# PRELIMINARY STUDY OF HYDROCHEMISTRY OF ELEYELE LAKE AND ITS TRIBUTRIES, IBADAN, NIGERIA.

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## ABSTRACT
*Hydrochemical evaluation and distribution of major and trace metals in water of Eleyele Lake and its feeding streams (tributaries) within Ibadan, south-western Nigeria is presented in respect of anthropogenic and geogenic contaminations from the surrounding catchments. The aim of the study is to delineate the degree of concentration of metals in the water phase. ICP-OES method was used for the hydrochemical analysis. The results revealed no practical contamination of these metals in terms of its domestic usability in both the tributaries and the main Lake because the values are below W.H.O. standard for potable water. The AF values are less than 1 and the Igeo- values less than 0. However, the average values of Sodium Absorption Ratio (SAR) recorded in the feeding stream (tributaries) is 10.6 and 5.9 in the main Lake. This is an indication of potential problem for irrigation water. Furthermore, the major metals have good correlation coefficient values (>0.6) with one another. This shows their close associations and could be attributed to their geogenic sources from the catchments' bedrock. Some of the trace metals show negative correlation with the major metals, TDS and the EC. This reflects different sources and controlling processes. The water is suitable for domestic purposes rather than Agriculture because of the $Na^+$ level contamination as revealed by the SAR value.*

**KEYWORDS:** Hydrochemistry, Physicochemical parameters, Major metals, trace metals, SAR,

## INTRODUCTION
Lakes in general are recipients of runoff and anthropogenic wastes from human activities within the catchments areas. However, the biogeochemical processes in Lakes, as open ecosystems, strongly reflect the input of energy, water and chemicals from the catchment areas. Nonetheless, climate, physiography, geological substrate, terrestrial vegetation, human activities as well as air pollution are dominant factors that regulate the chemical quality of such lake ecosystems. Disturbances within the catchment areas in form of human activities can also increase the input of waste materials into the Lake ecosystem.

Furthermore, the input of metals into natural water bodies and their bioavailability or toxicity is of environmental concern in term of negative impacts on human health and aquatic lives. According to Nriagu and Pacyna (1988), the major sources of trace metals' contamination in marine and fresh water systems come from domestic effluents, coal burning and dumping of sewage sludge into the aquatic environments. Hence, sampling analysis of water and sediments in aquatic systems are useful for the detection of natural and anthropogenic metal contamination levels (Savchenko, 1998), since sediments are generally regarded as sinks for such metals while re-dissolution into the water phase implies negative impact on the water quality too. In addition, metals are present as dissolved ions and complexes, colloids, suspended solids and solids in sediments within the aquatic systems (Larocque and Rasmussen 1998). Concentration of these metal ions are strongly dependent on the biological processes, redox potential, pH,. Ionic strength, activities of organic and inorganic chelators and scavenging processes.

In addition, the ecological risk produced by metals largely depends on their form in water, the capacity of metals for complexing, sedimentation and bioaccumulation (Tessier Et al.,1985; Moiseenko Et al., 1998). The transfer of contaminants between the water and the underlying bottom sediment has important implications for the ultimate fate of contaminants in an aqueous environment. Hence, there is the need for biochemical assessment of lake system with respect to possible anthropogenic contamination in view of their significant role as main sources of water for drinking, irrigation and industrial activities in many parts of the world.

Therefore, this study highlights the chemical profiles of water within Eleyele Lake in Ibadan with reference to the influence of human activities within the catchments area. Eleyele Lake is one of the main sources of water supply in Ibadan metropolis. It also supports fishing activities. There are several human activities around the lake catchments such as: agricultural and residential activities leading to the discharge of municipal and household wastes into the lake and its catchments. Therefore, the study is aimed at assessing the water quality of Eleyele Lake with respect to possible contamination from the catchment areas.

## Description of the study area

Eleyele lake catchment area covers about 24 square km and it is surrounded by farmlands. The study area is situated between latitude $7^o25^/$N and $7^o27^/$N and longitude $3^o51^/$E and $3^o53^/$N Fig 1. The catchment areas cover Apete (north eastern part), Ijokodo (south eastern part), Olopomewa (southern part) and Awotan in Ibadan metropolis, Nigeria.

Ibadan city is situated in the south-western part of Nigeria and is the largest pre-colonial city in Nigeria and in Sub-Saharan Africa. It is ranked fourth after Cairo, Lagos and Johannesburg in the whole of Africa continent. As at 1991, Ibadan recorded a total population of 1.3 million and estimated population of 1.76 million in 2001, based on annual growth rate of 3%. Nevertheless, the growth has little to do with industrialisation (with only few industries) rather it is traced to the age long role of the city as regional administrative capital since the colonial era, coupled with massive rural urban migration. ‘By and large, Ibadan metropolis with a total area of about $540km^2$ is characterised by high population density of about 3,250 persons per sq. kilometre in comparison to the national average of 137 persons per square kilometre’, Tijani et al., 2004.

Just like several urban centres in developing nations, Ibadan is characterised by poor land-use planning, lack of proper sewage and waste disposal systems as well as high traffic congestion. Consequently, many households, especially within the Eleyele catchments of the city lake toilet and waste disposal facilities, as a result, direct discharge of sewage water and dumping of domestic wastes into the catchments areas is a common practices. In addition, there are quite a number of small scale subsistence and commercial farmlands located along the areas of the lake, with potential risks of contamination through manure and fertilizers.

