DETERMINATION OF SOME HEAVY METALS IN KAINJI LAKE

BY

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B.Sc (CHEM) (A.B.U) 1986, P.G.D.E. (A.B.U) 1994

(M.Sc./SCIE/50223/2004-2005)

A THESIS SUBMITTED
TO THE POST GRADUATE SCHOOL AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE (ANALYTICAL CHEMISTRY)

Date: AUGUST 2006

DECLARATION

I hereby declare that this thesis is a record of my research work in the Department of Chemistry Ahmadu Bello University Zaria. I have not presented it in any previous application for a higher degree. All sources of information are duly acknowledged by means of references.

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Ibrahim Musa Date

CERTIFICATION

This thesis entitled "Determination of some Heavy Metals in Kainji Lake" by Ibrahim Musa meets the regulations governing the ward of the Degree of Master of Science(Analytical Chemistry) of Ahmadu Bello University Zaria and is approved for its contribution to Scientific knowledge and literary presentation

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DEDICATION

To my Parents

and

Daughters, Zainab and Khadijah

ACKNOWLEDGEMENT

I give thanks to God almighty ALLAH, for His bounty and sustenance. I thank Him for His guidance and Protection. His blessings upon His noble Prophet Muhammad (S.A.W.)

I thank my parents for their love, support and guidance.

I am extremely grateful to my Supervisor Dr. A. O. Oyewale for his immense contribution and valuable guidance, which made the programme almost hitch free.

I am grateful to Alh. (Dr.) A.U. Zezi for his invaluable support throughout my Programme. I thank his entire family too. I remain ever grateful to them.

I wish to thank my brothers Mall. T. Nugwa, Mall. M.A. Musa, Usman Ame Musa, Haruna D. Musa, and my friends Suleiman Bello, Ali Baba, Bala Shehu for their encouragement.

I am grateful to Prof. E.B. Agbaji (Mrs) of Chemistry Dept and Dr. P.A. Audu of Biological Science Dept, both of A.B.U. Zaria, for their individual efforts.

I am also grateful to all the lecturers during the Programme and laboratory staff of Chemistry Department A.B.U Zaria, National Research Institute for Chemical Technology (NARICT) Zaria and Centre for Energy Research and Training (CERT) Zaria.

Finally I want to thank Mr. Titus Hassan Umayi of National Institute for Freshwater Fisheries Research (NIFFR) who agreed to type the manuscript at the shortest notice.

ABSTRACT

The levels of Pb, Cr, Ni Zn, Fe,Cu, Co, Mn, Cd and Hg were determined in water, Sediment and Fish Samples taken monthly for six months from march 2002 – August 2002, from the Southern basin of Kainji Lake and below the dam (Jebba Lake), in order to determine the pollution status of the Lake and the impact of the hydro-power plant as per heavy metal discharge. Flame AAS and EDXRFS techniques were used for the analysis and both techniques indicate the order of relative abundance as Fe > Mn > Cr > Pb > Co > Ni > Cu > Zn > Cd > Hg > in water; Fe > Mn > Zn > Ni > Co > Cr > Cu > Pb > Cd > Hg in sediments; and Fe, Zn > Mn > Cu > Ni > Co > Cr > Pb > Cd > Hg in fish.

The level of these metals in all the samples were within the tolerable and internationally acceptable limits. This implies that the Lake is safe. The results also do not show the hydro-power plant as a major source of these metals in the Lakes.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND STUDY

Problems such as the destruction of environments, soil erosion and the extinction of species are important for the future of mankind, yet it is pollution which arouses interests because of its direct impact on health, food supply, degradation of items of cultural heritage, overt effects on forests, rivers, coastlines and ecosystems (Alloway and Ayres, 1993).

Pollution is the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm living resources and ecological systems, damage to structures, amenity or interference with legitimate uses of the environment (Holdgate, 1979). Substances that cause pollution are termed pollutants. Environmental pollution is insidious and its harmful effects become apparent after long periods of exposure. Many toxic chemicals are used in our daily lives because their particular use is not thought to constitute a hazard to health and the advantage of using them out weigh their possible risks. Sometimes materials which are considered as harmless may constitute pollutants if they are present in excess or in the wrong place at the wrong time (BMA, 1991). Certain substances may also be present in the environment not causing any obvious harm but their careful analysis and diagnosis will reveal their harmful effect.

Pollutants are responsible for many illnesses such as cancer, neurological conditions, chronic bronchitis, asthma and so on (IAEA, 1976). For these reasons pollutants have been classified into primary which exert harmful effects in the form in which they enter the environment, and secondary pollutants which are synthesized as a result of chemical processes, from less harmful precursors in the environment.

Most pollutants enter the environment as emissions or as discharges (to water bodies) either from discrete point (e.g. factory) or diffuse sources e.g. run-off from agricultural land. The effect of any pollutant discharged into the environment depends on its toxicity, persistence, dispersion properties, chemical reactions including decomposition that the compound undergoes, tendency to be bio-accumulated in food chains and ease of control. Every pollution has a pathway which involves the pollutant, the source, the medium of transport (air, water, land) and the target (organisms, ecosystem) (Holdgate, 1979).

Most industrial and municipal wastes end up in rivers, Lakes and seas. Lakes and reservoirs are natural sinks for nutrients, metals, salts and organic matter which enter through storm run-off, controlled waste discharges and feeder streams. Significant concentration of these pollutants can accumulate in bottom sediment over the years. A number of complex biological and chemical processes occur between the contaminants, the bottom sediments and overlying waters. These processes and associated reactions exert a significant oxygen demand satisfied primarily by dissolved oxygen (DO) in overlying waters. (Hayes *et al.*, 1998).

Lakes and surface water reservoirs are important freshwater resource. They provide water for domestic and for irrigation. They provide an essential resource for industry and a source of renewable energy in the form of hydro-power. Lakes are a source of essential protein in the form of fish and a home to significant elements of the world's biological diversity. They are important source for tourism and recreation, and are culturally and aesthetically important for people throughout the world. They play important role in flood control (UNEP, 1994).

Lakes attract human settlement hence pollution from agriculture run-off and toxic chemicals are common. Unlike the rapidly flowing water in rivers, water remains in Lakes for months or years is easily polluted. Water quality in Lakes is degraded when human activities are intensified and there is population increase in the drainage basin around them. The level of deterioration of the environment in any community depends on the effect of population, affluence and technology (Meadows *et al.,* 1992).

The Kainji Lake is important to Nigeria in many respects. It's establishment was a dream come true. (Olagunju, 1972) had this to say about the dam:

Men have dreamed, men have planned,

Men have toiled to bring to life,

The vision of those who first saw,

The Potential of the River Niger,

For harnessing its waters,

To provide Power for progress.

The completion of the project represented the foundation stone for the modernization of Nigeria (Gowon, 1969). The hydro-electricity generated from the dam provides the energy supply for both industrial and domestic use. It is source of fish supply. The flood control achieved as a result of the construction of the dam has led to expansion of irrigation agriculture in areas down stream. Its excellent panoramic view makes it an attraction for tourism (NEPA, 1977).

The expansion of agriculture around the Lake has its attendant consequences. Addition of chemical substances to soils and crops has become a general practice in agriculture. The purpose of the chemicals are the improvement of the nutrient supply in soil (fertilizers) or crop protection and diseases control (Pesticides). These practices may result in soil degradation as result of accumulation of the chemical substances at undesirable levels. Fertilizers are usually not sufficiently purified during the processes of manufacture, for economic reasons. They usually contain several impurities amongst them heavy metals (Eugenia *et al*., 1996). Heavy metals also form part of the active compounds of pesticides.

Excess of heavy metals in soils is caused by using fertilizers, metallo-peslicides and sewage sludges or by industrial activities and the concentration of heavy metals in soils can increase by repeated and excessive fertilizer and pesticide applications. Some countries have set tolerance limits on heavy metal addition to soil because their long-term effects are unknown (Berth and L'Hermite, 1987). These limits are usually established for the tillage layer of soil where most crop-root activity occurs.

The Kainji Lake is formed from river Niger and is located at about 3200 Km South of its source (NEDECO, 1959) and receives water from the numerous inflowing rivers that form its tributaries. The Lake receives inflowing water from Malende, Kpan, Wata, Swashi streams and Teme, Dero streams as well as storm run-off from Yelwa, Mahuta, Ulaira, Gafara, Wara, Garafini, Monai and Anfani settlements (Obot, 1984). (Fig 1.1).

In this study, water, sediment and fish samples taken from Kainji Lake and below the dam (Jebba Lake) are examined in order to determine the level of heavy metals such as Pb, Cr, Cd, Cu, Zn, Hg, Fe, Co, Mn and Ni. The extension of sampling to below the dam (Jebba Lake) is to gauge relatively the level of contribution as per heavy metal discharge into the Lake by the hydro-generation station. Both flame atomic absorption spectrometry (FAAS) and X-ray fluorescence spectrometry (EDXRFS) have been used in the determination.

1.2 History and Description of the Kainji Lake

Due to rising demand for electricity about 50 years ago the then electricity corporation of Nigeria (ECN) saw the need for a large and cheap source of power. It therefore commissioned Balfour Beatty and Company Limited of Britain to investigate the hydro-electric potential of the Niger in the Vicinity of Jebba. Also a separate investigation of the hydro-electric potential of the Kaduna river at Shiroro gorge was carried out by the then Northern Nigeria government in collaboration with ECN The federal government had commissioned the Netherlands Engineering Consultants (NEDECO) to carry out a hydrological survey of the rivers Niger and Benue (Olagunju, 1972).

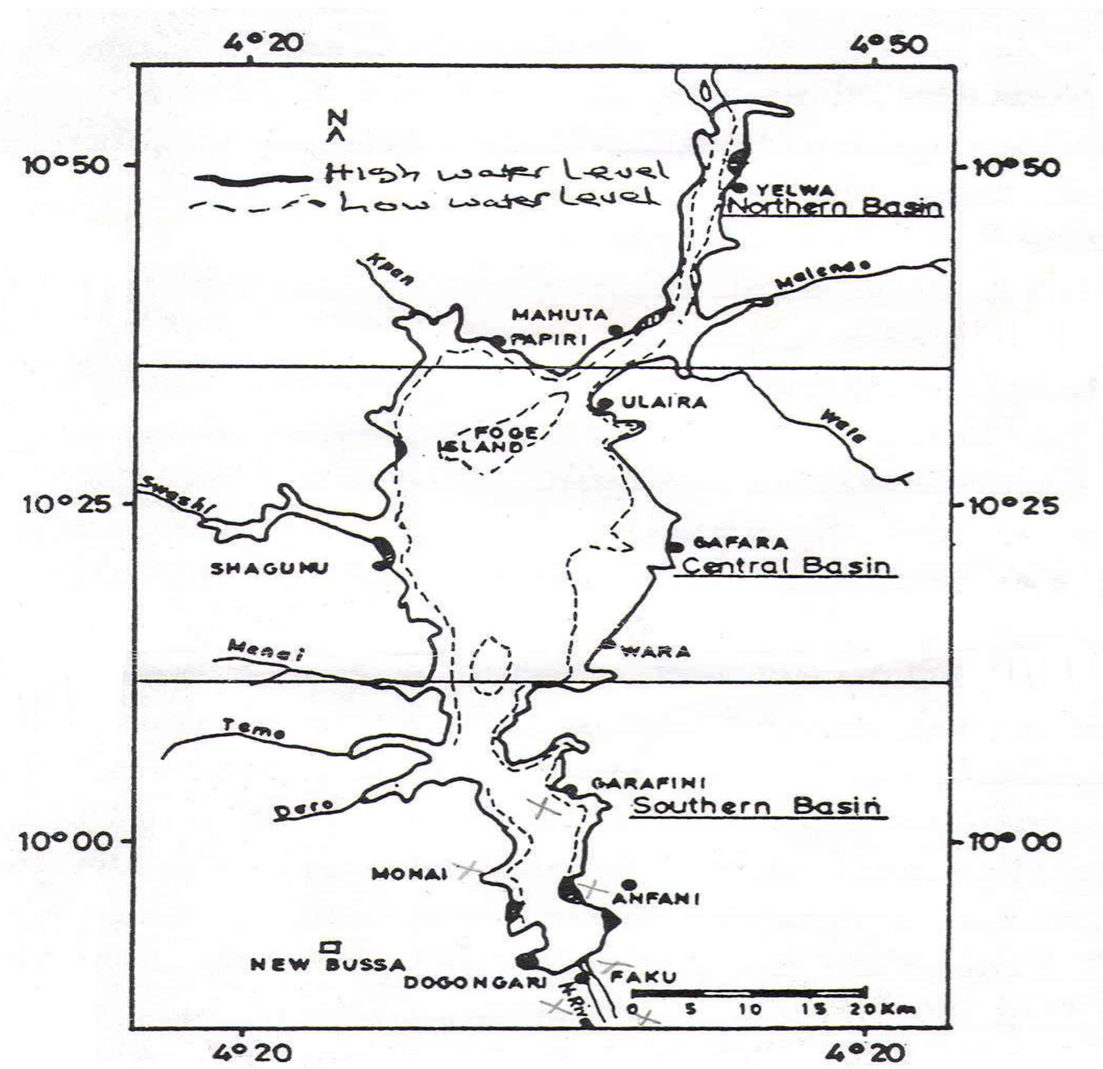

Fig.1. 1: Map of Kainji lake showing the basins. (Source: Obot, 1984)

representative of the Federal Government, the Northern Region and ECN) recommended that initial development be carried out at near Kurwasa (in Kainji area) to be later followed by developments at Shiroro and Jebba. Further detailed investigation led to the first dam being built at Kainji (102km upstream of Jebba) (NEDECO and Balfour Beatty, 1961). (Plate 1 & Fig1.2).

Construction works for the Kainji dam began in March 1964 and was completed in December 1968. This work marked the first engineering intervention on the river Niger. Hence that portion of the river Niger is now a Lake and has lost some attributes of a river due to backup effects of the dam.

The reservoir (Kainji Lake) covers an area of ≈ 800 Km^2. and is 136 Km long. It is 24 Km at the widest point (NEPA 1977). The building of Jebba dam (102 Km) downstream of Kainji dam has created the Jebba Lake which extends to below the Kainji dam. By implication, river Niger seizes to be a river as from Yelwa. Downstream Yelwa up to Kainji, it is a Lake (Kainji Lake). Another Lake (Jebba Lake) terminates at Jebba.

1.3 The Niger River, it's Discharge and Sediment Transport

The Niger rises in the mountains of Sierra-leone on the Fouta Djallon Highlands (240 Km from the atlantic Ocean) and runs in north-easterly direction. At Mopti (Kilometer 2856) the river enters the swamp area around Timbuctu where it looses 65% of its water by evaporation and infiltration. (NEDECO and Balfour Beatty 1961). It then takes a South-easterly course through a semi-desert with hardly any rainfall in Niamey and then into Nigeria.

Between Niamey and Nigerian frontier the river flows through floodplains of Yelwa receiving water from the drainage area South and West of Malanville and from the tributary the Sokoto river. It flows through undulating Guinea Savannah and to Jebba. At Kainji (102 Km upstream Jebba) (Olagunju, 1972) the Niger river was dammed and this backed up the river upstream to form a Lake (Lake Kainji) its surface level hundreds of metres higher than the old river level at the dam. The Lake is regulated to flow through the dam, producing power by turning turbines.

The reigme of the Niger river is determined by its geographical situation. The run-off from the rains in the Fouta Djallon Highlands travels 2720Km before reaching Nigeria, six months later (NEDECO, 1959). On its way it passes the swamp area around Timbuctu where it looses ≈ 65% of its water by evaporation and infiltration. The water from the upper catchment area is comparatively clean when it reaches Nigeria, having deposited its silts in the swampy areas. For this reason it is known as the Black flood (Fig 1.2). The 'black flood' occurs between December and March .

The second drainage area contributing to the run-off starts downstream of Niamey where tributaries in Benin flow north into the Niger. In Nigeria rivers Sokoto, Malendo, Kontagora, Oil, Moshi, Awum and others contribute to the local flood. This local flood is milky due to the silt it carries than the clean black flood and is called the white flood. The white flood occurs between August and November. The black flood fills a considerable part of the gap between consecutive wet seasons in Nigeria.

1.4 Objectives of the Research

All aquatic organisms are contaminated with metal compounds discharged into natural waters by man. These substances may be toxic not only to man and the ecosystem but may render water unsuitable for irrigation and domestic purposes (Kahraman *et al.,* 1976).

Lakes can become polluted without obvious signs (Biney *et al*., 1994; Alloway *et al.,* 1993). As a result, environmental monitoring as a means of detecting insidious pollutants becomes pertinent. The objectives of this work therefore are:

(i) To ascertain the presence of the heavy metals such as Pb, Cr, Cd, Cu, Zn, Hg, Fe, Co, Mn and Ni in Kainji Lake.

(ii) To determine the concentrations of these metals in water, sediment and fish samples from the Lake.

(iii) To determine the impact of the Kainji hydropower generation.

