in the grey mangrove, Avicenna marina (Forsk). *Vierh Aquatic Botany*, **68**: 45-59.

Maiti, S.K. (2004). *Handbook of Methods in Environmental Studies*: *Water and Wastewater Analysis*. Second Edition ABD Publishers B-46, Natraj Nagar, Imliwala Phatak Jaipur, India. Vol. 1 Pp.255-258.

Mallin, M.A. (1994). Phytoplankton ecology of North Carolina estuaries. *Estuaries*, **17**: 561-574.

Malmquivst, B. (2002). Aquatic invertebrates in riverine landscapes. *Freshwater Biology*, **47**: 679-694.

Mason, C.F. (1991). *Biology of Freshwater Pollution*. Longman Scientific Technical, New York, USA. 350pp.

Melack, J.M. (1976). Primary productivity and fish yields in tropical lakes. *Transactions of the American Fisheries Society*, **105**: 575-580.

Minshall, G.W. and Robinson, C.T. (1998). Macroinvertebrate community structure in relation to measures of lotic habitat heterogeneity. *Archiv fūr Hydrobiologie*, **141**: 129-151.

Miranda, L.E. (2001). A review of guidance and criteria for managing reservoirs and associated riverine environment to benefit fish and fisheries. In: Marmulla, G. (Ed) *Dams, fish and fisheries- opportunities, challenges and conflict resolution*. FAO Fisheries Technical paper Rome, Italy, 419pp.

Miranda, L.E. (2007). Extending the Scale of Reservoir Management. In: Allen, M. and Sammons, S. (Ed). *Balancing fisheries management and water uses for impounded river systems*. American Fisheries Society. Bethesda, Maryland U.S.A., Pp. 135-144.

Moore, W.L. (1989). *NALMS management guide for lakes and reservoirs*. North American Lake Management Society. Madison, WI, USA. 44 pp.

Moss, B. (1980). *Ecology of Fresh Waters. Man and medium*, 2nd edn. Blackwell, Oxford. 362 pp.

Mustapha, M.K. (2003). A Pre-impoundment study of the limno-chemical conditions of Oyun Lake in Ilorin, Kwara State, Nigeria. *African Journal of Applied Zoology and Environmental Biology*, **5**: 44-48.

Mustapha, M.K. (2005). Alleviating poverty and enhancing food security through fish production in Man-made lakes. In: Araoye, P.A (Ed.) *Proceedings of the 19th conference of the Fisheries Society of Nigeria*. Pp. 893-896.

Mustapha, M.K. (2006). Effects of human activities on the biodiversity of a tropical man-made lake. *Nigerian Journal of Pure and Applied Sciences*, **21**: 1960-1968.

Mustapha, M.K. and Omotosho, J.S (2006). Hydrobiological studies of Moro Lake. *Nigerian Journal of Pure and Applied Sciences*. **21**: 1948-1954.

Nkwoji, J.A. and Edokpayi C.A. (2013). Hydrochemistry and community structure of macrobenthic invertebrates of Lagos lagoon, Nigeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, **5**: 119-1130.

Odum, E.P. (1971). *Fundamentals of Ecology*.3rd ed. London,W.B. Sanders. 546 pp.

Ogbeibu, A. E. and Oribhabor, B. J. (2002). Ecological impact of river impoundment using benthic macro invertebrates as indicators, *Water Research,* **36**: 227-236.

Olaniyan, C.I.O. (1975). *An Introduction to West African Animal Ecology*. 2nd Edition. Heineman Educational Books Ltd, London. 170 pp.

Pennak, R.W. (1978). *Freshwater Invertebrates of the United Stastes*. John Wiley and Sons Inc. 803 pp.

Petrovic, G. (1981). Chemical investigation of water and sediments of Lake Skadar. In: Karaman, G.S. and Beeton, A.M. (Ed) *The Biota and Limnology of Lake Skadar*, Smithsonian Institution Washington D.C., U.S.A 468 pp.

Post, G. (1983). *Textbook of Fish Health*. T.F.H Publication Inc. New Jersey, 4556pp.

Rabalais, N.N. (2002). Nitrogen in aquatic ecosystems. *Ambio,* **31**: 102–112.

Rast, W., Holland, M. and Ryding, S.O. (1989). *Eutrophication, Management framework for policy makers*. MAB digest 1.UNESCO, Paris. 83 pp.

Reid, G.K. and Wood, R.D. (1976). *Ecology of Inland Waters and Estuaries.* 2nd Ed. Van D. Nostrand Company, New York. 485 pp.

Reiger, H.A., Cordone, A.J. and Ryder, R.A. (1982). Total fish landings from freshwaters as function of limnological variables of East-Central Africa. Fish Stock in African Inland Waters. *Working Paper No. 3*. FAO Rome, 13 pp.