Therefore, the potential primary inputs of trace and major elements (metals) above the geogenic background values in the study area may be summarized as to include: liquid sewage, domestic solid wastes, and vehicular repair products such as oil, grease, and tyre wears.

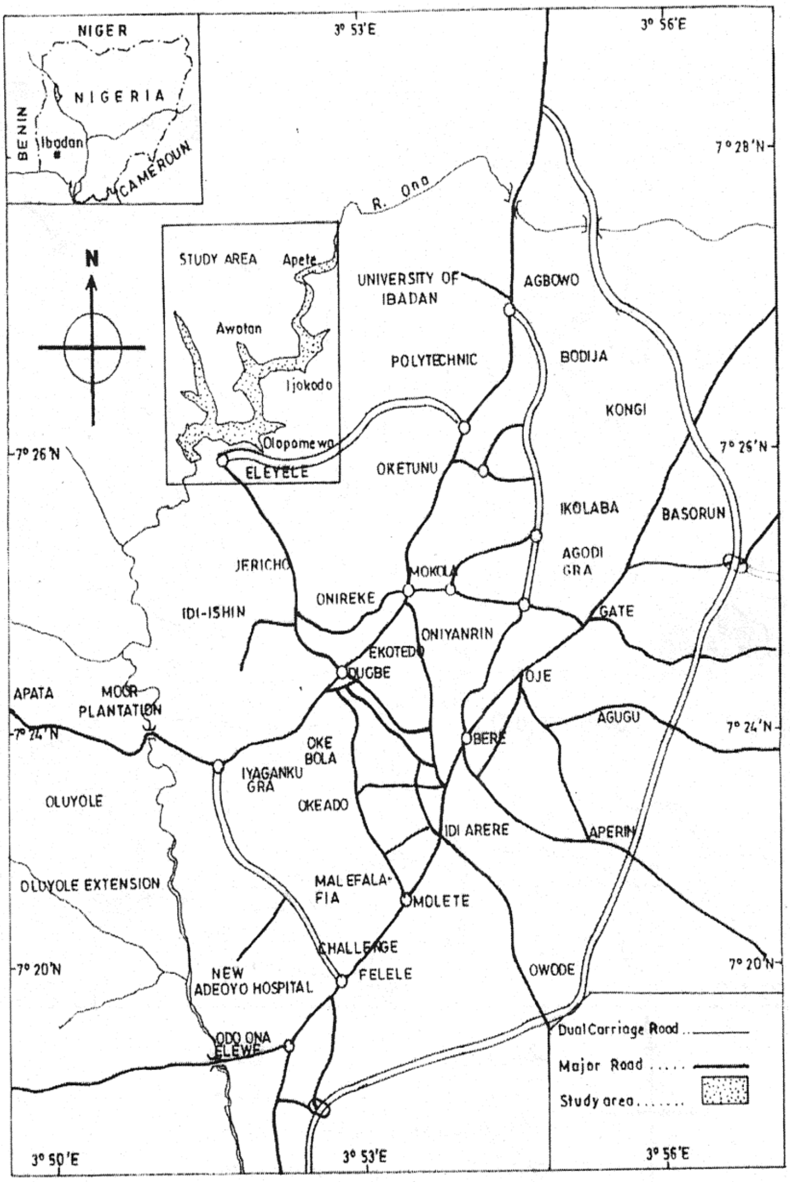


**Figure 1: Map of the study area**

**Geological and geomorphology features**

The study area occurs within the Precambrian basement complex composed of quartzite, quartz-schist, biotite-and-biotite-hornblende-gneiss (migmatite) as the main rock units Fig 2. The quartz-schist covered about 60% of the study area, forming ridges and most of the exposed ones are highly weathered. Samples are medium to coarse grained, jointed and fractured minerals like quartz, feldspar and mica. "Topographically, Ibadan city is characterized by undulating terrain with quartzite ridge and Inselbergs of gneisses surrounded by adjoining plains" (Tijani et. al, 2004).

The catchment area of Eleyele Lake is characterized by two distinct seasons: the wet season which occurs between March and October with an average annual rainfall of about 1 250mm and the dry season, from November to February (Tijani et.al, 2004). The velocities of the flowing water in the respective catchment drop during the dry season.

Eleyele Lake has influx of about four through which it receives its various discharges. Apete (north eastern part), Ijokodo (south eastern part), Olopomewa (southern part) and Awotan (North western part). More so, the water flowing in some of the tributaries are obstructed by water weed named Nymphae Lotus Lin (Nymphaeaceas,), which reduce the velocity of flow and also by waste dumps within the stretches of the stream channels.