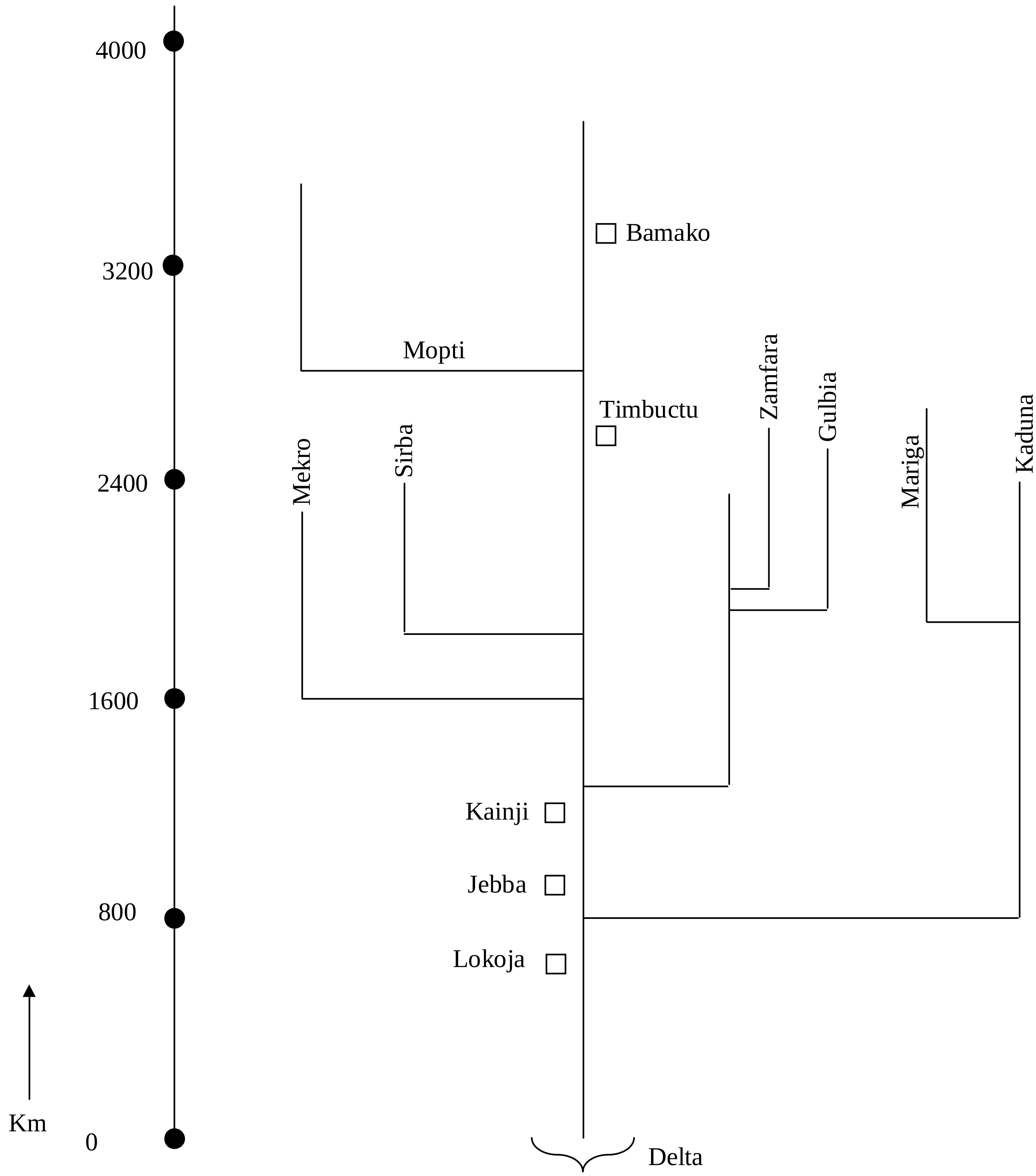

Fig.1. 2: The Niger and its Main Tributaries (NEDECO, 1959)

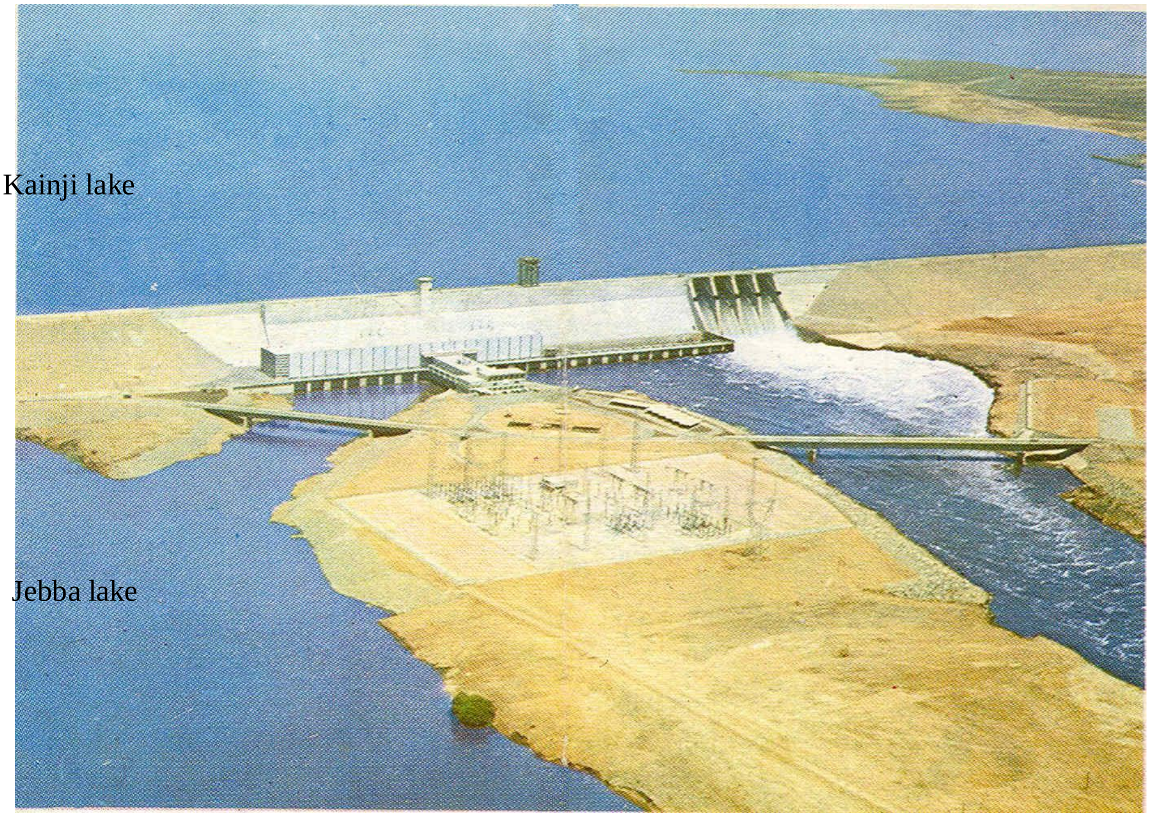

Plate1. 1: Aerial picture of Kainji dam

CHAPTER TWO

LITERATURE REVIEW

2.1 Heavy Metals and Their Sources

Heavy metals' is a collective term that applies to metals and metalloids with atomic density greater than 6g/cm^2. Heavy metals occur naturally in rock-forming and ore minerals, hence there is a range of normal background concentrations of these elements in soils, sediments, waters and living organisms. It is the concentration of the metals relative to the normal background concentration which determine whether or not an item is polluted (Bio-ellite, 2000; Holdgate, 1979).

Some elements (micro-nutrients) are beneficial to most living organisms as they are required in small but critical concentrations for healthy growth. Examples are Cu, Mn and Zn. Excess concentrations can however cause toxicity. Some have no known essential biochemical functions and are toxic at concentrations above the tolerance of the organism (Holdgate, 1979). Examples are As, Cd, Hg, Pb. The toxic effects caused by excess concentration of these metals include competition for sites with essential metabolites, replacement of essential ions, reactions with – SH groups, damage to cell membranes and reactions with the phosphate groups of adenosine diphosphate (ADP) and adenosine triphosphate (AT) (Holdgate, 1979; Biney *et al.,* 1994; Bio-ellite, 2000).

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2.1.1 Geochemical Sources

This is the primary source. Heavy metals form part of the group of elements referred to as trace `elements' in geology and they constitute less than 1% of the rocks in earth crust. Trace elements exist as impurities in primary minerals found in igneous rocks which are formed from molten magma, (Biney *et al.,* 1994). In sedimentary rocks, trace elements occur sorbed to the secondary minerals.

2.1.2 Anthropogenic sources

Anthropogenic sources include the following.

a. Mining

Ores form the source of metals utilized in manufacturing. Tailings (which are finely divided or milled fragments of rock left behind after extraction of metals, or continued weathering of ore minerals in historical and abandoned mining sites are important sources of heavy metals.

b. Metallurgical industries

Heavy metals are used in the manufacture of steel and alloys and their manufacture, disposal and recycling can lead to environmental pollution.

c. Fossil fuel

A number of heavy metals in fossil fuel are either emitted into the atmosphere during combustion or remain as ash which may be leached in situ or transported. For example, most gasoline contain Pb additives and their combustion give rise to large amount of Pb particles (Alloway *et al.,* 1993).

d. Agricultural Materials

These are non-point sources and they include fertilizers, pesticides, herbicides and manure (composts and preservatives).

2.2 Distribution of Heavy Metals in the Aquatic Environment

In the aquatic environment, metals are distributed amongst the compartments, water, suspended solids, sediments and biota. The distribution is governed by dilution, advection, dispersion, sedimentation, and adsorption/desorption (Biney *et al* .,1994)

2.2.1 Heavy Metals in Lake Waters

Heavy metals in water can be found in the following forms:

(i) solution

(ii) in the lattice of the minerals of suspended load

(iii) adsorbed on the minerals of the suspended load

(iv) associated with organic material (Kahraman *et al* .,1976)

Lakes and reservoirs are natural sinks for nutrients, metals and organic matter which enter through storm run-off (including run-off from agricultural land), controlled waste discharges, feeder streams, industrial effluent (Harrison and Laren, 1980; Hayes *et al* .,1998).

The biological availability and toxic effects of metals once in a water body are closely related to their chemical forms. The forms in which the metals exist will also determine their availability and distribution (Harrison and Laren, 1980) whether they exist in suspension or association with bottom sediment. This in turn will influence the likelihood of the metal finding its way into public water supplies.

A number of works are available on levels of heavy metals in rivers/Lakes (Mombeshora *et al* .,1981; Ocheng, 1987; Saad, 1988; Okoye, 1991) and on Kainji Lake (Adeniji *et al.*, 1985; Mbagu and Ovie, 1999).

2.2.2 Heavy Metals in Sediments

Sediments play a role in the overall distribution of heavy metals in the aquatic environment ad give an indication of pollution (in river). Thus sediments are used as indicators of environmental pollution (Ashry,1973; Vivian and Maassie, 1977; Sheriff *et al.,* 1981). Accumulation of metals in (Lake) waters goes together with its accumulation in sediments as a consequence of suspended solids sedimentation (Gonzalez *et al.,* 2000). According to Awadallah *et al.,* (1994), in their study of distribution of trace metals in mud sediments of the Aswam High Dam Lake, factors such as: (i) Adsorption or co-precipitation on organic and detritus organic particles, (ii) Preferential accumulation of trace metals by benthic organisms, account for progressive accumulation of trace metals in bottom sediments.

The distribution of heavy metals in sediments depend on: (i) Source material, (ii) Weathering process, (iii) Sediment transport, (iv) Dissolution and reaction kinetics (Filipek and Owen 1979).

The importance of metals bound to sediments with respect to the overall concentration and mass transport of metals in an environment has been well established (Gibbs, 1973, 1977; Harowitz, 1991;Presley,1992) metal concentration in sediments, can be influenced by factors such as salinity (Coakly *et al.,* 1993), water discharge (Forstner and Whittmann, 1981) and flow rate (Schoelhammer, 1995).

2.2.3 Heavy Metals Accumulation in Fishes

One of the significant effects of metal pollution in Lakes or rivers is that aquatic organisms can absorb and accumulate concentrations in their tissues. Water polluted with heavy metals adversely affect fish production.

Metals may enter the systems of (fishes) aquatic organisms via three main path ways, namely:

(i) Free metal ions that are absorbed through respiratory surface (gills) are readily diffused into the blood stream

(ii) Free metal ions that are adsorbed onto body surfaces are passively diffused into the blood stream

(iii) Metals that are sorbed onto food and particulates may be ingested, as well as free ions ingested with water (Bio-ellite, 2000).

Heavy metals exert a range of effects, from metabolic and physiological to behavioral and ecological, on fishes (Forstner and Wittmann, 1981). Heavy metals are known to cause delayed embryonic development, malformation, and reduced growth of adult fishes, poor swimming performance, changes in circulation, change in biochemistry such as enzyme activity and blood chemistry, and changes in reproduction (Biney *et al* .,1994; Bio-ellite, 2000).

A number of works are available on the accumulation of heavy metals in fishes (Saad *et al.,* 1981; Biney, 1991; Kakulu *et al.,* 1987) and on Kainji Lake (Adeniji *et al.*, 1985; Adeniji and Mbagu, 1990).

2.3 Hydro-Electric Power Generation

Hydro-electric Power plants capture the energy released by falling water through a vertical distance and transform the energy into useful electricity. The falling water is channelled through turbine which converts the water energy into mechanical power. The rotation of the water turbine is transferred to the generator which produces electricity (Baird, 1993).

The amount of electricity which can be generated at a hydro-power plant is dependent on the vertical distance through which the water falls and it 's flow rate. Based on this, hydro-power plants are divided into two namely, high head and low head. High head utilizes a dam to store water at an increased elevation. Kainji Power plant is an example. Low head utilizes a low dam and uses the run of the rivers (Guthrie, 1969; Baird, 1993).

The Kainji hydro-power generation plant has eight generating sets. Each of the set is supplied with water from the reservoir through a steel lined intake passage in the dam. Each passage is protected by (metal) screens on the upstream face of the dam the function of which is to exclude debris.

2.3.1 Environmental Impact of Hydro-Power Generation

Hydro-power plants have many environmental impacts some of which are just beginning to be understood (Baird, 1993). The impacts are displacement of residents, loss of farm land, loss of wild river and in the event of dam collapse loss of lives and properties.

Power generation affects the environment not only through its fuel needs and pollution products but by requiring land to help generate and transport electricity

(Murdoch, 1975). The largest land users are hydro-electric dams which create reservoirs occupying several hundred square kilometers. By submerging vast land areas, hydro-dams can affect the ecological balance of entire river basins. Wild life and water fowl habitats are flooded by the reservoir upstream. Down stream fish may be chopped up by the turbines, or may become vulnerable to “gas bubble disease’. This is when water spilling over the top of a dam mixes with air and becomes super saturated with nitrogen which in turn enters the fish’s blood streams (Holloran ,1972).

Recent studies of large reservoirs created behind hydro-dams suggest that decaying vegetation submerged by flooding may give off quantities of green house gases equivalent to those from other sources of electricity (Baird, 1993). Over the past decade there has been focus on impact of human activities on global climate system due to emissions of green house gases (GHG). Bacteria present in decaying vegetation can change mercury present in rocks underlying a reservoir into a form which is soluble in water (Baird, 1993). The mercury accumulates in the bodies of fish and poses a health hazard on consumers. The water quality of many reservoirs also poses a health hazard due to new forms of bacteria which grow.

Deleterious effects of hydro-electric power plants on down stream aquatic life have been observed in some countries, which can be attributed to the abnormal lowering of the temperature (Wilson, 1968). The water to drive the turbine is taken normally from the lower depth of the reservoir or impoundment. At certain period of the year, the water is considerably cooler than normal air temperature. Rapid decrease in temperature may have adverse effects on aquatic life as sharp increases do.

CHAPTER THREE

MATERIALS AND METHOD

3.1. PREAMBLE

In the preparation of reagents, chemicals of analytical grade purity and distilled water where used. All glass wares were washed with detergents and rinsed with tap and distilled water before drying in the oven. All weighing were carried out on analytical balances.

3.2 Description of Sampling Area

The study area is the southern basin of Kainji Lake and the immediate area below the dam (Faku area in Jebba Lake).Sampling sites are shown in (Fig. 2.1). Each sampling site is located at a distance of about 10m from the shore. Site 1 is at GARAFINI, site 2 at MONAI and site 3 at ANFANI, all within the Kainji Lake.

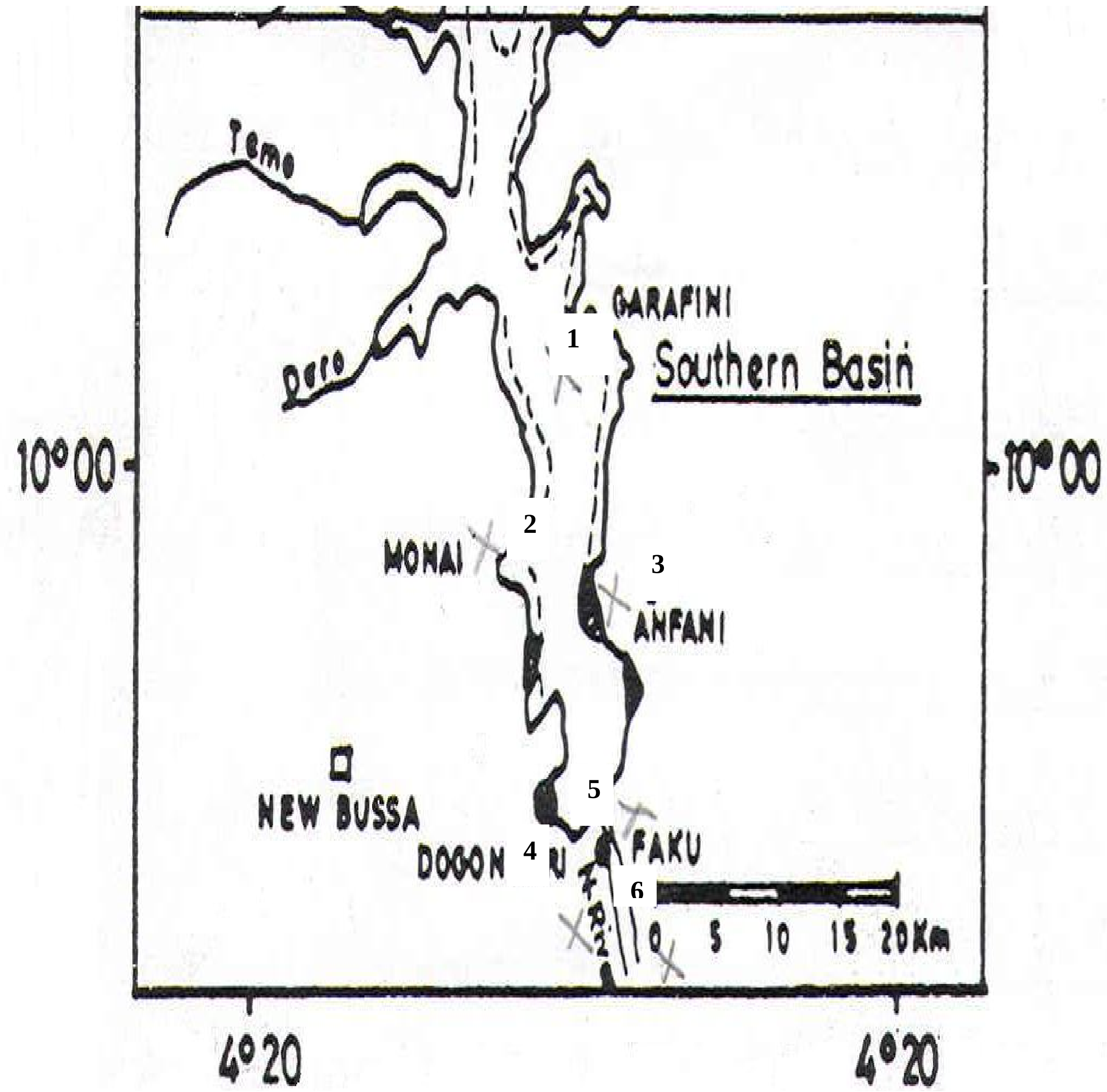

Fig 2.1: Map of the Southern basins of Kainji Lake showing the sampling sites

The three settlements are predominantly agricultural and fishing center. Site 4 is located about 50m below the dam. Site 5 is at Faku, another fishing/agricultural settlement while site 6 is located about 15m just before river Kontagora. All three sites (4,5&6) are located below the dam (Jebba Lake).