Reinfelder, J. R., Wang, W. X., Luoma S. N. and Fisher, N. S. (2013). Assimilation efficiencies and turnover rate of trace elements in marine bivalves: a comparison of oysters, clams and mussels. *Marine Biology*, **29**(19): 443 – 452.

Renn, C.E. (1970). *Investigating Water Problems*. *A Water Analysis Manual*. LaMotte Chemical Company, Chestertown, Maryland. 72 pp.

Robinson, J. E., Newell, R. C., Seiderer, L. J. and Simpson, N. M. (2005). Impacts of aggregate dredging on sediment composition and associated benthic fauna at an offshore dredge site in the southern North Sea. *Marine Environment Research*, **60**: 51−68.

Ryder, R.A. (1965). A method for estimating the potential fish production of north temperate lakes. *Annales Zoologici Fennici*, **94** (3): 214-218.

Scheffer, M. (2004). *Ecology of shallow lakes*. Kluwer Academic Publishers, the Netherlands. 357 pp.

Schindler, D.W. (1971): Carbon, Nitrogen and Phosphorous and the eutrophication of freshwater lakes. *Journal of Phycology,* **7** (4): 321-329.

Sharma, H. B., Agrawal, P. K. and Senagupta, P. (2000). Water quality of sewage drains entering Yamuna River at Mathura (UP). *Journal of Environmental Biology*, **21**(4):375-378.

Sharma, S., Sudha, D., and Dave, V. (2013). Macroinvertebrate community diversity in relation to water quality status of Kunda river, (M.P), India. *Discovery Publication*, **3**(9): 40-46.

Shuman, M. S., Smock, L. A. and Haynie, C. L. (1997). *Metals in the water, sediments and biota of the Haw and new hope rivers, North Carolina*. Department of Environmental Sciences and Engineering, School of Public Health University of North Carolina at Chapel Hill. Pp. 91-100.

Sugunan, V.V. (1995). Reservoir fisheries of India. *FAO Fish Technology Paper,* No. 345 Rome, Italy. 423 pp

Superales, J. B. and Zafaralla, M. T. (2008). Distribution of macrobenthic invertebrates at Malubog Bay of Moro Gulf, Western Mindanao, Philippines. *Journal of Environmental Research and Development*, **2**(3): 303-313.

Tampus, A. D., Tobias, E. G., Amparado, R. F., Bajo, L. and Sinco, A. L. (2012). Water quality assessment using macroinvertebrates and physico-chemical parameters in the riverine system of Iligan City, Philippines. *Environmental Sciences-International Journal of the Bioflux Society*, **4**(2): 59-68.

Tepe, Y. and Mutlu, E. (2005). Physico-chemical characteristics of Hatay Harbiye spring water, Turkey. *Journal of the Institute of Science and Technology of Dumlupinar University*, **6**: 77-88.

Tepe, Y., Turkmen, A., Mutlu, E. and Ates, A. (2005). Some physico-chemical characteristics of Yarselli Lake, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, **5**: 35-42.

Tundisi, J.G., Matsumura-Tundisi, T., Abe, D.S. and Reiss, V.L. (2002). Sustainable water sources in South America. The Amazon and La Plata basins. In: Mikiyasu N. and Juha I. U. (Ed) *Mikiyasu lakes and reservoirs as international water system, towards world lake vision*. Libor Jansky; United Nations University. Pp. 28-44.

Tundisi, J.G and Matsumura, T. (2003). Integration of research and management in optimizing multiple uses of reservoirs: the experience in South America and Brazilian case studies. *Hydrobiologia*, **500**: 231-242.

United State Environmental Protection Agency (U.S.E.P.A) (1976). *Quality criteria for Water*. Report No. EAP-440/9-76-023. Washington, D.C. 501 pp.

Veena, B., Radhakrishnan, C. K. and Chacko, J. (1997). Heavy metal induced biochemical effects in an estuarine teleost. *Indian Journal of Marine Science*, **26**: 74 – 78.

Vincent, W.F., Wurtsbaugh, W., Neale, P.J. and Richerson, P.J. (1986). Polymixis and algal production in a tropical lake. Latitudinal effects on the seasonality of photosynthesis. *Freshwater Biology*, **16**: 781-803.

Waters and Rivers Commission, (2010). Water Facts, 2nd Edition. Retrieved at http://www.wrc.wa.gov.au/ribbon. Pp. 10-23.

Welcomme, R.L. (1986). The effects of the Sahelian drought on the fishery of the central delta of the Niger River. *Aquaculture and Fisheries Management*. **17**: 147-154.

Wetzel, R.G. (2001). *Limnology: Lake and River ecosystems,* 3rd edition. Academic Press, New York. 1006 pp.

Yakubu, A.S. (2004). Assessment of water quality and plankton of effluent receiving lower Awba stream and reservoir, Ibadan. *African Journal of Applied Zoology and Environmental Biology*, **6**: 86-94.