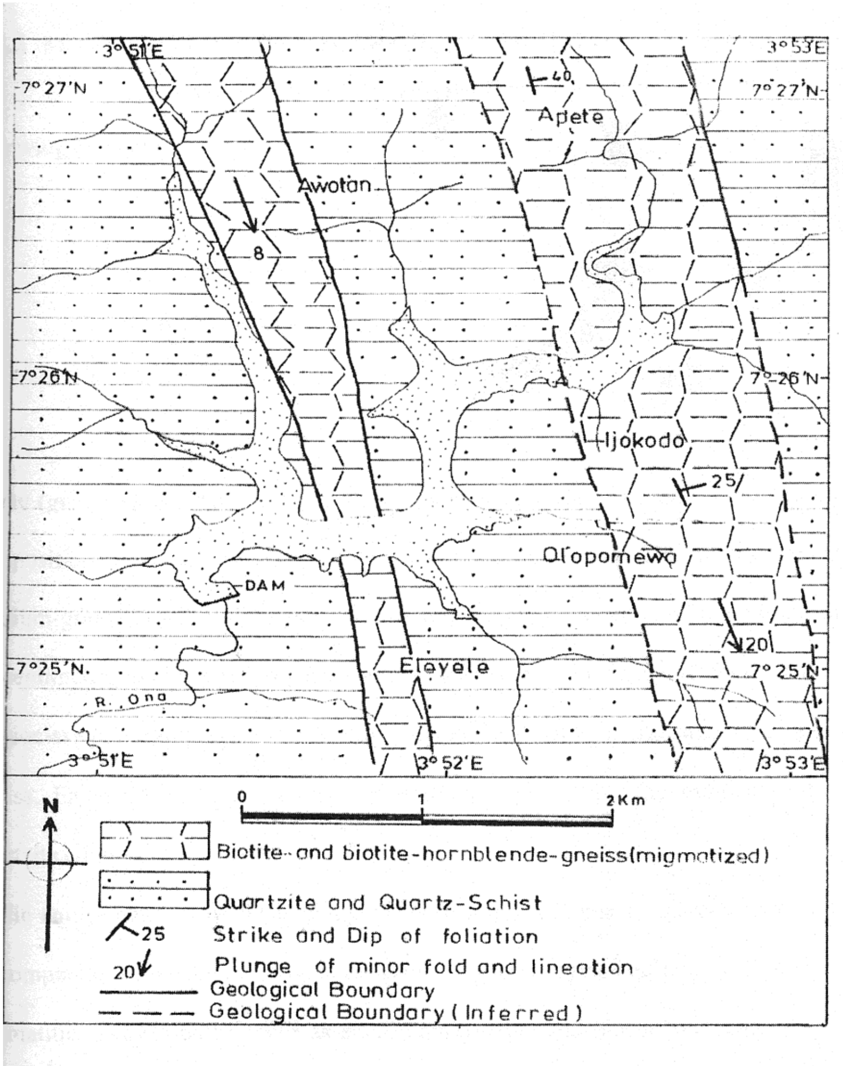


Figure 2: Geological Map of the study area. **(Carved from Geological Survey Map, 1963).**

## METHODOLOGY

### *Sampling and Analyses*

Water samples were collected at several locations (fig 3) within Eleyele Lake and its adjoining streams using plastic containers of 120ml. The sampling was carried out in February 2006 during the dry season so that the effect of the surface runoff and rainfall on the water chemistry insitu will be minimal. To avoid contamination from metallic containers, plastic containers were used for the water sampling. The water samples collected in 120ml plastic containers were acidified with concentrated nitric acid and refrigerated prior to hydrochemical analysis. Acidification was carried out in order to reduce the chemisorptions of the metal ions into the surfaces and prevents the hydrolysis and precipitation of cations. The water samples were subjected to cation and heavy metal (trace metal) determination. The pH, Electrical conductivity (EC) and temperature were measured insitu using pH-meter and Conductivity meter respectively.

Laboratory analyses of the water samples were carried out in Canment Energy Technology Centre-Devon, Alberta; Canada. Out of the 36 water samples collected, 26 were subjected into hydrochemical analyses, using ICP-OES method. The hydrochemical analyses of water samples involved the determination of major and trace metals' concentrations in the water samples. Each sample was filtered through 0.45µm nylon filter prior to hydrochemical analyse. The analyses were run in pre-determined groups:

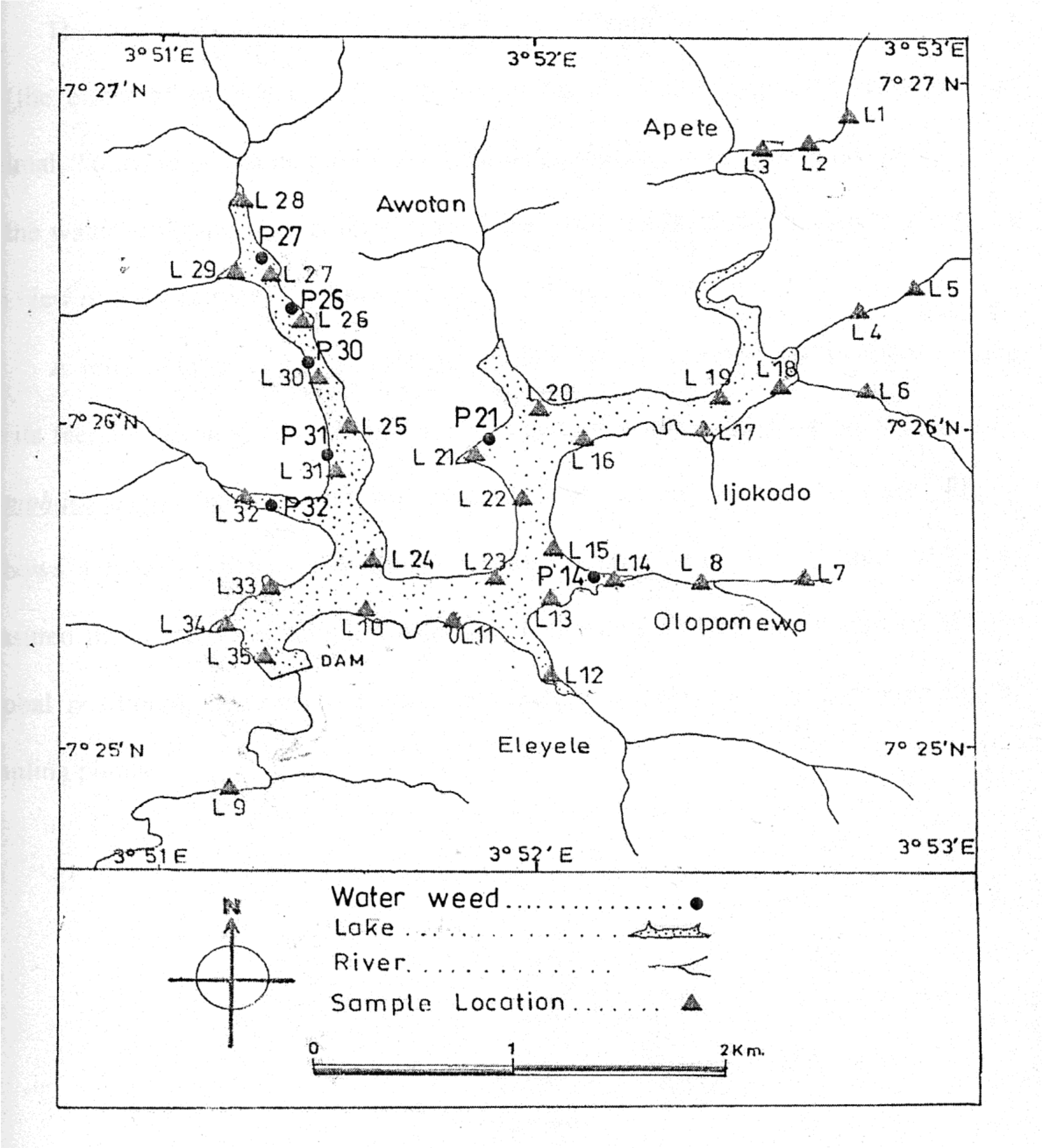


**Figure 3: Map of the Lake Catchments showing Sampling Points (carved from Geological survey map, 1963).**

**Data Evaluation**

For assessment of trace and major metals contamination in the study area, some quantitative indices were used to describe the concentration trends and also to allow for easy comparison between the parameters. The indices used include: correlation coefficient, sodium absorption ratio (SAR), anthropogenic factor (AF), and index of geo-accumulation (Igeo).

***Correlation coefficient***

Correlation is used to determine how closely a parameter or variable occurs in association with other parameter(s). The degree of closeness is given by numerical values. For an instance, correlation value of +1 is perfect and direct association where as, -1 is perfect but indirect association. The smaller the numerical value of coefficient, the less is the degree of association between variables. The linear correlation coefficients of metals in the water samples were carried out using Microsoft Excel Computer Package.

***Sodium Absorption Ratio (SAR)***

Sodium Absorption Ration is an index of the sodium hazard of water. It is based on the ratio of sodium to calcium and magnesium. SAR is calculated as follows:

$Na+/ \{0.5[(Ca^{2+}) + (Mg^{2+})]\}$

According to A and L Great lakes laboratory Inc., 2002, SAR is classified into three descriptive classes as follows: <3= no potential problem, 4-6= increasing potential problems, >6= severe potential problems.

***Anthropogenic factor (AF)***

This is a sort of quantification of the degree of contamination relative to either, average crustal composition of the respective metal or to measured background values from geologically similar and contaminated area. It is expressed as:

$AF = C_m/B_m$ where $C_m$ is the measured concentration in water and $B_m$ is the background concentration (value) of metal m, either taken from literature (average shale/average crustal abundance) or directly determined from a geologically similar area. In this study, the average igneous and basement complex were used to compute the AF values.

***Index of Geo-accumulation***

This is used to evaluate the degree of metal contamination in terrestrial, aquatic as well as marine environments (Sahu and Bhosale, 1991, Sutherland, 2000 and Manjunatha et al., 2001). It is expressed as:

$$Igeo = Log_2 [(C_m)/ (1.5 * B_m)]$$

Where Cm is the measure concentration in water and $B_m$ is the background concentration (value) of metal m, either taken from literature (average shale/average crustal abundance) or directly determined from a geologically similar area. 1.5 is a factor for possible variation in the background concentration due to lithologic differences. Igeo could be classified into seven descriptive classes as follows: <0 = practically uncontaminated, 0.1 = uncontaminated to slightly contaminated, 1-2 = moderately contaminated, 2-3 = moderately to highly contaminated, 3-4 = highly contaminated, 4-5 = highly to very highly contaminated and > 5 = very highly strongly contaminated. The latter is an open-end class that include all values above 5, while an Igeo of 6 is said to be indicative of 100-fold enrichment of a metal with respect to baseline value (Mueller, 1979, Tijani et al., 2004). In this study, the Average Igneous Rock Basement Complex- SW Nigeria compositions were used to compute the geo-accumulation values.