The sites were selected based on the nearness to the suspected agricultural pollution or hydro-power station.

In terms of geology, the two Lakes cut their beds through the sedimentary beds into underlying rocks of the basement complex, consisting of granites, gneiss, schists and quartzites (NEDECO, 1959). In some areas, partially granitised rocks of the basement complex are exposed in Lake banks.

3.3 Sample Treatment

Samples were collected over a period of six months (March 2002 – August 2002). Samples were collected monthly.

3.3.1 Water Samples

With the aid of water sampler, one litre of water at a depth of 50cm was collected from each site every month to give a total of 36 water samples studied.

The water samples were filtered using Whartman 0.45μm filter, into a previously cleaned plastic containers and acidified with 3 cm^3 50% HNO_3 (aq) per litre of water (Ramos *et al.,* 1999) and frozen till analysis to prevent loss of metals by surface adsorption (Kahraman *et al* .,1976).

3.3.2 Sediment Samples

Five core sediments were collected from each site using sediment grab sampler to make a bulk every month. This is to ensure representativity of samples. The sediments were stored in an ice box on site and then transported to the laboratory were it was further frozen. The thawed sample was passed through a 10-mesh screen to remove large pieces of foreign materials, homogenized by blending, oven dried at 40^0C for 48hr and cooled (Ramos *et al.,* 1999).

3.3.3 Fish Samples

Two fish species, *Oreochromis niloticus (*Tilapia), a surface feeder and chrysicthys auratus, a bottom feeder were sampled monthly from each Lake (Kainji and Jebba). The selection of the feeders is to determine the relative distribution of metal levels between surface and bottom. The choices of species were determined by availability, easy identification, species non-migratory, and geographic spread (Dybern, 1983; de Boer and Brinkman, 1994).The species were of uniform size. The *O. niloticus* averaged 15.67 cm ±0.84 cm total length and 22.19±2.31g body weight, while chrysicthys *auratus* of average total length of 18.21±1.59 cm and body weight of 24.85±0.98g were used. Four fish samples (two from each Lake) per month gives a total of 24 samples studied.

The fish samples were cleaned with distilled and deionized water and chilled at point of sampling in an ice box. Each fish was scaled and filleted, and the fillet dried at 40C in an oven for 96hr. The dried fillet was ground, homogenized in a blender and passed through a 125μm sieve (Bio-Ellite,2000; Bio-Ellite,johannesburg, South Africa).

3.4 Sample Preparation

3.4.1 Wet Digestion of Sediments

1.0g of the dry homogenized sediment were weighed into a clean beaker. 25 cm^3 of 50% HNO_3, and 20 cm^3 Concentrated $HClO_4$ were added. The mixture was heated gently on a hot plate until solution was clear and white fumes of $HClO_4$ appeared. This was cooled and 50cm^3 of distilled water was added. This was then filtered and made up to 100cm^3 in a volumetric flask (Greenberg *et al*., 1980).

3.4.2 Wet Digestion of fish

1.0g of homogenate was digested with two 5cm^3 portion of concentrated HNO_3 acid and made up to a 100cm^3 volume with distilled/deionised water (Greenberg *et al*., 1992).

3.5 Sample analysis:

AAS.

3.5.1 Preparation of standard solutions for AAS

3.5.2 Preamble

Stock standard solutions were prepared from high purity metal compounds and appropriate volumes were diluted to obtain working solutions used to plot the calibration cures. The preparations were as follows.

a. Lead stock solution.

0.1599g of lead nitrate $Pb(NO_3)_2$ was dissolved in 20 cm^3 of 1% v/v HNO_3 and made up to 1000 cm^3 with distilled water.

10cm^3 of the stock was diluted to 100 cm^3 of give100ppm. 0.2, 0.4, 0.6, 0.8 and 1.0ppm working solutions were prepared by diluting 0.2, 0.4, 0.6, 0.8, and 1cm^3 of the stock (100ppm) solution respectively to a 100cm^3 mark in a volumetric flask.

b. Chromium stock solution

0.1414g of potassium heptaoxochromate VI $K_2Cr_2O_7$ was dissolved in water and made up to 1000cm^3 (1cm^3=50ppm).

$1cm^3$ of stock solution was made up to $1000cm^3$ to give 5ppm. 0.1, 0.5, 1.0, 1.5 and 2ppm working solutions were prepared by diluting 2, 10, 20, 30 and $40cm^3$ of (5ppm) stock respectively to 100 cm^3 mark in a volumetric flask.

c. Cadmium stock solution.

2.282g of hydrous cadmium sulphate $CdSO_4.8H_2O$ was dissolved in distilled water and made up to 1000 cm^3 ($1cm^3$ =100ppm). $10cm^3$ was made up to $100cm^3$ to give 10ppm. 0.1, 0.5, 1.0, 1.5 and 2.0ppm working solutions were prepared by diluting 1, 5, 10, 15 and $20cm^3$ of (10ppm) stock respectively to $100cm^3$ in a volumetric flask.

d. Copper stock solution

0.3930g hydrous copper II sulphate $CuSO_4.5H_2O$ was dissolved in distilled water and made up to 1000 cm^3 (1 cm^3=100ppm). 0.5, 1.0, 1.5, 2.0 and 2.5ppm working solutions were prepared by diluting 0.5, 1.0, 1.5, 2.0 and 2.5 cm^3 stock respectively to $100cm^3$ in a volumetric flask.

e. Zinc stock solution

0.4398g 0f hydrous zinc sulphate $ZnSO_4.7H_2O$ was dissolved in distilled water and made up to 1000 cm^3 ($1cm^3$=100ppm). 0.5, 1.0, 1.5, 2.0 and 2.5ppm working solutions were prepared by diluting 0.5, 1.0, 1.5, 2.0 and $2.5cm^3$ stock respectively to $100cm^3$ in a volumetric flask.

f. Iron stock solution

$20cm^3$ of concentrated H_2SO_4 was slowly added to 50 cm^3 of distilled water.1.404g of ammonium iron II sulphate Fe $(NH_4)_2$ $SO_4.6H_2O$ was dissolved in it. 0.1M $KMNO_4$ solution was added drop wise until a faint pink color persisted. This was made up to 1000 cm3 with (Fe free) distilled water. ($1cm^3$ = 200ppm). 1.0, 1.5, 2.0, 2.5 and 3.0ppm working solutions were prepared by diluting 5.0, 7.5, 10, 12.5 and 15 cm^3 stock respectively to 100 cm^3 mark in a volumetric flask.

g. Cobalt stock solution

0.4770g of dry cobalt sulphate $CoSO_4.7H_2O$ was dissolved in distilled water and made up to 1000 cm^3 (1 cm^3 =100ppm). 1.0, 2.0, 3.0, and 5.0ppm working solutions were prepared by diluting 10, 20, 30, 40 and 50 cm^3 of stock respectively to 100 cm^3 mark in a volumetric flask.

h. Manganese stock solution

3.2g of potassium tetraoxomanganate VII $KMnO_4$ was dissolved in distilled water and made up to100 cm^3 to give 10ppm. 0.1, 0.5, 1.0, 1.5 and 2.0ppm working solutions were prepared by diluting 1, 5, 10, 15 and 20 cm^3 of (10ppm) stock respectively to 100 cm^3 in a volumetric flask

i. Nickel stock solution

0.4479g of Nickel sulphate $NiSO_4.6H_2O$ was dissolved in distilled water and made up to 1000 cm3. (1cm^3=100ppm). 2.0, 4.0, 6.0, 8.0 and 10ppm working solutions were prepared by diluting 2, 4, 6, 8, and 10cm^3 of stock solution to 100 cm^3 in a volumetric flask.

The analysis was carried out at the National Research Institute for Chemical Technology (NARICT) Laboratory in Zaria. A pye unicam 969 atomic absorption spectrometer (equipped with background correction) was used. Analyses were in duplicate for all samples. The operating conditions for the analysis is shown in table 1.

Table I: Operating conditions of atomic absorption spectrophotometer

Metal	Wave-length nm	Band-pass	Flame type
Pb	283.3	0.2	Air/C_2H_2
Cr	357.9	0.5	Air/C_2H_2
Cd	228.8	0.2	Air/C_2H_2
Cu	324.7	0.2	Air/C_2H_2
Zn	213.9	0.2	Air/C_2H_2
Fe	248.3	0.2	Air/C_2H_2
Co	240.7	0.2	Air/C_2H_2
Mn	279.5	0.2	Air/C_2H_2
Ni	232.0	0.2	Air/C_2H_2

EDXRFS

3.5.3 Water and Fish

For water and fish, 100 cm^3 of each digest was acidified to pH 2. This was followed by addition of 2 cm^3 of 1% ammonium pyrrolidine dithiocarbamate (APDC) solution. The solution was allowed to stand for 30min (Elder *et al*., 1975; Vulkovic, 1989). The metal carbamates precipitated were filtered using whartman 0.45μm, dried and ground. 0.3g of the ground metal carbamate of each sample was homogenized with three drops of organic liquid binder (polystyrene in toluene) and was pressed at 10torrs with a hydraulic press (Funtua, 1999) into pellet of 19mm diameter.

3.5.4 Sediments

0.3g of the (blended and oven dried) sediment sample was also homogenized with three drops of the organic liquid binder and pressed at 10 torrs with a hydraulic press into a pellet of 19mm diameter. The spectra of each sample were then measured using energy dispersive x-ray fluorescence (EDXRF) system.

Measurements were performed using an annular 25mCi ^{109}Cd as the excitation source, that emits Ag-K X-rays (22.1 KeV) in which case all elements with lower characteristic excitation energies were accessible for detection in the samples.

The system consists of a Si (Li) detector, with a resolution of 170 eV for the 5.90 KeV line coupled to a computer controlled ADC – Card Each sample was analysed for 5000 sec.

The analysis was carried out at the Centre for Energy Research and Training, Ahmadu Bello University Zaria.

3.6 Statistical Analysis

Two types of statistical analysis were used.

(i) Analysis of variance (ANOVA) was used to conduct a test of significance at $p<0.05$ between pairs of data (Both one tail and two tail analysis).

(ii) Correlation matrix was obtained for all metals determined.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 PREAMBLE

Both AAS and EDXRFS indicate the same order of relative abundance of the metals in each of the samples water, sediment and fish. The levels of the metals in each sample are discussed below.

4.1.1 Water

Lead (Pb)

Using AAS technique the highest level of lead was 1.57ppm recorded in June at site 1 while the least was 0.58ppm recorded in March at site 6 (Fig 3). The highest mean lead concentration and standard deviation was 1.38±0.11ppm recorded at site 1. In general, level of lead is lower below the dam (sites 4-6) than the level within the Kainji Lake (sites 1-3). The monthly variation of the level of lead does not show any seasonal pattern from the on set of the raining season (March – May) to the heavy raining season (June – August). Apparently increase in the water volume within this period does not affect the concentration of lead in the water body. The mean and monthly level of lead in all the sites are below WHO and USEPA recommended maximum permissible level (50ppm) in drinking water (Ramos *et al.,* 1999). Similarly the lead level is below the levels in waters and Lakes reported for some countries of the world

Using EDXRFS technique the highest level of lead was 1.83ppm recorded in march at site 1 while the least was 0.40ppm at site 5 (Fig 4). The highest mean concentration and standard deviation of lead was 1.67±0.12ppm recorded at site 1.

Lead level was lower below the dam than within the Lake. The mean and monthly levels of lead are below the WHO and USEPA. recommended level (Ramos *et al* .,1999). They are also below values reported for some countries of the world.

Chromium (Cr)

The highest chromium level was 2.70ppm recorded in May at site 3 while the least level was 1.48ppm recorded in March at site 6 (Fig 5).The highest mean concentration and standard deviation of chromium over the period of study and at all the sites was 2.30±0.26 at site 2. The overall level of chromium within the Lake was higher than below the dam. The monthly variation of chromium at each of the site is constant over the entire March – August periods.

Using EDXRFS the highest chromium level was 2.74ppm recorded in June at site 5 while the least was 1.80ppm recorded at site 1 (Fig 6). The highest mean concentration and standard deviation was 2.43±0.43ppm recorded at site 5 chromium levels are constant over the period of study.

Nickel (Ni)

The highest nickel level using A.A.S. was 1.23ppm recorded in July at site 1 while the least level was 0.57ppm recorded in July/March in sites 3/5 respectively (Fig. 7). The highest mean concentration and standard deviation of nickel 1.05±0.15ppm was recorded at site 2. The nickel levels are lower below the dam (sites 4-6) than within the Lake.

EDXRFS result showed the highest nickel level was 1.35ppm was recorded in August in site 4 while the least was 0.38ppm recorded in July in site 4 also (Fig.

8). The highest mean nickel concentration and standard deviation of 1.12±0.14ppm was recorded at site 2. Similarly the results indicate that nickel levels are lower below the dam (sites 4,5,6) than within the Lake (sites 1,2,3).

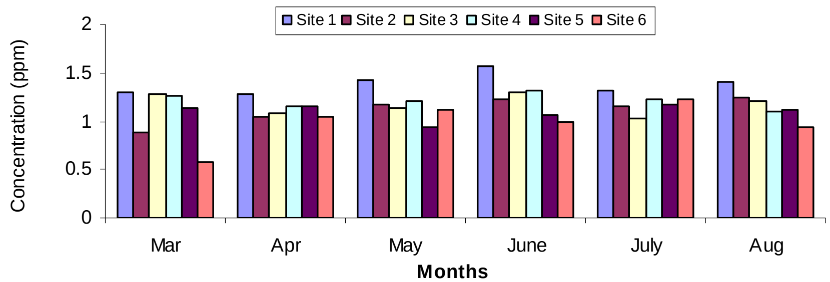

Fig. 3 Lead level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

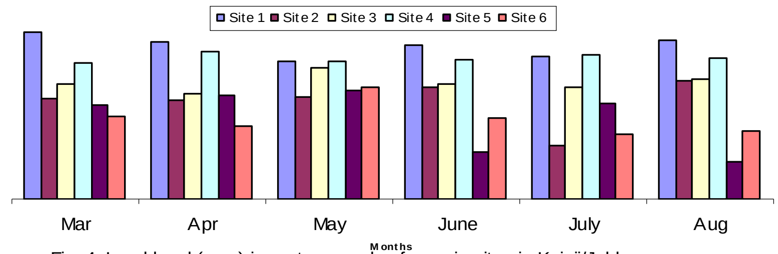

Fig. 4: Lead level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using XRFS

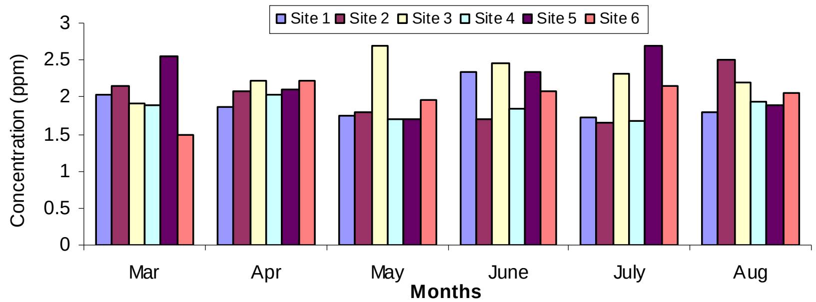

Fig. 5 Cromium level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

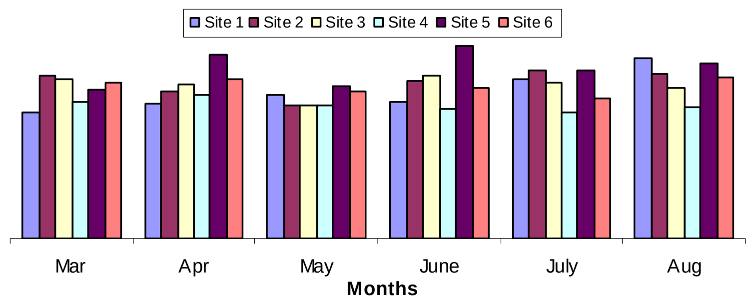

Fig. 6: Cromium level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using XRFS

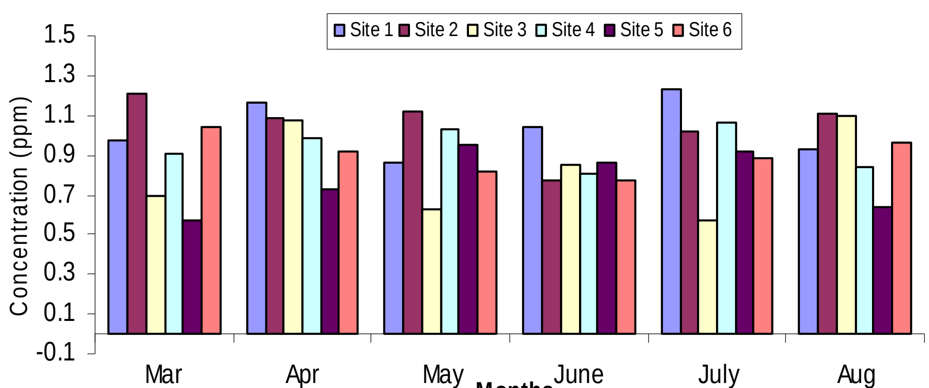

Fig. 7 Nickel level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

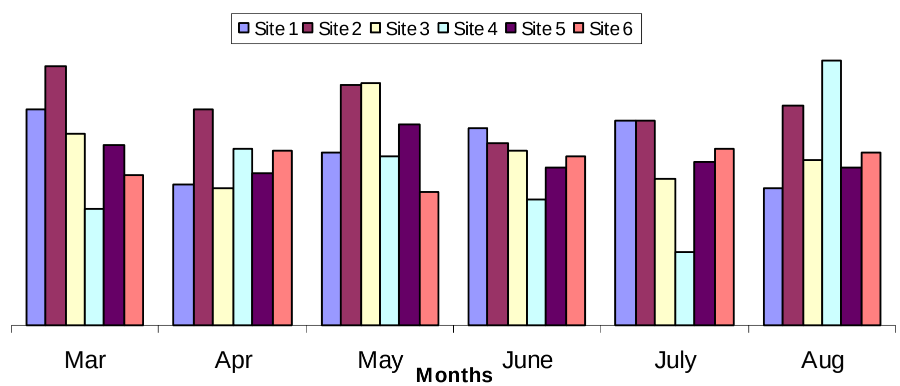

Fig. 8: Nickel level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

Zinc (Zn)

The highest zinc level of 1.43ppm was recorded at March in site 4 while the least was 0.37ppm recorded in August at site 2 (Fig 9). The highest mean concentration and standard deviation of zinc over the period 1.22±0.14ppm was recorded at site 4. Levels of zinc are relatively higher below the dam (site 4-6) than within the Lake. The mean levels are below the WHO and USEPA recommended level (5000ppm) in drinking water (Ramos *et al* ., 1999)and are also lower than values reported for other countries of the world.

Using EDXRFS the highest zinc level of 1.52ppm was recorded in March at site 5 while the least value of 0.42ppm was recorded in July at site 2 (Fig. 10). The highest mean zinc concentration and standard deviation of 1.10±0.21ppm was recorded at site 4. Levels of zinc are higher below the dam (site 4-6) than within the Lake (site 1-3). Similarly the mean levels are below the WHO and USEPA recommended level in drinking water. They are lower than values reported for other countries of the world.

Iron (Fe)

Using A.A.S. the highest iron level of 13.71ppm was recorded in June at site 3 while the least level was 9.85ppm recorded in April at site 6 (Fig. 11). The highest mean Iron concentration and standard deviation of 13.30±33ppm was recorded at site 3. Levels of iron are comparatively higher within the Kainji Lake than below the dam . The levels are lower than values reported in some countries of the world

Using EDXRFS the highest iron level of 16.28ppm was recorded in May at site 2 while the least level of 10.21ppm was in April at site 4 (Fig 12). The highest mean iron concentration and standard deviation of 14.80±1.75ppm was at site 2.

Copper (Cu)

A.A.S. technique indicates the highest Copper level of 1.63ppm was recorded in August at site 2 while the least level of 0.68ppm was recorded in March at site 1 (Fig. 13). The highest mean Copper concentration and standard deviation of 1.50±0.19ppm was recorded at site 6. The levels of copper are higher below the dam than within the Lake (site 1-3). The monthly and mean levels are below the WHO and USEPA recommended level (1000ppm) in drinking water (Ramos *et al*., 1999).

Results of EDXRFS show the highest copper level of 1.98µg/l was recorded in August at site 4 while the least was 0.56ppm in May at site 1 (Fig. 14). The highest mean copper concentration and standard deviation of 1.58±0.17ppm was recorded at site 6. The levels of copper are higher below the dam than within the Lake. The mean levels are lower than the WHO and USEPA recommended level in drinking water. They are also lower than values reported in some countries of the world.

Cobalt (Co)

The highest cobalt level of 1.37ppm was in June at site 2 while the least was 0.87ppm in March at site 1 (Fig. 15). The highest mean cobalt concentration and standard deviation over the period was 1.27±0.58ppm at site 5. The levels cobalt are higher below the dam than within the Lake.

Using EDXRFS the highest cobalt level of 1.49ppm was in May at site 4 while the least level of 0.94ppm was in May at site 1 (Fig. 16). The highest mean cobalt concentration and standard deviation of 1.33±0.014ppm was at site 5. The levels of cobalt are higher below the dam than within the Lake.

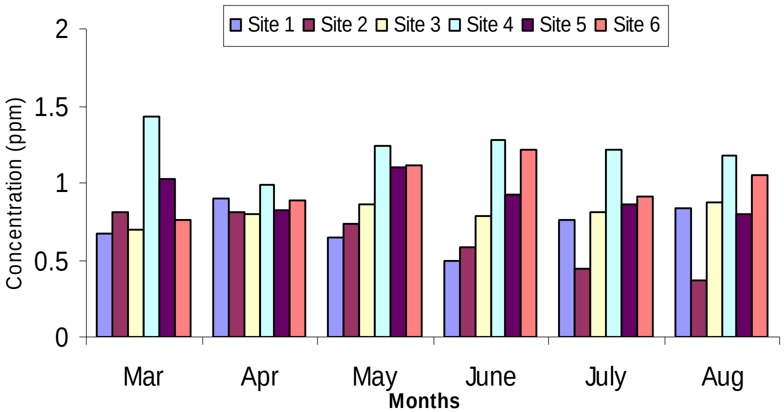

Fig. 9. Zinc level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

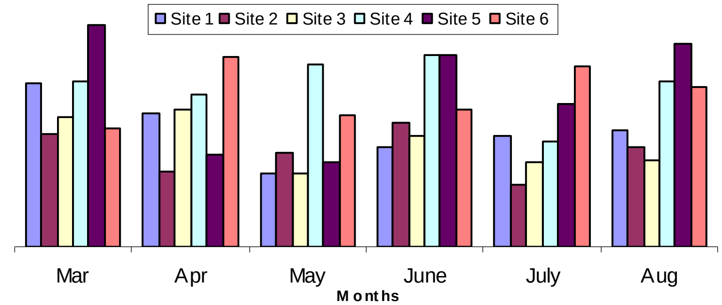

Fig. 10: Zinc level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

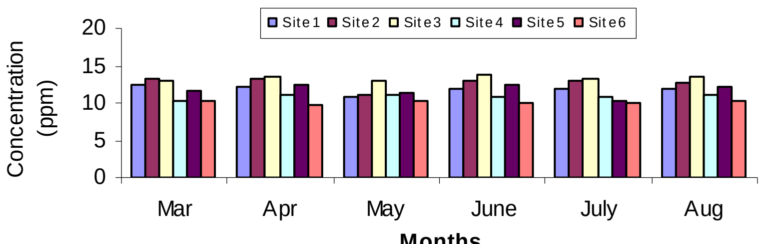

Fig. 11. Iron level (ppml) in w ater samples from six sites in Kainji/Jebba Lake using AAS

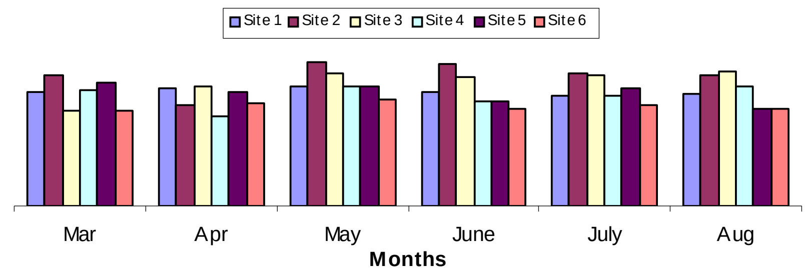

Fig.12: Iron level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using XRFS

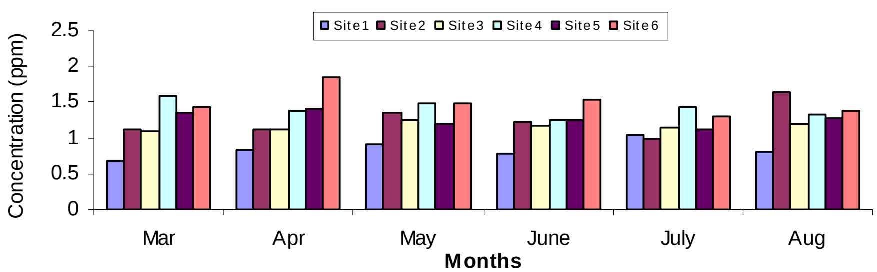

Fig. 13 Copper level (ppm) in water samples from six sites in Kainji/Jebba Lake using AAS

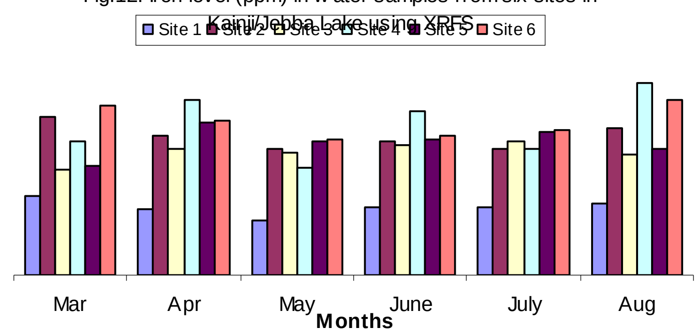

Fig. 14: Copper level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

Manganese (Mn)

The highest level of manganese was 14.67ppm recorded in May at site 5 while the least was 4.63ppm recorded in July at site 1 (Fig. 17). The highest mean manganese concentration and standard deviation of 13.92±0.61ppm was at site 5. The levels of manganese are higher below the dam than within the Lake. In general the result does not indicate any seasonal variation (June – August). The levels of manganese are lower than values reported in some countries of the world.

EDXRFS indicates the highest manganese level of 16.43ppm was in April at site 5 and the least level was 4.7ppm in July at site 4 (Fig. 18). The highest mean manganese concentration and standard deviation of 14.80±1.18ppm was at site 5. The result indicates that the levels of manganese are higher below the dam than within the Lake. The levels are also lower than values reported in some countries of the world.

Cadmium(Cd)

This was analysed for using AAS only as Cd was the excitation source in EDXRFS. The highest mean Cd level and standard deviation was 0.017±0.005ppm at site 5 and the least was 0.009±0.004μg/l at site 3. the mean levels were higher in Jebba Lake than within Kainji Lake.

Mercury (Hg)

For lack of facilities, this could not be determined using A.A.S. technique.

Using EDXRFS the highest mercury level of 0.03ppm was in May at site 4 while the least value was 0.00ppm also in May at site 1 (Fig. 20). The highest mean mercury concentration and standard deviation was 0.02±0.007ppm at site 4. In general the levels of mercury are higher within Kainji Lake (site 1,2,3) than below the dam (site 4-6). The monthly and mean levels of mercury are below EEC, WHO (1.0ppm) and USEPA (2.0ppm) recommended levels in drinking water (Ramos *et al*., 1999).

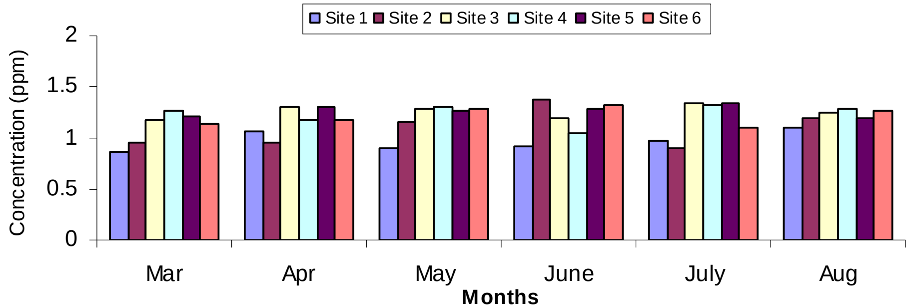

Fig. 15 Cobalt level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

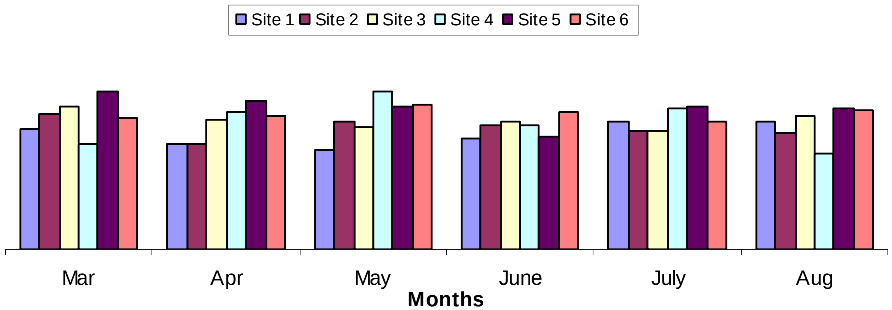

Fig. 16: Cobalt level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

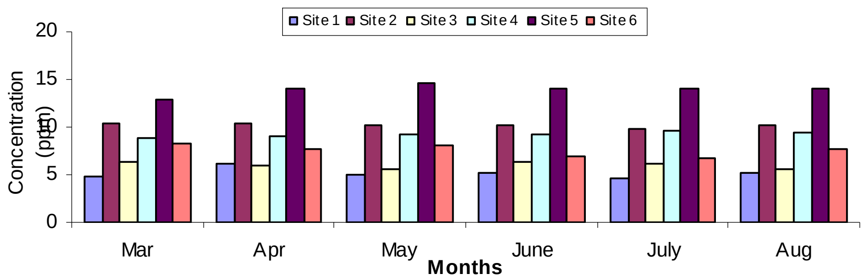

Fig. 17 Manganese level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using AAS

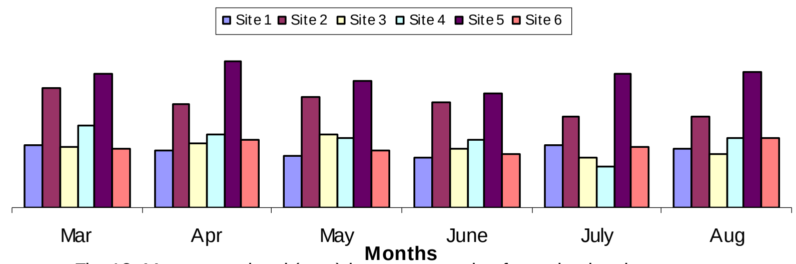

Fig. 18: Manganese level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

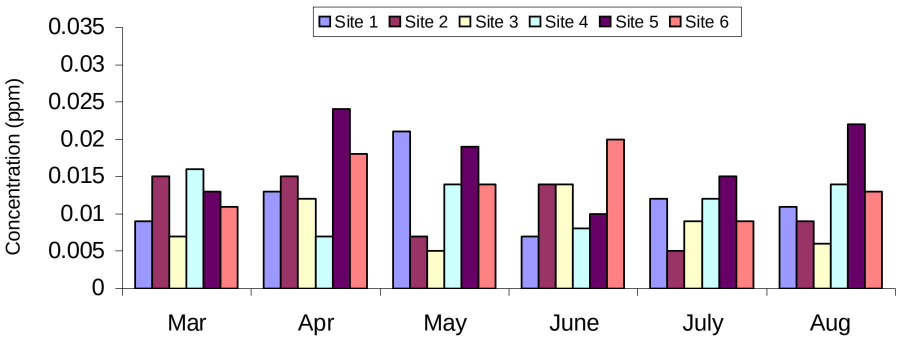

Fig. 19 Cadmium level (ppm) in water samples from six sites in Kainji/Jebba Lake using AAS

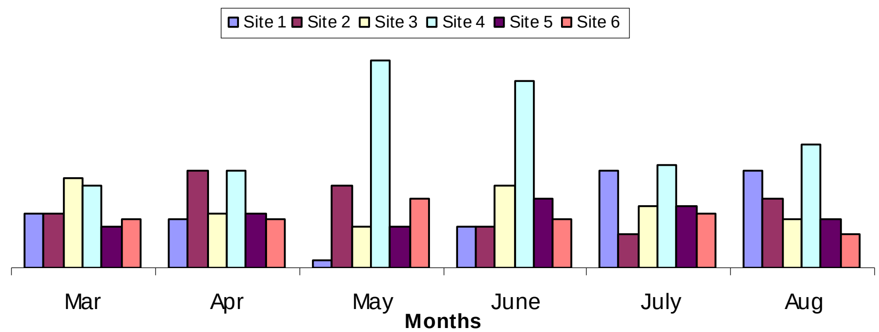

Fig. 20: Mercury level (ppm) in w ater samples from six sites in Kainji/Jebba Lake using EDXRFS

4.2 PREAMBLE

The results of flame AAS and EDXRFS of sediment samples from the same six sites, in the Southern basin of Kainji Lake/Jebba Lake from March – August 2002 are discussed as follows

4.2.1 Sediments

Lead (Pb)

Using AAS technique, the highest level lead of 21.99ppm was recorded in June at site 4 while the least value was 13.98ppm recorded in May at site 1(Fig. 21). The highest mean lead concentration and standard deviation of 20.18±0.98ppm was at site 5. The lead level was lower below the dam (sites 4-6) than the level within the Lake (sites 1-3). The monthly variation of lead does not indicate any seasonal variation. Similarly, the change in water volume within this period has not affected the concentration of lead in the sediment. The mean levels are lower than values of inland water sediments in some countries of the world. The mean levels are within range in literature value (19.0ppm) cited for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984).

Using EDXRFS technique, the highest lead level of 26.08ppm was in May at site 2 while the least value was 13.69ppm in March at site 6 (Fig. 22). The highest mean lead concentration and standard deviation was 20.82±3.11ppm at site 2. Lead level was lower below the dam (sites 4-6) than within Lake (sites 1-3). The monthly value does not indicate any seasonal variation. The mean levels obtained are lower than values for inland water sediment in some countries of the world. They are also within value (19.0ppm) cited for un-polluted inland water sediments (GESAMP, 1982; Solomons and Forstner, 1984).

Chromium (Cr)

The highest level of chromium was 34.20ppm recorded in July at site 5 and the least level was 19.16ppm recorded in March at site 1 (Fig. 23), using AAS. The highest mean chromium concentration and standard deviation over the period was 32.21±2.53ppm. Overall, the level of chromium below the dam (sites 4-6) is higher than within the Lake (sites 1-3). The monthly figures of chromium level do not indicate any seasonal variation

Using EDXRFS technique, the highest chromium level was 34.00ppm in March at site 3 while the least chromium level was 18.35ppm recorded in July at site 1 (Fig. 24). The highest mean chromium concentration and standard deviation was 30.31±2.56ppm recorded at site 2. The level of chromium within the Lake was higher than below the dam. The monthly variation does not follow any seasonal variation.

Iron (Fe)

The highest iron level of 8046ppm was recorded in April at site 5 while the least level was 4042ppm recorded in march at site 1 (Fig. 25). The highest mean iron concentration and standard deviation was 7043±660ppm at site 5. Iron level was higher below the dam (sites 4-6) than within the Lake. The monthly count variation of iron does not follow seasonal pattern from the on set of rain (March – May) to the heavy rainy period (June – August). The mean and monthly iron levels in all sites are below the literature value (4.1×10^4ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984). They are also below values from inland water sediments in some countries of the world.