## PRESENTATION OF RESULTS AND THE INTERPRETATIONS.

*PHYSICO-CHEMICAL PARAMETERS:*

The main physical parameters measured are: hydrogen ions concentration (pH), total dissolved solids (TDS) and electrical conductivity (EC). The results of these insitu measurements are presented in Appendix 1. In general, the TDS values range between 154mg/l and 1050mg/l (average, 227mg/l) while the electrical conductivity values range between 181µS/cm and 1494µS/cm (average, 327.19µS/cm). However, the high values in EC and TDS observed in location 6 are indications of contamination, which could be attributed to anthropogenic source from household waste discharge from the catchments areas. Insitu determination of pH revealed values of 6.8 to 8.7 (average, 7.6), which indicate a slightly alkaline water phase while the values of temperature range between 34$^oC$ in location 8 and 28.2$^oC$ in location 1, (average, 30.44$^oC$).

The physico-chemical parameters are strongly influenced by the degree of dissolution and the conductivity of the solutes in the water. Based on the average values, the feeding streams have the highest values of TDS (290.15mg/l) and EC (420.08µS/cm), which could be attributed to the dissolution of anthropogenic wastes from the catchment areas. The relatively low values of TDS and EC in the Lake compared with the feeding streams could be attributed to dilution effect. However the average values of the physico-chemical parameters concentrations of the water samples in the feeding streams are still below the permissible limits.

***RESULTS OF HYDROCHEMICAL ANALYSES***

The simple statistical summaries of hydrochemical analyses were presented in Table 1 and Table 2 respectively.

**Table 1: Simple Statistics of Hydrochemical Analysis (Feeding Streams)**

| METALS | Average (ppm) | Stdev (ppm) | Min (ppm) | Max (ppm) | Median (ppm) |
|---|---|---|---|---|---|
| Ca | 32.2 | 17.6 | 20.4 | 70.2 | 24.8 |
| Mg | 12.8 | 8.2 | 7.3 | 25.5 | 7.6 |
| Na | 54.7 | 46.9 | 20.1 | 149.6 | 26.9 |
| K | 24.0 | 29.3 | 7.5 | 84.8 | 9.4 |
| Al | 0.3 | 0.1 | 0.2 | 0.6 | 0.3 |
| Fe | 1.1 | 1.0 | 0.6 | 3.4 | 0.7 |
| Mn | 0.6 | 0.5 | 0.2 | 1.3 | 0.2 |
| Ba | 0.2 | 0.1 | 0.1 | 0.0295 | 0.1 |
| Cu | 0.0042 | 0 | BDL | 0.0295 | 0 |
| Zn | 0.0466 | 0 | 0.031 | 0.068 | 0 |
| Co | 0.0032 | 0 | BDL | 0.0226 | 0 |
| V | 0.0258 | 0.0205 | 0.0258 | 0 | 0 |
| S | 2.8 | 3.7 | 0.4 | 10.5 | 0.7 |
| Sr | 0.2 | 0.1 | 0.1 | 0.4 | 0.2 |

*BDL= BELOW DETECTION LIMIT*

**Table 2: Simple Statistics of Hydrochemical Analysis (Main Lake)**

| METALS | Average (ppm) | Stdev (ppm) | Min (ppm) | Max (ppm) | Median (ppm) |
|---|---|---|---|---|---|
| Ca | 22.7 | 2.117433 | 17.612 | 25.8 | 23.1 |
| Mg | 7.2 | 0.445254 | 6.099 | 7.6 | 7.3 |
| Na | 22.9 | 1.427527 | 18.841 | 24.4 | 23.4 |
| K | 9.4 | 0.499239 | 7.9 | 9.8 | 9.6 |
| Al | 0.2 | 0.056367 | 0.1 | 0.3 | 0.2 |
| Fe | 0.5 | 0.498295 | 0.1 | 2.3 | 0.4 |
| Mn | 0.2 | 0.130541 | BDL | 0.5 | 0.2 |
| Ba | 0.1 | 0.020396 | 0.088 | 0.2 | 0.1 |
| Cu | 0.0155 | 0.01532 | BDL | 0.0391 | 0 |
| Zn | 0.033 | 0.006298 | 0.024 | 0.0493 | 0 |
| Co | 0.0128 | 0.013399 | BDL | 0.039 | 0 |
| V | 0.0298 | 0.005572 | 0.0214 | 0.0428 | 0 |
| S | 0.6 | 0.09596 | 0.406 | 0.7 | 0.6 |
| Sr | 0.2 | 0.008913 | 0.135 | 0.2 | 0.2 |