Results of EDXRFS show the highest iron level was 10,310ppm in May at site 5 while the least value 3993ppm also in May at site 1 (Fig. 26). The highest mean iron concentration and standard deviation over the period of study was 9299±672ppm recorded at site 5. Levels of iron are higher below the dam (sites 4-6) than within the Lake (sites 1-3). Mean and monthly levels are below value in some countries of the world. They are also below the literature value ($4.1x10^4$ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984).

Manganese (Mn)

AAS technique shows, the highest manganese level was 556.10ppm recorded in April at site 5 while the level was 230.89ppm in March at site 4 (Fig. 27). The highest mean manganese concentration and standard deviation was 451±79ppm recorded at site 5. In general, levels of manganese are higher below the dam (site 4-6) than within Lake (site 1-3). The levels of manganese are lower than values obtained for inland water sediments in some countries of the world. They are also lower than literature value (770ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomon and Forstner, 1984).

Using EDXRFS technique, the highest manganese level was 481ppm recorded in July at sites 5 while the least value was 232ppm in June at site 1(Fig. 28). The highest mean manganese concentration and standard deviation over the period of study was 434±40ppm recorded at site 5. The levels of manganese are higher below the dam (site 4-6) than within the Lake (site 1-3). Levels of manganese are lower than values from some countries of the world. They are also lower than literature value (770ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984).

Copper (Cu)

The highest level of copper was 30.02ppm recorded in August at site 5 while the least level was 15.81ppm in May at site 2 (Fig. 29). The highest mean copper concentration and standard deviation of 27.06±1.76ppm was at site 5. Levels of copper are higher below the dam (site 4-6) than within the Lake (site 1-3). The increase in the volume of water from the on set of rain (March – May) to the heavy rainy season (June – August) has not affected the level of copper, as the result does not indicate any seasonal pattern. The monthly and mean levels of copper are lower than values from inland water sediments in some countries of the world. They are also lower than literature value (33.0ppm) for un-polluted inland water sediments (GESAMP, 1982; Solomons and Forstner, 1984).

Using EDXRFS the highest copper level was 33.64ppm recorded in May at site 5 while the least level was 18.21ppm in May at site 5 while the least level was 18.21ppm recorded in August at site 4 (Fig. 30). The highest mean copper concentration and standard deviation was 31.60±2.14ppm recorded at site 5. The levels of copper are below values obtained for inland water sediment in some countries of the world. They are also below literature value (33.0ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner ,1984).

Zinc (Zn)

AAS indicates the highest zinc level was 95.89ppm recorded in July at site 6 while the least value 26.66ppm was recorded in April at site 6 also (Fig. 31). The highest mean zinc concentration and standard deviation was 92.22±5.39ppm recorded at site 5. Except for site 5, mean zinc levels are lower below the dam (sites 4-6) than within the Lake (site, 1-3). The mean levels are lower than values obtained for inland water sediments in some countries of the world. They are also below literature value (95ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984).

Using EDXRFS technique, the highest level of zinc was 120ppm recorded in April at site 5 while the least was 24.68ppm in June at site 6 (Fig. 32). The highest mean zinc concentration and standard deviation was 106±15ppm at site 5. The mean values of zinc except for site 5 are lower below the dam (sites 4-6) than within the Lake (site 1-3). The mean values are below values from inland water sediments in some countries of the world and are below literature value for un-polluted inland water sediment.

Nickel (Ni)

The highest level of nickel was 48.00ppm recorded in July at site 2 while the least level was 16.51ppm recorded in July at site 4 (Fig. 33). The highest mean nickel concentration and standard deviation was 41.50±6.20ppm at site 2. The nickel level is lower below the dam (sites 4-6). Than within the Lake (site 1-3).

Using EDXRFS

Cobalt (Co)

Using AAS technique the highest cobalt level was 55.33ppm recorded in April at site 5 while the least level was 21.96ppm recorded in March at site 1 (Fig. 35). The highest mean cobalt concentration and standard deviation over the period was 51.78±2.43ppm at site 5. The levels of cobalt are higher below the dam (site 4-6) than within the Lake (site 1-3). The monthly variation of the level of Cobalt does not show any seasonal pattern

Results of EDXRFS indicate the highest cobalt level was 61.70ppm recorded in August at site 5 while the least was 22.84ppm in June at site 1 (Fig. 36). The highest mean cobalt concentration and standard deviation was 59.20±2.47ppm recorded at site 5. The levels of cobalt are higher below the dam (site 4-6) than within the Lake.

Cadmium (Cd)

From the AAS technique, the highest cadmium level of 0.26ppm recorded in March at site 1 while the least level was 0.07ppm recorded in May at site 4 (Fig. 37). The highest mean cadmium concentration and standard deviation over the period was 0.23±0.049ppm recorded at site 1. The levels of cadmium are lower below the dam (site 4-6) than within the Lake (site 1-3). The levels are lower than values obtained from some countries of the world; they (except site 4) are relatively higher than the literature value (0.11ppm) for un-polluted inland water sediment (GESAMP, 1982; Solomons and Forstner, 1984).

Mercury (Hg)

This was not analyzed for, using AAS for reason of inadequate facilities.

Using EDXRFS technique, the highest mercury level was 0.27ppm recorded in July at site 2 while the least was 0.06ppm recorded in June at site 1 (Fig. 37). The highest mean mercury concentration and standard deviation was 0.22±0.04ppm. Levels of mercury are higher below the dam (sites 4-6) than within the Lake (sites 1-3). The levels of mercury are lower than literature value (0.3ppm) for un-polluted inland water sediment (GESAMP, 1982). The levels are also below some levels reported in some countries of the world.

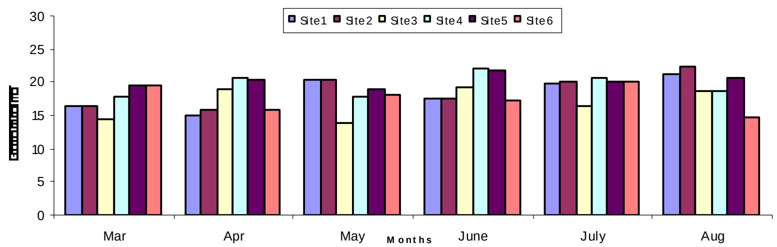

Fig. 21lead level (ppm) in sediment samples from six sites in Kainji/ Jebba Lake using AAS

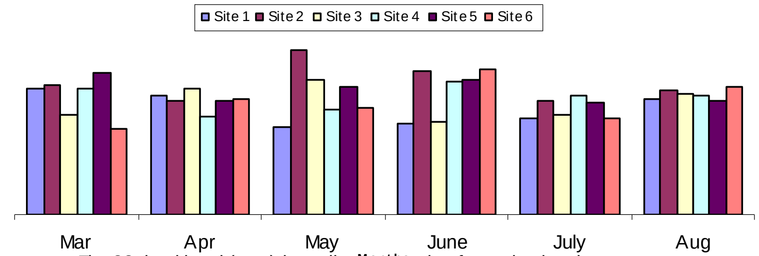

Fig. 22: lead level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using EDXRFS

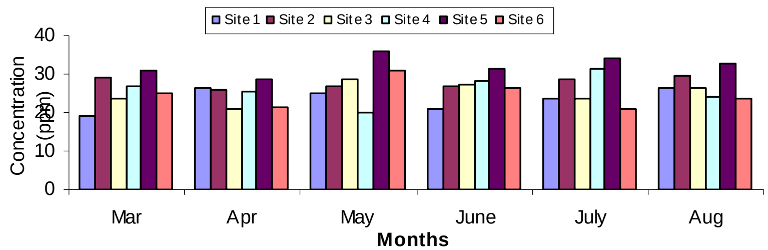

Fig. 23 Cromium level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

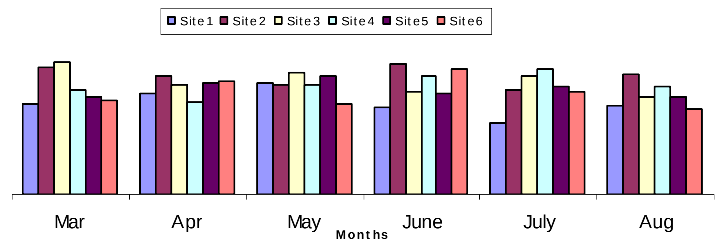

Fig. 24 Cromium level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using EDXRFS

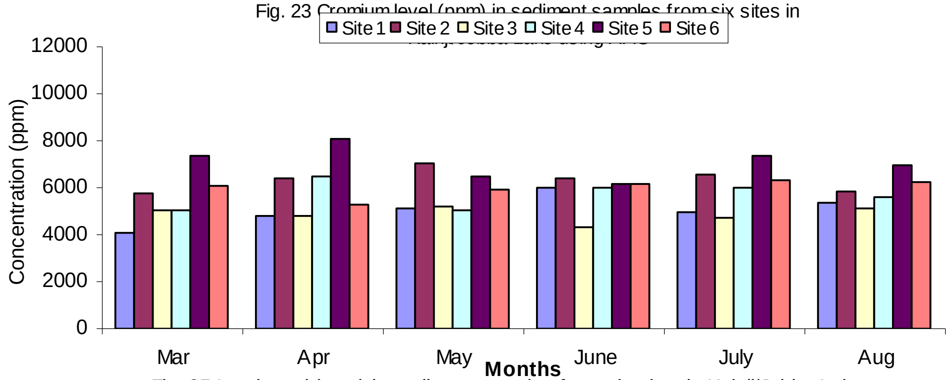

Fig. 25 Iron leveel (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

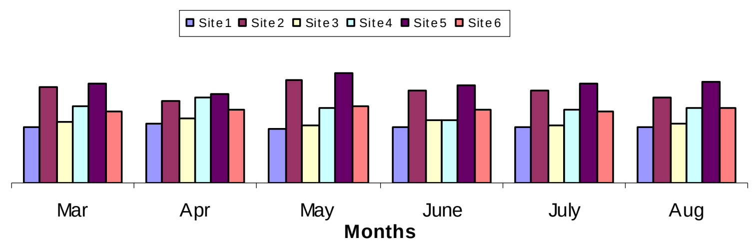

Fig. 26 Iron level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

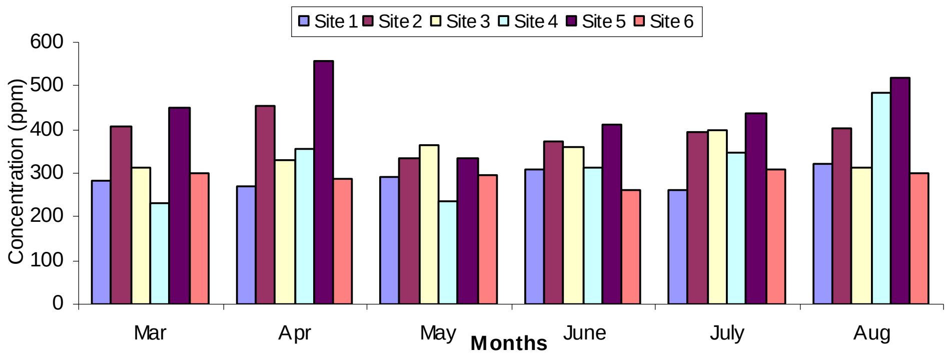

Fig. 27 Manganese level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

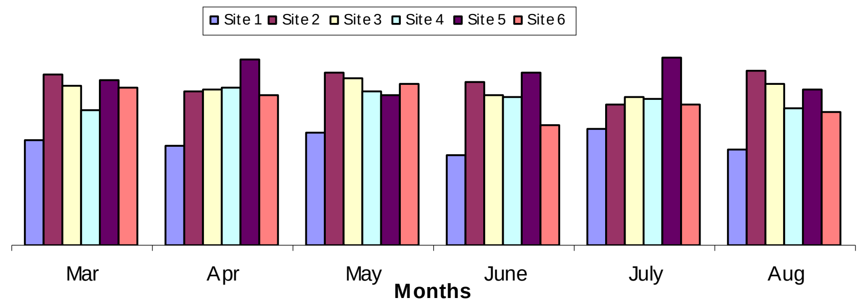

Fig. 28 Manganese level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

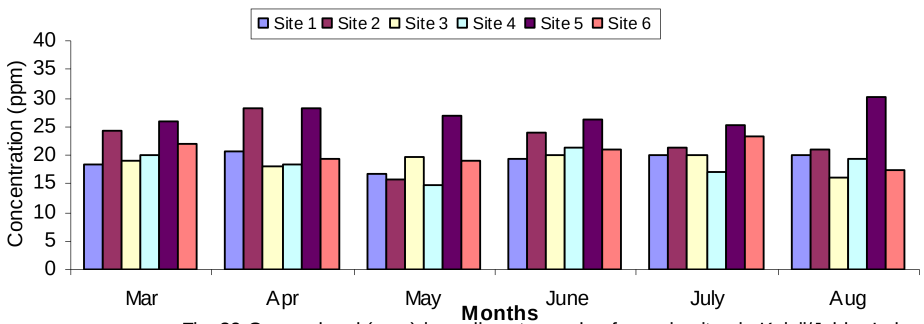

Fig. 29 Copper level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

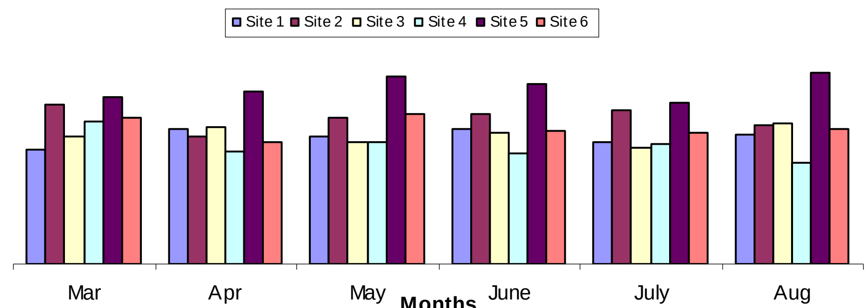

Fig. 30 Copper level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

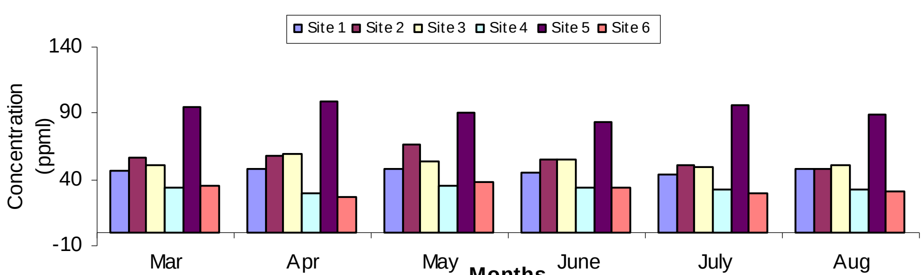

Fig. 31 Zinc level ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

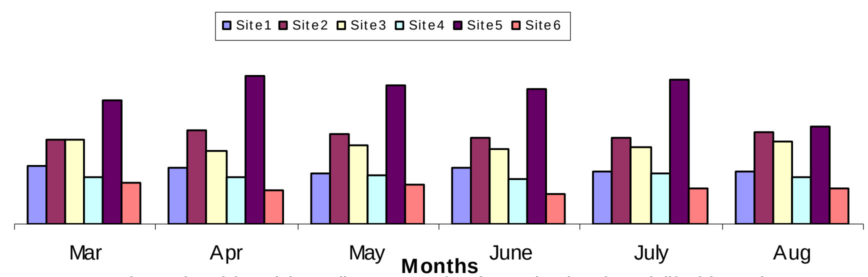

Fig. 32 level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

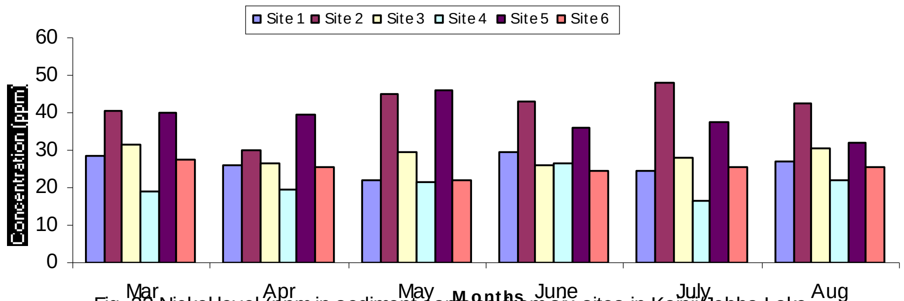

Fig. 33 Nickel level (ppm in sediment samples from six sites in Kainji/Jebba Lake using AAS

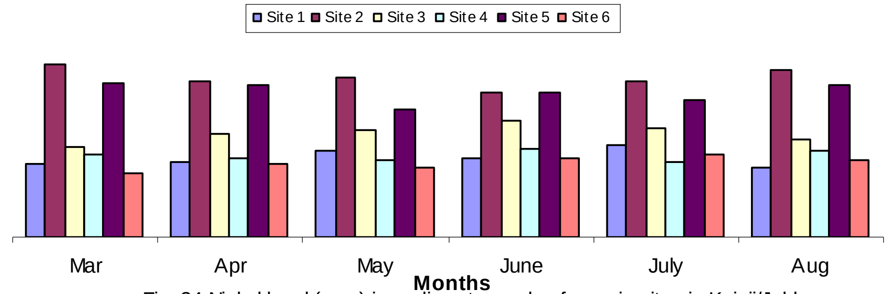

Fig. 34 Nickel level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

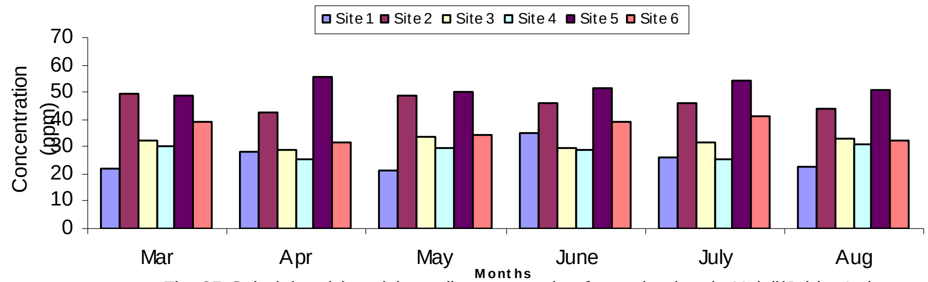

Fig. 35 Cobalt level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

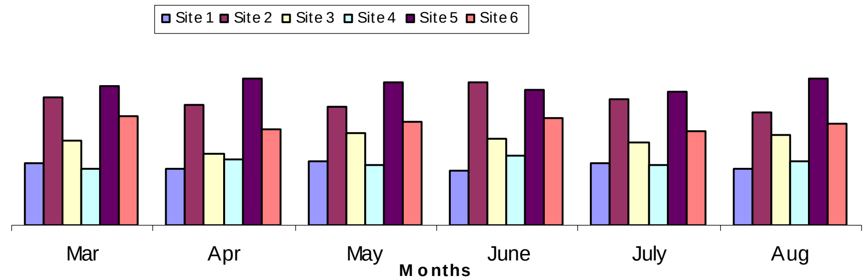

Fig. 36 Cobalt level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using XRFS

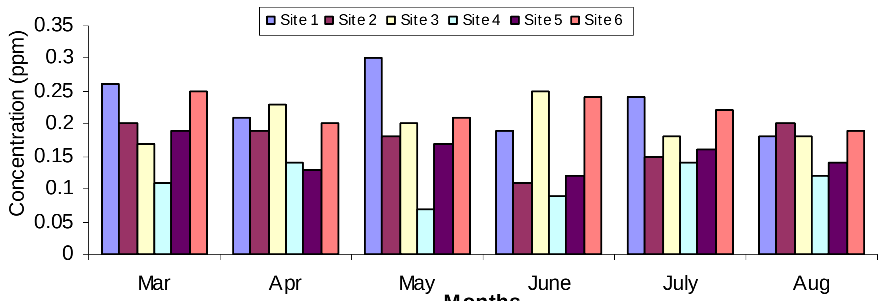

Fig. 37 Cadmium level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

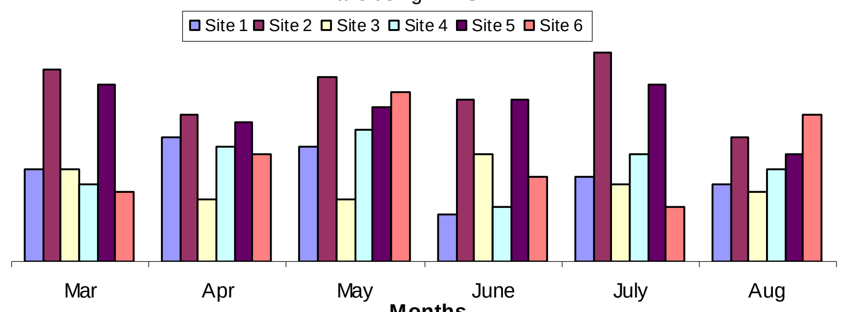

Fig. 38 Mercury level (ppm) in sediment samples from six sites in Kainji/Jebba Lake using AAS

4.3 PREAMBLE

The results of flame AAS and EDXRFS of fish samples from Kainji and Jebba Lakes from March- August 2002 are discussed as follows.

4.3.1. Fish

Lead (Pb)

Using AAS technique the highest lead level was 0.098ppm fresh weight in Tilapia in August below the dam and 0.22ppm in chrysicthys in June, also below the dam. The highest mean lead concentration and standard deviation was 0.088±0.01ppm fresh weight in tilapia below the dam and 0.17±0.04ppm in chrysicthys below the dam (Fig. 39). Levels of lead in fishes below the dam (Jebba Lake) are higher than in fishes within the Lake. The monthly and mean levels of lead in the fishes are less than values reported for in inland water fishes in some countries of the world. They are also below the WHO limit (2.0ppm fresh weight) (Kakulu *et al.*, 1987).

Result from EDXRFS indicate, the highest lead level in tilapia was 0.11ppm in Tilapia recorded in May below the dam and 0.26ppm in chrysicthys in March below the dam. The highest mean lead concentration and standard deviation was 0.21±0.028ppm in tilapia in Kainji Lake and 0.24±0.02ppm in chrysicthys also recorded within Kainji Lake (Fig. 40). The lead levels in fishes within kainji Lake are higher then those below the dam. The mean levels are lower than values reported in some countries of the world. They are also below the WHO recommended permissible level.

Chromium (Cr)

Results from AAS indicate, the highest chromium level was 0.14ppm in tilapia recorded in June below the dam (Jebba Lake) and 0.18ppm in chrysicthys below the dam. The highest mean chromium level and standard deviation was 0.10±0.033pm in Tilapia and 0.14±0.028ppm in chrysicthys also below the dam (Fig. 39). The levels of chromium are higher below the dam than within the Lake.

Using EDXRFS, the highest chromium level was 0.20ppm in tilapia 0.26ppm in chrysicthys both below the dam. The highest mean chromium level and standard deviation was 0.16±0.034ppm in tilapia and 0.18±0048ppm in chrysicthys (Fig. 40).

Nickel (Ni)

The highest levels of nickel, using AAS was 0.20ppm in tilapia and 0.26ppm in chrysicthys. The highest mean nickel concentration and standard deviation was 0.17±0.027ppm in Tilapia recorded below the dam and 0.21±0.033 in chrysicthys recorded within Kainji Lake (Fig. 39).

Results of EDXRFS indicate, the highest nickel level was 0.24ppm in tilapia, and 0.28ppm in Chrysicthys. The highest mean nickel concentration and standard deviation 0.19±033ppm in tilapia and 0.23±034ppm in chrysicthys both below the dam (Fig. 40).

Zinc (Zn)

Analysis by AAS indicates the highest zinc level of 3.42ppm in Tilapia and 3.86ppm in chrysicthys. The highest mean zinc concentration and standard deviation was 2.96±0.27ppm in Tilapia within Kainji Lake and 3.41±0.34ppm in chrysicthys below the dam (Fig. 39). The mean zinc levels in both species are lower than obtained in some countries of the world. They are also lower than the WHO limit of 1000µg/g fresh weight (Kakulu *et al*., 1987).

Using EDXRFS, the highest zinc level was 3.50µppm in tilapia and 4.0ppm in chrysicthys both within Kainji Lake and the least levels were 1.20ppm in tilapia and 1.50ppm in chrysicthys both within Kainji Lake. The highest mean zinc level and standard deviation was 2.99±085ppm in tilapia and 6.1±0.95ppm in chrysicthys both within Kainji Lake (Fig. 40). Values of Zn levels in both species are lower than reported for inland water fishes in some countries of the world and lower than WHO recommended permissible limit.

Iron (Fe)

Using AAS technique, the highest Iron level was 4.0ppm in Tilapia and 5.22ppm in chrysichtys. The highest mean Iron level and standard deviation was 3.69±0.48ppm in Tilapia and 4.53±0.42ppm in chrysicthys both below the dam (Fig 39). These indicate, the levels of iron in the fishes are higher below the dam than within Kainji Lake. The mean levels are lower than levels in inland water fishes in some countries of the world .

Using EDXRFS technique, the highest mean Iron concentration and standard deviation 3.94±0.76ppm in Tilapia and 5.27±0.362ppm in chrysicthys both below the dam (Fig. 40). The mean levels are lower than values reported for inland water fishes in some countries of the world.

Copper (Cu)

The highest mean Copper concentration and standard deviation was 0.22±0.037ppm in Tilapia within the Kainji Lake and 0.26±0.39ppm in chrysicthys recorded below the dam (Fig. 39). The mean levels of copper are lower than values in some countries of the world. They are also below the WHO recommended limit (30ppm fresh weight) (Kakulu *et al* .,1987).

Using EDXRFS, the highest mean copper concentration and standard deviation was 0.28±0.034ppm in Tilapia within Kainji Lake and 0.31±0.067ppm in chrysicthys recorded below the dam (Fig. 40). The mean levels are lower than values reported for inland water fishes in some countries of the world. The levels are lower than WHO recommended permissible level.

Cobalt (Co)

The highest Cobalt level from AAS analysis was 0.15µg/g in Tilapia in July/June within the Kainji Lake and below the dam respectively and 0.21ppm in chrysicthys in April, within the Kainji Lake. The highest mean cobalt concentration and standard deviation was 0.12±0.0221ppm in Tilapia recorded below the dam and 0.16±09.04ppm in chrysicthys within the Kainji Lake (Fig. 39.

Using EDXR.S, the highest mean cobalt concentration and standard deviation was 0.13±0.22ppm in tilapia recorded below the dam and 0.22±0.065ppm in chrysicthys within Kainji Lake.

Manganese (Mn)

Using AAS The highest mean manganese concentration and standard deviation was 0.74±0.12ppm in Tilapia and 0.66±0.089ppm in chrysichtys both withn the Kainji Lake (Fig. 39). Mean levels of manganese are lower than values in inland water fishes in some countries of the world.

Results of EDXRFS indicate, the highest mean manganese concentration and standard deviation was 0.98±0.23ppm in tilapia below the dam and 0.94±0.316ppm in chrysicthys both below the dam (Fig. 40). The mean levels of manganese in the fishes are below values reported for inland water fishes in some countries.

Cadmium (Cd)

This was analysed using AAS technique only. The highest mean cadmium concentration and standard deviation was 0.04±0.007ppm in Tilapia and 0.03±0.005ppm in chrysicthys both recorded below the dam. (Fig. 39). The mean levels are lower than values in inland water fishes in some countries of the world. The values are lower than the WHO recommended limit of 2.0ppm fresh weight (Kakulu *et al.*, 1987).

Mercury (Hg)

This was analysed using EDXRFS only. The mean mercury concentration was constant 0.02±0.009ppm in both fishes (Fig. 40). The mean levels of mercury are lower than WHO recommended permissible level in inland water fishes (Kakulu *et al.*, 1987). They are also below values reported for inland water fishes in some countries of the world.

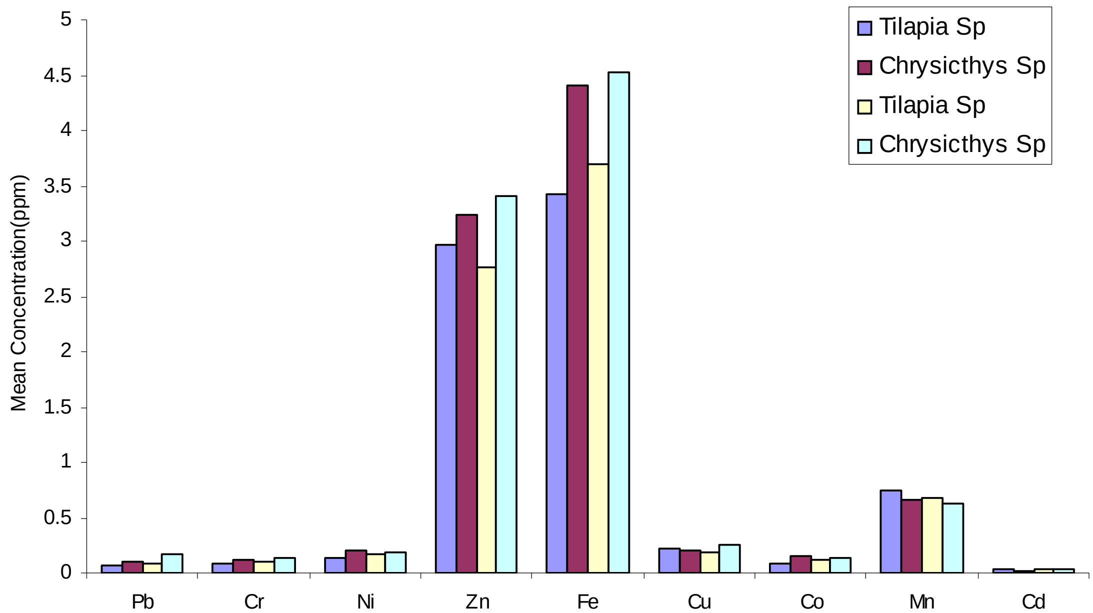

Fig 39. Mean metal levels in Tilapia /Chrysicthis from Kainji and Jebba Lakes (AAS)

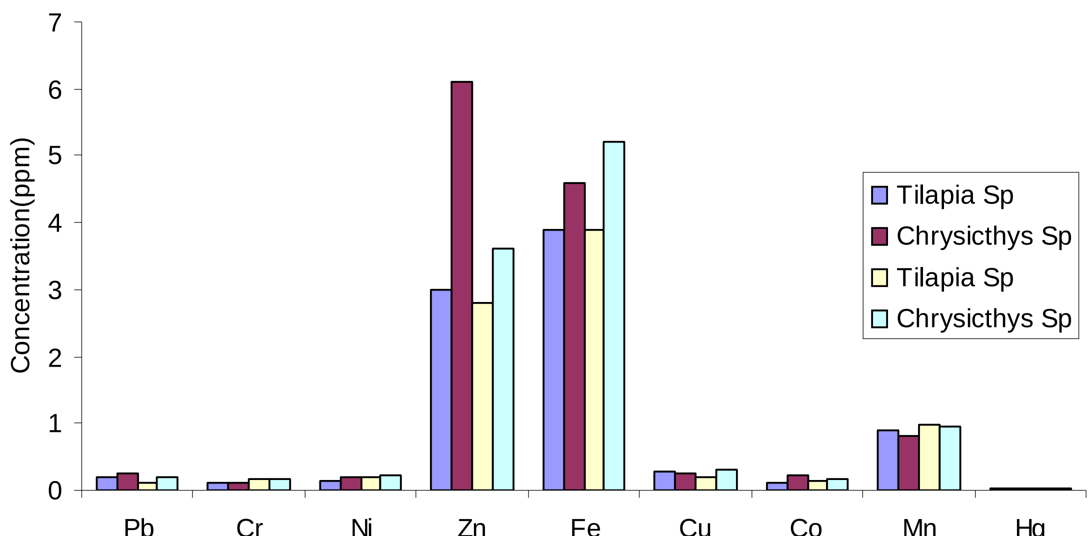

Fig 40. Mean metal levels in Tilapia /Chrysicthis from Kainji and Jebba Lakes (EDXRFS)

4.4 Summary of Metal levels in the samples

Water

At all sites the mean level of iron was higher than for the other metals determined (both by AAS and EDXRFS), followed by manganese (Mn) and chromium (Cr) ranked third. Lead, nickel, copper, cobalt and zinc are present within the 1-2ppm range. Cadmium was least of all the elements determined by AAS and mercury was least of those determined by EDXRFS. The concentration of Pb, Fe, Ni and Cr as recorded were higher in the Kainji Lake (sites 1-3) than below the dam (sites 4-6). The mean levels of all the metals were within the tolerable concentration in drinking and Lake water; an indication that the water body is safe for human use.

Correlation analysis of these elements indicate strong correlation in the pairs Pb-Cr, Cr-Cu, Zn-Mn, Zn-Fe.

Sediments

The results of both AAS and EDXRFS indicate that mean iron level was highest of all metals determined in all the sites, followed by manganese while Zinc was third. Cadmium ranks the least. Other metals were present within the range 20-30-ppm. The mean levels of Ni and Cr were higher within Kainji Lake than below the dam. Site five recorded higher mean levels of all metals than the remaining sites. The location of the site is unique as it was the only site in the direct line of waste discharge, run-off from the neighbouring Faku settlement. However, the mean level of most metals were within literature value for un-polluted inland water sediments, this implies that the sediment is safe. Cd concentration was slightly above the literature value. Correlation co-efficient indicate strong correlation in the pairs Cu-Fe, Mn – Pb

Fish

Like water and sediment, the mean iron level was higher than other metals determined (by both AAS and EDXRFS) in both species in the two Lakes. This was followed by zinc (Zn) and then manganese (Mn). Cadmium level was least (using AAS) and mercury least (using EDXRFS). The levels of metals were below 1ppm except Fe and Zn.

In general, mean levels of metals were higher in chrysicthys than in Tilapia. The mean levels of metals in the fishes were within permissible levels, an indication that the fishes are safe for human consumption.

4.5 Comparison of Mean levels of heavy metals in water, Sediments and fish

Lead (Pb)

The mean levels of lead in all sites are lower in water than in fish and in sediment, for both AAS and EDXRFS but Pb concentration 4th in order of abundance of the heavy metals in water, ranked 8th in both fish and sediments. This suggests a low process of Pb accumulation compared to other metals in both fish and sediment.

Adsorption is one of the first steps in the removal of metals from water. Microbial and redox processes may change the properties of sediments and hence decrease their adsorption capacity (Biney *et al.,* 1994). This could account for the low Pb level relative to other metals in the sediments. The accumulation of Pb relative to other metals in fish may be due to the rate of Pb turn over in the tissues (Annune and Iyaniwura, 1993).

Chromium (Cr)

The mean chromium level in water was about 2% of it's level in fish and 1.5% it's level in sediments. In other words, the level was least in water and highest in sediments. The ranking dropped from 3rd in water to 6th/7th in sediments and fish respectively. This apparently indicates low rate of chromium absorption compared to some metals reported in the fish, and also low adsorption rate in the sediments.

Nickel

The mean nickel level was highest in sediments followed by fish and least in water. Nickel however moved up in ranking from 6th in water to 5th in fish and 4th in sediments. This suggests higher rate of nickel removal from water compared to other metals, over the same period.

Zinc (Zn)

As in all other heavy metals studied, mean Zn level was highest in sediments and least in water. A striking feature however was that, Zn recorded the highest shift in ranking. In water, cadmium ranked lower. But in sediments, only Fe and Mn recorded higher mean levels than Zn. In fish, mean level of Zn ranked 2nd to Fe. It is widely believed Zn associates with oxides of Fe, Mn and Al (Kuo *et al*., 1983;

Gonzalez *et al*., 1994). This makes it concentrated and relatively immobilized in sediments.

In water, the mean concentration of Pb was twice that of Zn. Yet the accumulation of Zn in the fishes was about 30 times higher than Pb. Zinc is essential and metabolically useful and is therefore concentrated in tissues in excess of requirements to be drawn in time of starvation or low input (Love 1970; Bowen, 1972).

Iron (Fe)

The mean iron levels were high compared to other metals in each of the samples water, fish and sediments. It recorded highest mean levels amongst metals studied in all samples. Its mean levels was highest in sediments and least in water.

Copper (Cu)

The highest mean copper level in sediments, followed by fish and water. It's ranking in order of abundance remains same in both water and sediments and (4^{th}) in fish. Only Zn showed higher shift. This indicates high rate of copper absorption in the fishes.

Cobalt (Co)

The ranking in order of abundance of Co remains 6^{th} in both water and sediments and 5^{th} in fish. The highest mean level was in sediments, followed by fish then water.

Cadmium (Cd)

This is based on AAS only. The mean cadmium level was least amongst all metals studied in each of the samples water, fish and sediments. The mean cadmium level was highest in sediments followed by fish and then water.