*BDL= BELOW DETECTION LIMIT*

***VARIED CONCENTRATIONS OF THE MAJOR CATIONS IN WATER***

$Ca^{2+}$ and $Mg^{2+}$ have respective average values of 32.16ppm and 12.77ppm with respective ranges of 20.33-70.16ppm and 7.26 to 25.54ppm in the feeding streams. However, Na and K show a higher concentration to Ca and Mg with average values of 54.71ppm and 23.98ppm respectively, in the feeding streams. The higher concentration in Na and K in the feeding streams could be attributed to the additional influence of anthropogenic input from the catchments over the geogenic influence on the major cations in the area. Similarly, in the main Lake, Ca and Mg have average values of 22.6ppm and 7.2ppm respectively. The lowered concentrations of the major cations in the main Lake compared with the higher concentrations in the feeding streams could be attributed to dilution effect along the water column. The ranges and averages of other metals are stated in Appendix 2 Generally, the low values of the major and trace metals in the Lake compared to the feeding streams may be due to dilution effect in the Lake as a result of the large water volume. Figures 4 to 7 show the profiles of the trace and major metals in the feeding streams and the main lake respectively.

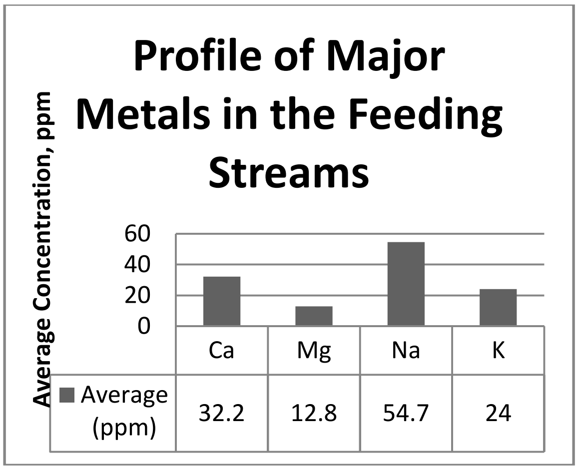


Fig 4. Profile of Major Metals in the Feeding streams (Tributaries)

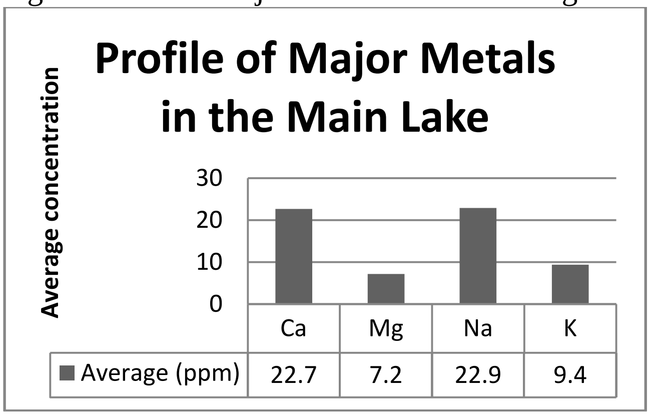


Fig. 5: Profile of Major Metals in the Main Lake.

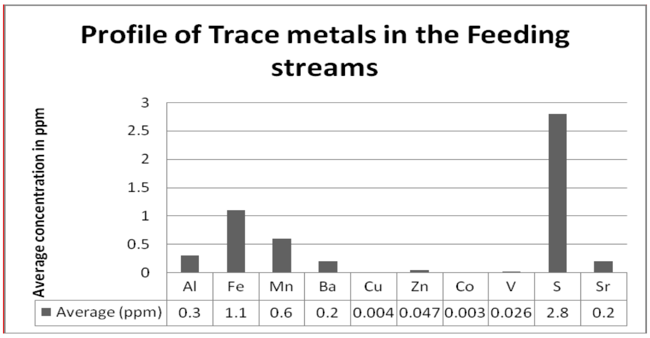


Fig.6: Profile of trace Metals in the Feeding Streams (tributaries)

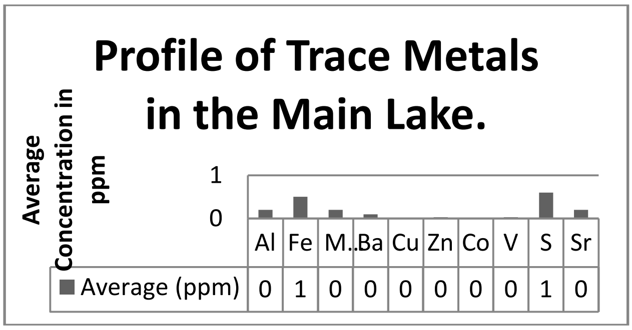


Fig.7: Profile of Trace Metals in the Main Lake

**ASSESSMENTS OF METAL CONTAMINATION.**

The average crustal abundance and average composition of igneous bedrock were used as background values for the water samples. The results of Anthropogenic factor (AF) and Geo-accumulation show that the feeding streams and the main lake are practically uncontaminated because the average values are less than 1 for AF and less than 0 for Igeo.(Table 3 and 4). However,the AF and the Igeo values observed do not totally depict absence of contamination. The values only implied that there were no appreciable effect of anthropogenic input on the water samples taken from the feeding streams and the main lake. The hydrochemcal analyses result is compared with the W.H.O. standard in appendix 2 and 3.