Mercury (Hg)

This is based on EDXRFS only. The mean mercury level was least amongst metals studied, in each of the samples water, fish and sediments. Its highest mean level was in sediments, followed by fish and water.

The trend observed in all of the metals was that, mean levels were highest in sediments, followed by fish and then water. Normally, sediments serve as temporary or permanent store of metals (Biney *et al*., 1994). Adsorption and sedimentation of suspended particles serve to remove metals from water. The levels of heavy metals observed is a consequence of age long (past) and present adsorption and sedimentation.

In fish, metal accumulation is dependent on the physical and chemical characteristics of the metal (Bio-ellite, 2000). Metal up take rate vary according to the metal in question. Fish can also excrete metals, such as Cu, Zn, Fe that are present in excess.

4.6 Comparison of mean levels of heavy metals in Tilapia (*O. niloticus*) and chrysicthys (*C. auratus*)

For both species, the order of relative abundance of the metals was same that is Fe > Zn > Mn > Cu> Ni > Co > Cr > Pb > Cd. However, except for Mn and

Cd, the mean levels of other metals were generally higher in chrysicthys than in Tilapia. The tissues of chrysicthys absorb metals more than those of Tilapia. The difference in the rate of absorption of metals in these species may be attributed to the difference between them.

Chrysicthys is a scaleless fish and the body is in direct contact with the metal contaminants, while Tilapia has scales that provide some protection from the metal contaminants. The difference may also reflect differences in homeostatic control abilities (Annune and Lyaniwura, 1993).

The result indicate, that for each species, the level of each metal varies between the two Lakes. For example, in Tilapia the levels the metals were higher below the dam than within the Kainji Lake. This is also true for chrysicthys. Statistical tests of significance, using ANOVA at $p<0.05$ indicate that these differences between the species and between the Lakes are not significant.

4.7 Comparison of mean heavy metal levels between Kainji Lake and Jebba Lake

The area of focus is the sampling area which was the Southern basin of Kainji Lake and below the dam (Jebba Lake). The hydro power plant separates the two Lakes (Plate 1).

Water

Generally the levels of heavy metals were higher in water below the dam (Jebba Lake) than within the Kainji Lake except for Pb, Fe and Hg.

Sediments

The levels and mean levels of most metals were higher in sediments below the dam (Jebba Lake) than within Kainji Lake except Ni and Cr.

Fish

For Tilapia, the mean levels of metals were constant in fish samples from the two Lakes except for iron that was higher below the dam and Zn which was higher within Kainji Lake. This was same in chrysicthys.

Strictly, the margin of difference between metal levels in samples from the two Lakes is only relative. They were so close that no implication may be drawn. The aim was to assess the role of the hydro power plant which separates the two Lakes, in terms of heavy metal discharge into the Lake. The possibility of heavy metal discharge by the hydro power plant can be hypothesized based on the increase in levels of most metals below the dam.

4.8 Comparison of Results from AAS and EDXRFS

For each of the samples water, sediment and fish, both techniques used in analysis indicate the same order of relative abundance of metals. This order for example was, Fe > Mn > Cr > Pb > Co > Ni > Cu > Zn > Cd in water. It was Fe > Mn > Zn > Ni > Co > Cr > Cu > Pb > Cd in sediment and Fe > Zn > Mn > Cu > Ni > Co > Cr > Hg > Cd. in fish. This is an indication of the specificity and accuracy of the two techniques.

In general, values from EDXRFS were higher than those from AAS. These differences may be due to sample handling. AAS is a solution technique and requires some form of sample preparation. Loss could arise during the process. The ANOVA tests (at $P<0.05$) indicate the difference is not significant.

By characterization, EDXRFS needs only simple preparation for aqueous/ solid materials. The technique is non-destructive and many elements can be determined simultaneously. It has high sensitivity for Co, Ni, Fe, Cu, Zn, Cr, V and Mn. One disadvantage however is high counting time (over 300 sec) required to obtain a suitable statistics. Counting time of 5000 sec. was used for each sample in this study. This is high where large sample numbers are involved.

On the other hand, AAS requires less time for analysis, it has high precision, cost low, but lack simultaneous multi-element analysis i.e analyses of an element at a time, it is a solution technique that requires sample preparation and given the short analyte residence time in the observation region of most flames, the overall efficiency of atom production is low

CHAPTER FIVE

CONCLUSION

5.1 Summary of Findings

The results obtained from AAS and EDXRFS of heavy metals in water, sediments and fish show the same order of relative abundance of the metals in each of the samples.

Although results of the two techniques show differences in the mean concentration of metals, these are not significant as indicated by ANOVA tests (both one tail and two tail) at $p<.0.05$.

The higher values in the results of EDXRFS. as compared to AAS might not be unconnected with sample handling. In other words, the lower levels recorded by AAS may be due to loss during sample preparation and loss during analysis by the instrument.

The results indicate, metal concentrations were least in the water, higher in fish and highest in sediments. In all samples, some metals recorded higher levels below the dam while some did within Kainji Lake. Results of sediments indicate striking outcome at site 5. Site 5 was Faku village, a fishing/farming settlement below the dam. The sampling site was close to where domestic discharges drain into the river thus contributing to the high values obtained from the area.

The concentration difference between Kainji Lake and below the dam was not significant as to warrant any suggestion of discharges from the hydropower station that separates the two Lakes. That is not to say there is no metal contaminant from the hydro – station. This is either difficult to prove or insignificant.

Most of the contaminants sources are traceable to agricultural activities and other anthropogenic sources. The results obtained from correlation analysis for instance reveal pairing of metals which are commonly associated with fertilizers, biocides (Pesticides, herbicides), paints, alloys and solders, fuel and pigments amongst others. None of the six sites is an industrial area. All are agricultural/fishing.

For a number of metals, the mean values were below those in a number of countries and within levels internationally permitted or recommended. This implies that the results of this work has not identified any major metal pollution problem associated with either water, fish or sediments in the Southern basin of Kainji Lake/below the dam.

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APPENDICES

Table 1: Heavy metal concentration in ppm in Water collected from six sites in Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By AAS)

	Kainji Lake																	
	Site 1						Site 2						Site 3					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	1.30	1.28	1.42	1.57	1.32	1.40	0.89	1.05	1.17	1.23	1.15	1.25	1.28	1.08	1.14	1.30	1.03	1.21
Cr	2.02	1.86	1.74	2.34	1.72	1.80	2.16	2.07	1.79	1.70	1.66	2.51	1.92	2.23	2.70	2.45	2.31	2.20
Ni	0.97	1.16	0.86	1.04	1.23	0.93	1.21	1.09	1.12	0.77	1.02	1.11	0.69	1.07	0.63	0.85	0.57	1.10
Zn	0.67	0.90	0.65	0.49	0.76	0.84	0.81	0.81	0.74	0.58	0.44	0.37	0.70	0.80	0.86	0.78	0.81	0.87
Fe	12.42	12	10.76	12	11.90	11.85	13.1	13.12	11.04	13.06	13.00	12.67	12.98	13.46	12.88	13.71	13.21	13.56
Cu	0.68	0.83	0.92	0.77	1.04	0.81	1.11	1.11	1.36	1.23	0.98	1.63	1.09	1.11	1.25	1.18	1.14	1.20
Co	0.87	1.06	0.89	0.91	0.98	1.11	0.96	0.96	1.15	1.37	0.90	1.19	1.18	1.31	1.29	1.20	1.34	1.25
Mn	4.89	6.06	5.04	5.21	4.63	5.24	10.5	10.45	10.11	10.27	9.90	10.16	6.28	5.94	5.64	6.35	6.17	5.51
Cd	0.009	0.01	0.021	0.01	0.012	0.011	0.02	0.015	0.007	0.014	0.005	0.009	0.007	0.012	0.005	0.014	0.009	0.006

	Jebba Lake																	
	Site 4						Site 5						Site 6					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	1.27	1.15	1.20	1.31	1.22	1.10	1.13	1.15	0.94	1.06	1.17	1.11	0.58	1.05	1.12	0.989	1.23	0.93
Cr	1.89	2.04	1.71	1.85	1.67	1.93	2.56	2.11	1.7	2.33	2.69	1.88	1.48	2.22	1.96	2.09	2.15	2.05
Ni	0.91	0.98	1.03	0.81	1.06	0.84	0.57	0.73	0.95	0.86	0.92	0.64	1.04	0.92	0.82	0.77	0.88	0.96
Zn	1.43	0.99	1.24	1.28	1.21	1.18	1.02	0.82	1.1	0.93	0.86	0.8	0.76	0.88	1.11	1.22	0.91	1.05
Fe	10.33	11.1	11.00	10.9	10.79	11.07	11.7	12.41	11.28	12.31	10.4	12.16	10.2	9.85	10.17	9.94	10.10	10.29
Cu	1.58	1.37	1.48	1.26	1.42	1.33	1.35	1.41	1.19	1.24	1.11	1.27	1.43	1.86	1.48	1.54	1.31	1.39
Co	1.27	1.18	1.30	1.05	1.32	1.28	1.21	1.31	1.27	1.29	1.34	1.19	1.14	1.17	1.28	1.33	1.10	1.26
Mn	8.86	8.98	9.23	9.15	9.52	9.41	12.8	14.03	14.67	13.96	14.08	14	8.26	7.77	8.00	6.93	6.78	7.61
Cd	0.016	0.01	0.014	0.01	0.012	0.14	0.01	0.024	0.019	0.01	0.015	0.022	0.011	0.018	0.014	0.020	0.009	0.013

Table 2: Mean heavy metal concentration expressed in ppm in water collected from Kainji/Jebba Lake (det. by A.A.S)

	Kainji Lake			**Jebba Lake**		
Metal	1	2	3	4	5	6
Pb	1.38±0.11	1.12±0.13	1.17±0.11	1.21±0.077	1.09±0.084	0.98±0.22
Cr	1.91±0.24	1.98±0.33	2.30±0.26	1.85±0.14	2.21±0.39	1.99±0.27
Ni	1.03±0.14	1.05±0.15	0.82±0.23	0.94±0.10	0.78±0.16	0.90±0.097
Zn	0.72±0.15	0.60±0.17	0.80±0.062	1.22±0.14	0.92±0.12	0.99±0.17
Fe	11.82±0.56	12.50±0.81	13.30±0.33	10.87±0.29	11.7±0.77	10.09±0.17
Cu	0.84±0.12	1.29±0.23	1.16±0.060	1.41±0.11	1.26±0.11	1.50±0.19
Co	0.97±0.098	1.10±0.17	1.26±0.63	1.23±0.10	1.27±0.058	1.2±0.090
Mn	5.18±0.49	10.21±0.20	5.98±0.35	9.19±0.25	13.92±0.61	7.56±0.59
Cd	0.012±0.005	0.010±0.004	0.009±0.004	0.012±0.004	0.017±0.005	0.014±0.004

Table 3. Mean Heavy Metal Concentration in ppm in Water per Lake (AAS)

	Kainji	Jebba
Pb	1.23+0.16	1.09+0.17
Cr	2.06+0.31	2.01+0.30
Ni	0.98+0.10	0.87+0.133
Zn	0.71+0.15]	1.04+0.19
Fe	12.6+0.84	10.89+0.81
Cu	1.80+0.22	1.39+0.17
Co	1.10+0.16	1.24+0.08
Mn	7.13+2.30	10.22+2.81
Cd	0.01+0.00	0.02+0.02

Table 4: Heavy metal concentration in ppm in Water collected from six sites in Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By EDXRFS)

	Kainji Lake																	
	Site 1						**Site 2**						**Site 3**					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	1.83	1.71	1.50	1.69	1.56	1.74	1.10	1.08	1.11	1.22	0.58	1.30	1.25	1.15	1.43	1.26	1.23	1.31
Cr	1.80	1.93	2.06	1.96	2.27	2.57	2.33	2.10	1.89	2.24	2.4	2.35	2.28	2.21	1.9	2.32	2.22	2.16
Ni	1.10	0.72	0.88	1.00	1.04	0.70	1.32	1.10	1.22	0.93	1.04	1.12	0.98	0.70	1.23	0.89	0.75	0.84
Zn	1.12	0.92	0.50	0.68	0.76	0.80	0.77	0.52	0.65	0.85	0.42	0.68	0.89	0.94	0.50	0.76	0.58	0.60
Fe	12.98	13.36	13.57	12.88	12.5	12.7	14.87	11.45	16.28	16.14	15.12	14.93	10.94	13.66	15.04	14.6	14.99	15.36
Cu	0.81	0.68	0.56	0.70	0.69	0.73	1.62	1.43	1.30	1.37	1.29	1.52	1.08	1.30	1.26	1.34	1.38	1.25
Co	1.13	0.99	0.94	1.05	1.21	1.20	1.27	1.00	1.21	1.16	1.11	1.10	1.34	1.22	1.15	1.20	1.11	1.25
Mn	7.03	6.50	5.79	5.55	6.93	6.70	13.48	11.6	12.32	11.88	10.11	10.2	6.85	7.22	8.14	6.59	5.62	6.03
Hg	0.008	0.007	0.001	0.006	0.014	0.014	0.008	0.014	0.012	0.006	0.005	0.010	0.013	0.008	0.006	0.012	0.009	0.007

	Jebba Lake																	
	Site 4						**Site 5**						**Site 6**					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	1.48	1.61	1.50	1.52	1.58	1.54	1.02	1.13	1.18	0.51	1.05	0.40	0.91	0.80	1.23	0.88	0.70	0.75
Cr	1.95	2.04	1.9	1.86	1.81	1.88	2.13	2.62	2.17	2.74	2.41	2.50	2.22	2.28	2.11	2.15	1.99	2.31
Ni	0.60	0.9	0.86	0.64	0.38	1.35	0.92	0.78	1.02	0.80	0.83	0.80	0.77	0.89	0.68	0.86	0.90	0.88
Zn	1.13	1.05	1.25	1.32	0.72	1.14	1.52	0.63	0.58	1.32	0.98	1.40	0.81	1.30	0.90	0.94	1.24	1.10
Fe	13.12	10.21	13.66	11.83	12.59	13.6	14.11	12.90	13.56	11.85	13.4	10.96	10.9	11.72	12.18	11.0	11.53	11.06
Cu	1.38	1.80	1.10	1.69	1.3	1.98	1.12	1.57	1.37	1.39	1.48	1.30	1.75	1.58	1.40	1.44	1.49	1.80
Co	0.99	1.3	1.49	1.17	1.33	0.91	1.48	1.40	1.35	1.06	1.35	1.32	1.24	1.25	1.36	1.30	1.20	1.31
Mn	9.16	8.26	7.78	7.56	4.7	7.78	15.08	16.43	14.19	12.9	15.0	15.19	6.67	7.52	6.36	6.10	6.88	7.82
Hg	0.012	0.014	0.030	0.027	0.015	0.018	0.006	0.008	0.006	0.010	0.009	0.007	0.007	0.007	0.01	0.007	0.008	0.005

Table 5: Mean heavy metal concentration expressed in ppm in water collected from Kainji/Jebba Lake (det. by EDX.R.F.S)

	Kainji Lake			**Jebba Lake**		
Metal	**1**	**2**	**3**	**4**	**5**	**6**
Pb	1.67±0.12	1.07±0.25	1.27±0.09	1.54±0.05	0.88±0.34	0.88±0.19
Cr	2.10±0.28	2.22±0.19	2.18±0.15	1.91±0.08	2.43±0.24	2.18±0.12
Ni	0.91±0.17	1.12±0.14	0.90±0.19	0.79±0.33	0.86±0.09	0.83±0.09
Zn	0.80±0.19	0.65±0.16	0.71±0.18	1.10±0.21	1.07±0.40	1.05±0.20
Fe	13.00±0.37	14.80±1.75	14.10±1.65	12.51±1.31	12.81±1.18	11.40±0.50
Cu	0.70±0.08	1.42±0.13	1.27±0.10	1.54±0.33	1.37±0.15	1.58±0.17
Co	1.09±0.11	1.14±0.10	1.21±0.08	1.20±0.22	1.33±0.14	1.28±0.06
Mn	6.42±0.61	11.60±1.29	6.74±0.81	8.04±0.60	14.80±1.18	6.89±0.67
Hg	0.01±0.003	0.009±0.003	0.01±0.003	0.02±0.001	0.008±0.002	0.008±0.002

Table 6: Mean Heavy Metal Concentration in ppm in Water per Lake (EDXFRS)

	Kainji	Jebba
Pb	1.33+0.30	1.09+0.38
Cr	2.17+0.20	2.17+0.27
Ni	0.98+0.19	0.82+0.19
Zn	0.71+0.18	1.07+0.27
Fe	13.96+1.53	12.23+1.17
Cu	1.13+0.34	1.40+0.23
Co	1.15+0.10	1.27+0.15
Mn	8.25+2.60	9.74+3.84
Hg	0.00+0.00	0.01+0.00

Table 7: Heavy metal concentration in ppm dry weight sediments collected from six sites in Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By AAS)

	Kainji Lake																	
	Site 1						Site 2						Site 3					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	16.51	14.86	20.39	17.59	19.8	21.27	16.52	15.76	20.28	17.49	19.98	22.40	14.34	18.88	13.98	19.37	16.55	18.77
Cr	19.16	26.49	24.96	20.85	23.57	26.34	29.08	25.82	26.81	26.93	28.66	29.58	23.62	20.92	28.47	27.44	23.82	26.52
Ni	28.3	25.79	21.90	29.30	24.46	27.04	40.53	30.00	45.24	42.89	48.00	42.34	31.31	26.45	29.66	25.93	27.85	30.51
Zn	45.99	48.36	47.85	44.55	43.85	48.09	55.94	58.02	66.09	55.38	50.40	47.88	51.22	59.40	53.44	55.02	49.99	50.24
Fe	4042	4802	5094	6009	4925	5338	5774	6386	7012	6432	6590	5833	5007	4794	5218	4338	4691	5089
Cu	18.2	20.61	16.71	19.34	20.15	20.03	24.20	28.20	15.81	24.06	21.38	20.94	19.07	17.99	19.77	20.10	20.00	16.12
Co	21.96	28.45	20.99	34.87	26.30	22.66	49.6	42.47	48.88	45.92	46.27	43.89	32.09	28.84	33.53	29.73	31.78	32.62
Mn	283.16	271.57	289.81	309.03	260.44	320.00	405.5	456.2	334.55	373.36	392.8	401	310.83	331.62	363.76	358.34	400.21	311.2
Cd	0.26	0.21	0.30	0.19	0.24	0.18	0.20	0.19	0.18	0.11	0.15	0.20	0.17	0.23	0.20	0.25	0.18	0.18