**Table 3: AVERAGE VALUES OF GEO-ACCUMULATION OF WATER SAMPLES (BASEMENT COMPLEX COMPOSITION)**

| METALS | FEEDING STREAMS | MAIN LAKE | SUMMARY |
|---|---|---|---|
| Ca | -8.155 | -8.5 | NO CONTAMINATION |
| Mg | -6.126 | -6.7 | NO CONTAMINATION |
| Na | -9.6 | -10.5 | NO CONTAMINATION |
| K | -11.63 | 12.3 | NO CONTAMINATION |
| Al | -18.31 | -19 | NO CONTAMINATION |
| Fe | -14.6 | -16.1 | NO CONTAMINATION |
| Mn | -9.8 | -11.4 | NO CONTAMINATION |
| Ba | - | - | |
| Cu | -9.3 | -9.3 | NO CONTAMINATION |
| Zn | -11.2 | -11.7 | NO CONTAMINATION |
| Co | -8 | -8.1 | NO CONTAMINATION |
| V | 10.1 | -9.7 | |
| S | - | - | |
| Sr | -9.8 | -10.2 | NO CONTAMINATION |

**TABLE 4: AVERAGE VALUES OF AF OF WATER SAMPLES (BASEMENT COMPLEX COMPOSITION)**

| METALS | FEEDING STREAMS | MAIN LAKE | SUMMARY |
|---|---|---|---|
| Ca | 0.006 | 0.0041 | NO CONTAMINATION |
| Mg | 0.025 | 0.0141 | NO CONTAMINATION |
| Na | 0.0025 | 0.0011 | NO CONTAMINATION |
| K | 0.001 | 0.0003 | NO CONTAMINATION |
| Al | 4.88E-06 | 2.9E-06 | NO CONTAMINATION |
| Fe | 7.39E-05 | 3.156E-05 | NO CONTAMINATION |
| Mn | 0.0024 | 0.0007 | NO CONTAMINATION |
| Ba | - | - | |
| Cu | 0.00034 | 0.0012 | NO CONTAMINATION |
| Zn | 0.001 | 0.0005 | NO CONTAMINATION |
| Co | 0.001 | 0.003 | NO CONTAMINATION |
| V | 0.00139 | 0.002 | NO CONTAMINATION |
| S | - | - | |
| Sr | 0.0018 | 0.0013 | NO CONTAMINATION |

**SODIUM ABSORPTION RATIO (SAR)**

For water to be used for irrigation, the concentration of $Ca^{2+}$ and $Mg^{2+}$ must be higher than that of $Na^{2+}$. This will cancel the hazardous effect through ion exchange reaction. However, the concentration of Na in the water of the study area is higher than those of Ca and Mg. This reflects in the average value of SAR estimated (Table 5). The range of SAR in the feeding streams is 5.4 in location 1 to 21.8 in location 6, with an average of 10.6. In the main lake, SAR ranges from 5.5 in location 28 to 6.2 in location 12, with an average of 5.9. The average values of SAR in the feeding streams and in the main lake give an indication of Na metal contamination in the lake and the feeding streams. According to the guidelines for irrigation water analysis, the SAR for the lake water is potentially higher for irrigation purposes especially in location 6 with SAR value of 21.6 which could be attributed to geogenic contamination of the basement rocks and as little contribution from anthropogenic influence. The statistical summary of SAR in the feeding streams and the main lake is presented in Tables 5 and 6. The low average value of SAR in the main lake compared with the high average value in the feeding streams is due to dilution effect in the lake as a result of the large water volume. Table 7 shows the interpretive guidelines for irrigation water analyses.

**Table 5: SIMPLE STATISTICS OF SODIUM ABSORPTION RATIO (SAR) IN THE FEEDING**
STREAMS.

| METALS | Ca | Mg | Na | SAR |
|---|---|---|---|---|
| AVERAGE | 32.2 | 12.8 | 54.7 | 10.6 |
| STDEV | 17.6 | 8.2 | 46.9 | 6.2 |
| MIN | 20.4 | 7.3 | 20.1 | 5.4 |
| MAX | 70.2 | 25.5 | 149.6 | 21.8 |
| MEDIAN | 24.8 | 7.6 | 26.9 | 6.8 |

**Table 6: SIMPLE STATISTICS OF SODIUM ABSORPTION RATIO (SAR), IN THE MAIN STREAM**

| METALS | Ca | Mg | Na | SAR |
|---|---|---|---|---|
| AVERAGE | 22.7 | 7.2 | 22.9 | 5.9 |
| STDEV | 2.11 | 0.45 | 1.43 | 0.16 |
| MIN | 17.612 | 6.099 | 18.841 | 5.472 |
| MAX | 25.8 | 7.6 | 24.4 | 6.2 |
| MEDIAN | 23.1 | 7.3 | 23.4 | 5.9 |

**Table 7: INTERPRETIVE GUIDELINES FOR IRRIGATION WATER ANALYSES AFTER; A AND L GREAT LAKES LABORATORY INC., CONESTOGA DRIVE, FORT WAYNE (2002).**

INTERPRETIVE GUIDELINES FOR IRRIGATION WATER ANALYSIS

| PARAMETERS | UNIT | POTENTIAL PROBLEMS | | |
|---|---|---|---|---|
| | | NONE | INCREASING | SEVERE |
| pH | - | 5.5-7.5 | <5.5 or > 7.5 | <4.5 or > 8.5 |
| SAR | - | <3 | 4-6 | >6 |