	Jebba Lake																	
	Site 4						Site 5						Site 6					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	17.84	20.56	17.95	21.99	20.76	18.69	19.44	20.33	18.97	21.81	20.00	20.52	19.53	15.77	18.23	17.25	20.12	14.75
Cr	26.80	25.54	19.82	28.04	31.36	23.95	30.72	28.68	35.70	31.28	34.20	32.69	25.05	21.57	30.91	26.55	20.99	23.50
Ni	18.81	19.62	21.45	26.32	16.51	22.04	40.02	39.31	46.01	35.85	37.65	31.99	27.30	25.45	21.99	24.58	25.72	25.61
Zn	33.84	29.33	35.31	34.05	32.57	31.95	94.56	99.02	90.65	83.92	95.88	89.28	35.05	26.66	38.73	33.57	29.93	30.35
Fe	5015	6441	5025	6005	5982	5569	7331	8046	6500	6173	7326	6983	6120	5271	5914	6133	6315	6234
Cu	20.11	18.30	14.62	21.20	17.00	19.30	25.76	28.20	26.88	26.11	25.40	30.02	22.05	19.30	18.96	20.99	23.21	17.37
Co	30.14	25.68	29.38	28.85	25.42	30.61	48.89	55.33	49.97	51.64	53.99	50.75	39.45	31.43	34.05	38.87	41.29	32.31
Mn	230.89	356.11	234.85	311.22	348.64	486.3	450.12	556.10	334.05	410.08	435.35	520.21	302.14	287.50	296.76	259.85	310.20	301.51
Cd	0.11	0.14	0.07	0.09	0.14	0.12	0.19	0.13	0.17	0.12	0.16	0.14	0.25	0.20	0.21	0.24	0.22	0.19

Table 8: Mean heavy metal concentration expressed in ppm dry weight, in sediments collected from six sites in Kainji/Jebba Lakes from March 2002 – August 2002 (det. by.AAS)

	Kainji Lake			**Jebba Lake**		
Metal	**1**	**2**	**3**	**4**	**5**	**6**
Pb	18.40±2.49	18.74±2.56	16.98±2.40	19.63±1.71	20.18±0.98	17.61±2.10
Cr	23.56±3.00	27.81±1.50	25.13±2.83	25.92±3.90	32.21±2.53	24.76±3.66
Ni	26.13±2.70	41.50±6.20	28.62±2.21	20.79±3.35	38.47±4.68	25.11±1.76
Zn	46.80±2.34	55.62±6.37	53.22±3.60	32.84±2.09	92.22±5.39	32.38±4.28
Fe	5035±648	6338±469	4856±319	5673±576	7043±660	5998±381
Cu	19.17±1.47	22.43±4.15	18.84±1.55	48.42±2.36	27.06±1.76	20.31±2.16
Co	24.21±2.85	46.17±2.76	31.43±4.79	28.51±2.04	51.78±2.43	36.23±4.15
Mn	289±22	380±53	346±53	328±95	451±79	293±18
Hg	0.23±0.049	0.17±0.035	0.20±0.032	0.11±0.028	0.15±0.026	0.22±0.023

Table 9: Mean Heavy Metal Concentration in ppm in Sediments per Lake (AAS)

	kainji	**Jebba**
Pb	18.04±2.46	19.14±1.93
Cr	25.50±2.99	27.63±4.65
Ni	32.08±7.93	28.12±8.40
Zn	51.78±5.73	52.48±29.18
Fe	5409±824	6243±801
Cu	20.15±3.03	21.93±4.30
Co	34.49±9.43	38.78±10.42
Mn	342.97±54.06	357±97
Cd	0.20±0.04	0.16±0.05

Table 10: Heavy metal concentration in ppm dry weight in sediments collected from six sites in Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By EDXRFS)

	Kainji Lake																	
	Site 1						Site 2						Site 3					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	20.1	18.96	13.78	14.50	15.18	18.21	20.42	17.98	26.08	22.64	17.99	19.80	15.86	20.00	21.35	14.67	15.71	19.14
Cr	23.2	25.72	28.24	22.29	18.35	22.61	32.60	30.30	28.02	33.53	26.85	30.49	34.00	28.10	31.04	26.12	30.06	25.03
Ni	22.78	23.00	26.59	23.99	28.17	21.62	53.25	47.81	49.08	44.66	47.87	51.32	27.53	31.74	32.81	36.0	33.61	29.90
Zn	47.28	45.40	40.72	45.00	42.10	42.89	68.83	75.62	72.02	69.75	69.38	73.51	68.07	59.84	63.75	60.67	61.97	66.15
Fe	5250	5478	4993	5245	5267	5199	9000	7740	9662	8581	8610	8006	5649	6021	5332	5801	5439	5597
Cu	20.56	24.14	23.00	24.33	21.79	23.21	28.6	22.87	26.22	26.84	27.63	24.91	22.86	24.65	21.77	23.65	20.82	25.08
Co	26.11	23.93	27.09	22.84	26.00	24.15	54.08	50.51	49.98	60.10	53.31	47.89	35.40	29.96	38.94	36.5	34.56	38.23
Mn	270	254	287	232	300	246	435	392	442	420	358	447	410	397	425	386	377	412
Hg	0.12	0.16	0.15	0.06	0.11	0.10	0.25	0.19	0.24	0.21	0.27	0.16	0.12	0.08	0.08	0.14	0.10	0.09
	Jebba Lake																	
	Site 4						Site 5						Site 6					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	20.00	15.46	16.59	21.16	19.00	18.83	22.41	17.94	20.14	21.3	17.77	17.98	13.69	18.20	17.00	23.11	15.26	20.36
Cr	26.86	23.65	28.02	30.11	32.03	27.34	24.69	28.30	30.37	25.57	27.39	24.91	23.85	29	23.15	32	26.2	21.7
Ni	25.44	24.09	23.71	27.29	22.96	26.60	47.33	46.65	38.96	44.21	42.19	46.47	19.75	22.62	21.50	24.14	25.37	23.41
Zn	38.39	38.50	40.00	35.76	40.6	37.43	99.50	120	112.11	108.57	117.3	78.68	32.61	27.73	32.45	24.68	28.59	29.12
Fe	7179	8052	6984	5862	6780	6960	9320	8244	10310	9054	9372	9531	6755	6900	7106	6839	6701	7000
Cu	25.55	20.31	22.00	19.94	21.48	18.21	29.81	30.88	33.64	32.30	28.80	34.16	26.33	21.98	27.00	23.91	23.4	24.25
Co	23.61	27.90	25.19	29.20	25.57	26.92	58.9	61.67	60.43	56.78	55.93	61.70	46.13	40.64	43.41	45.00	39.95	42.86
Mn	344	401	396	381	374	350	421	475	382	444	481	400	402	384	413	309	361	340
Hg	0.10	0.15	0.17	0.07	0.14	0.12	0.23	0.18	0.20	0.21	0.23	0.14	0.09	0.14	0.22	0.11	0.07	0.19

Table 11: Mean heavy metal concentration expressed in ppm dry weight, in sediments collected from six sites in Kainji/Jebba Lakes from March 2002 – August 2002 (det. by EDXRFS)

	Kainji Lake			**Jebba Lake**		
Metal	**1**	**2**	**3**	**4**	**5**	**6**
Pb	1879±2.63	20.82±3.11	17.79±2.73	18.51±2.12	19.11±2.73	17.94±3.43
Cr	23.40±3.35	30.31±2.56	29.06±3.32	28.00±2.87	26.87±2.22	26.01±3.91
Ni	24.36±1.65	49.02±3.00	31.93±2.96	25.00±1.70	44.30±3.24	22.80±1.99
Zn	43.90±2.42	71.52±2.68	63.41±3.24	38.46±1.76	106±15	29.20±3.01
Fe	5240±155	8600±690	564±236	6971±704	9299±672	6802±152
Cu	22.84±1.44	26.18±2.05	23.14±1.70	21.28±2.49	31.60±2.14	24.48±1.87
Co	25.02±1.62	52.63±4.30	53.61±3.26	26.39±2.01	59.20±2.47	43.00±2.40
Mn	265±26.7	416±36	401±22	374±23	434±40	368±39
Hg	0.12±0.04	0.22±0.04	0.10±0.02	0.13±0.04	0.20±0.03	0.14±0.06

Table 12: Mean Heavy Metal Concentration in ppm in Sediments per Lake (EDXFRS)

	Kainji	Jebba
Pb	18.47±3.19	18.68±2.54
Cr	27.58±4.25	26.95±3.02
Ni	35.10±10.93	30.71±10.19
Zn	59.61±12.21	57.89±36.24
Fe	6492.78±1595	7719±1271
Cu	24.05±2.25	25.78±4.9
Co	37.75±12.10	42.88±13.96
Mn	360.56±74.34	392.11±44.91
Hg	0.146±0.063	0.153±0.053

Table 13: Heavy metal concentration in ppm fresh weight in Fish collected from Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By AAS)

	Kainji Lake												Jebba Lake											
	Tilapia Sp						Chrysicthys Sp						Tilapia Sp						Chrysicthys Sp					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	0.068	0.06	0.071	0.095	0.059	0.081	0.14	0.12	0.09	0.11	0.07	0.13	0.079	0.12	0.083	0.075	0.071	0.098	0.15	0.19	0.15	0.22	0.11	0.2
Cr	0.1	0.07	0.06	0.04	0.12	0.09	0.09	0.16	0.14	0.1	0.12	0.09	0.07	0.13	0.09	0.14	0.06	0.12	0.11	0.17	0.12	0.14	0.18	0.13
Ni	0.16	0.13	0.14	0.09	0.13	0.12	0.17	0.24	0.19	0.26	0.2	0.22	0.17	0.2	0.19	0.15	0.13	0.19	0.16	0.19	0.21	0.15	0.18	0.2
Zn	3.13	2.82	2.7	3.42	2.9	2.78	2.91	3.06	3.72	3.59	2.87	3.28	2.43	2.73	3.12	2.55	2.69	3.09	3.86	3.6	3.15	3.21	2.99	3.66
Fe	3.26	2.99	3.51	4.03	3.58	3.2	3.88	4.29	5.22	4.89	4.18	3.93	3.45	4.06	4.09	2.84	3.9	3.79	4.21	4.75	4.9	5.02	3.97	4.34
Cu	0.19	0.22	0.25	0.27	0.17	0.23	0.16	0.2	0.22	0.18	0.24	0.19	0.21	0.19	0.16	0.2	0.18	0.15	0.22	0.31	0.25	0.27	0.21	0.29
Co	0.05	0.08	0.13	0.03	0.15	0.11	0.19	0.21	0.17	0.13	0.1	0.15	0.14	0.11	0.09	0.15	0.12	0.12	0.08	0.15	0.14	0.12	0.14	0.16
Mn	0.67	0.72	0.19	0.6	0.65	0.86	0.71	0.59	0.53	0.65	0.69	0.78	0.73	0.59	0.65	0.81	0.62	0.69	0.59	0.65	0.6	0.54	0.67	0.72
Cd	0.027	0.03	0.041	0.024	0.035	0.021	0.016	0.02	0.014	0.021	0.025	0.023	0.04	0.038	0.03	0.052	0.041	0.035	0.023	0.33	0.036	0.028	0.031	0.28

Table 14: Heavy metal concentration in ppm fresh weight in Fish collected from Kainji/Jebba Lakes from Mar. 2002 – Aug. 2002 (Det. By EDXRFS)

	Tilapia Sp						Chrysicthys Sp						Tilapia Sp						Chrysicthys Sp					
	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug	Mar	Apr	May	June	July	Aug
Pb	0.22	0.17	0.21	0.19	0.25	0.19	0.25	0.23	0.24	0.20	0.25	0.25	0.06	0.10	0.11	0.09	0.11	0.10	0.26	0.18	0.14	0.22	0.19	0.15
Cr	0.08	0.14	0.10	0.12	0.06	0.10	0.06	0.15	0.10	0.08	0.17	0.05	0.10	0.20	0.15	0.18	0.16	0.17	0.16	0.20	0.19	0.26	0.14	0.13
Ni	0.23	0.10	0.15	0.14	0.11	0.13	0.16	0.23	0.25	0.16	0.13	0.24	0.18	0.15	0.16	0.21	0.20	0.24	0.19	0.25	0.24	0.28	0.20	0.22
Zn	3.18	3.40	1.20	3.21	3.44	3.50	4.00	3.50	2.10	1.50	3.40	3.21	2.77	3.50	2.67	3.00	3.21	1.70	3.41	3.50	3.90	3.70	4.00	3.08
Fe	3.78	3.34	4.89	4.41	3.93	3.10	4.50	5.10	5.11	4.10	4.54	4.54	3.80	4.60	4.37	3.90	2.50	4.32	5.51	4.76	5.20	5.61	4.76	5.28
Cu	0.26	0.28	0.24	0.31	0.33	0.26	0.19	0.41	0.20	0.19	0.10	0.42	0.19	0.23	0.30	0.29	0.11	0.14	0.30	0.32	0.40	0.35	0.29	0.20
Co	0.10	0.11	0.12	0.09	0.12	0.12	0.30	0.23	0.27	0.21	0.11	0.21	0.10	0.13	0.11	0.14	0.16	0.14	0.16	0.14	0.18	0.19	0.18	0.15
Mn	0.98	0.81	1.04	0.80	0.96	0.78	0.73	1.20	0.87	0.60	0.80	0.60	0.81	0.98	0.74	0.99	0.97	1.39	1.20	1.30	0.94	0.53	0.60	1.07
Hg	0.01	0.03	0.06	0.01	0.01	0.02	0.03	0.02	0.05	0.04	0.01	0.04	0.02	0.03	0.01	0.01	0.02	0.03	0.02	0.01	0.02	0.02	0.03	0.02

Table 15: Mean dissolved metal concentration in inland waters (ppm)

Country	Hg	Cd	Pb	As	Cu	Zn	Mn	Fe	Ref
Lake Mariut (Egypt		0.22			10.6	18.3		42.5	Saad 1985
Lake Nukuru (Kenya)	<1.0	21	5	6	2	49	26		Greichus et al 1989
Lake Victoria (Kenya)		2.8	7-93.6		5-57.6	25-125	50-3276		Ochieng 1987
Lake George (Uganda)			6		100			4830	Bugenyi 1982
Lake Mollwaine (Zimbabwe)	<1.0	1	10	3	10	12	32		Greichus et al 1978
Voelvlei Dam (South Africa)	<1.0	2	12	3	13	25	38		Greichus et al 1977

Source: Biney et al 1994

Table 16: Mean metal concentration in inland water sediments ppm dry weight.

Country	Hg	Cd	Pb	Cu	Zn	Mn	Fex10^3	Ref
Lake Mariut (Egypt		0.2	7.3	38	94	95.8	25.6	Saad et al 1985
Lake Nukuru (Kenya)	<0.05	0.27	34	6.2	14	550		Greichus et al 1978
Lake Victoria (Kenya)		.55-1.02	6-69	.96-78	2.5-26	53-616	1.8-52	Onyari and Wandiga 1989
Lake George (Uganda)		3.8		10.2			69.0	Bugenyi 1982
Lake Mollwaine (Zimbabwe)		27		37			5.5	Bugenyi 1982
Voelvlei Dam (South Africa)	0.06	0.19	9.0	15.0	49	340		Greichus et al 1977

Source: Biney et al 1994

Table 17: Mean metal concentration in inland water fish (ppm fresh weight)

Country	Hg	Cd	Pb	As	Cu	Zn	Mn	Fe	Ref
Lake Mariuty (Egypt)	0.01	0.15			3.7	7.6	0.9	11.2	El-Nabawi et al 1987
Lake Nakuru (Kenya)	0.044	0.05	0.17	0.36	2.0	22	1.8		Greichus et al 1978
Lake Victina (Kenya)		0.04-0.12	.4-11		0.15-0.53	2.2-7.0	0.22-0.7	.53-4.65	Wandiga and Onyari 1987
Lake Mallwaine (Zimbabwe		0.02	0.17	0.28	1.08	9.6	5.4		Greichn et al 1978

Source: Biney *et a.,l* 1994

Table 18: Mean heavy metal concentration expressed in ppm fresh weight, in fish collected from Kainji/Jebba Lakes from March 2002 – August 2002 (det., by AAS)

KAINJI LAKE			JEBBA LAKE	
METAL	Tilapia Sp	Chrysicthys Sp	Tilapia Sp	Chrysicthys Sp
Pb	0.072±0.014	0.11±0.026	0.088±0.018	0.17±0.040
Cr	0.08±0.029	0.12±0.029	0.10±0.033	0.14±0.028
Ni	0.13±0.023	0.21±0.033	0.17±0.027	0.18±0.023
Zn	2.96±0.27	3.24±0.033	2.77±0.28	3.41±0.34
Fe	3.43±0.36	4.40±0.54	3.69±0.48	4.53±0.42
Cu	0.22±0.037	0.20±0.029	0.18±0.023	0.26±0.039
Co	0.09±0.047	0.16±0.040	0.12±0.021	0.13±0.029
Mn	0.74±0.12	0.66±0.089	0.68±0.082	0.63±0.064
Cd	0.03±0.007	0.02±0.004	0.04±0.007	0.03±0.005

Table 19: Mean heavy metal concentration expressed in ppm fresh weight, in fish collected from Kainji/Jebba Lakes from March 2002 – August 2002 (det., by EDXRFS)

	KAINJI LAKE		**JEBBA LAKE**	
METAL	**Tilapia Sp**	**Chrysicthys Sp**	**Tilapia Sp**	**Chrysicthys Sp**
Pb	0.21±0.028	0.24±0.02	0.10±0.019	0.19±0.045
Cr	0.10±0.028	0.10±0.049	0.16±0.034	0.18±0.048
Ni	0.14±0.046	0.20±0.051	0.19±0.033	0.23±0.0335
Zn	3.0±0.885	6.1±0.95	2.8±0.62	3.6±0.339
Fe	3.9±0.665	4.6±0.39	3.9±0.076	5.2±0.362
Cu	0.28±0.034	0.25±0.13	0.21±0.078	0.31±0.0669
Co	0.11±0.013	0.22±0.065	0.13±0.022	0.17±0.0197
Mn	0.9±0.11	0.8±0.22	0.98±0.23	0.94±0.316
Hg	0.02±0.0197	0.03±0.015	0.02±0.009	0.02±0.006