***Water Correlation:***

Further to the discussion of the results, the coefficients of correlation were estimated to determine the relationship between the metals, pH and the EC of the water samples. The correlation coefficient values are presented in Table 8. The major cations: Ca, Mg, Na and K show a very high positive correlation range of 0.95-1.0 with TDS and EC and this depicts their contributions to the overall concentration of the lake water in the study area. The major metals have good positive correlation coefficient (r>6) with one another. This shows their associations and could be attributed to their geogenic sources from the catchments' bedrock. Mg and Al have a good positive correlation of 0.74. This also reflects their geogenic sources as weathering products of the basement rocks of the area. The trace metals: Cu, V and Co show negative correlation with the physical parameters except Zn that show a weak positive correlation of 0.34 and 0.32 with TDS and EC respectively. This means that it is likely they do not contribute to the overall concentration of the lake water in the study area except Zn. In addition, Sr has good positive correlation with the major cations resulting from its substitution in feldspar minerals essentially in the basement rocks. Ca and Mg also have a good correlation coefficient (r=0.68) and this could be attributed to their geogenic source. Negative correlation typifies different environmental/ or natural input sources. For an instance, Cu has negative correlations of 0.1 with TDS and EC and negative correlation with Ba, Sr and Zn. These reflect different sources and controlling processes.

**Table 8: CORRELATION OF HYDROCHEMICAL PARAMETERS**

| | Ca | Mg | Na | K | Fe | Mn | Al | S | Ba | Sr | Zn | Cu | V | Co | TDS | EC | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ca** | 1.00 | | | | | | | | | | | | | | | | |
| **Mg** | 0.68 | 1.00 | | | | | | | | | | | | | | | |
| **Na** | 0.96 | 0.83 | 1.00 | | | | | | | | | | | | | | |
| **K** | 0.98 | 0.62 | 0.95 | 1.00 | | | | | | | | | | | | | |
| **Fe** | 0.08 | 0.07 | 0.12 | 0.15 | 1.00 | | | | | | | | | | | | |
| **Mn** | 0.28 | 0.15 | 0.34 | 0.37 | 0.73 | 1.00 | | | | | | | | | | | |
| **Al** | 0.22 | 0.74 | 0.40 | 0.15 | 0.27 | 0.35 | 1.00 | | | | | | | | | | |
| **S** | 0.04 | 0.68 | 0.28 | -0.02 | -0.03 | 0.09 | 0.79 | 1.00 | | | | | | | | | |
| **Ba** | -0.01 | 0.71 | 0.24 | -0.06 | 0.15 | 0.07 | 0.86 | 0.88 | 1.00 | | | | | | | | |
| **Sr** | 0.90 | 0.91 | 0.96 | 0.86 | 0.06 | 0.17 | 0.48 | 0.36 | 0.39 | 1.00 | | | | | | | |
| **Zn** | 0.20 | 0.56 | 0.32 | 0.16 | 0.05 | 0.43 | 0.74 | 0.50 | 0.67 | 0.41 | 1.00 | | | | | | |
| **Cu** | -0.10 | -0.22 | -0.24 | -0.20 | -0.23 | -0.26 | -0.12 | -0.25 | -0.25 | -0.20 | -0.33 | 1.00 | | | | | |
| **V** | -0.36 | -0.42 | -0.38 | -0.28 | -0.04 | -0.28 | -0.34 | -0.39 | -0.17 | -0.34 | -0.28 | 0.14 | 1.00 | | | | |
| **Co** | -0.16 | -0.24 | -0.25 | -0.20 | 0.05 | -0.15 | 0.00 | -0.25 | -0.12 | -0.23 | -0.18 | 0.62 | 0.54 | 1.00 | | | |
| **TDS** | 0.96 | 0.83 | 1.00 | 0.95 | 0.15 | 0.35 | 0.40 | 0.26 | 0.24 | 0.96 | 0.34 | -0.26 | -0.38 | -0.24 | 1.00 | | |
| **EC** | 0.95 | 0.83 | 1.00 | 0.95 | 0.15 | 0.34 | 0.39 | 0.26 | 0.24 | 0.96 | 0.32 | -0.26 | -0.36 | -0.25 | 1.00 | 1.00 | |
| **pH** | -0.31 | -0.40 | -0.33 | -0.23 | -0.15 | -0.41 | -0.56 | -0.38 | -0.25 | -0.27 | -0.48 | -0.04 | 0.55 | 0.01 | -0.34 | -0.33 | 1.00 |

## CONCLUSIONS AND RECOMMENDATIONS

The results of the physicochemical and the hydrochemical studies show that the Eleyele Lake is slightly alkaline. The trace metals show varied average results in the feeding streams and in the main lake. On the average, the respective values of the trace metals, major metals and the physicochemical parameters are generally below the World Health Organisation (WHO) standard for potable water (2006). Results of AF (<1) show that the lake and its feeding streams have not been heavily contaminated. The estimated results of geo-accumulation (<0) also confirmed this. The computed values of SAR on the average indicated that the water phase of the feeding streams and the lake contain a slight sodium hazard of 10.6 and 5.5 respectively and this may be potentially hazardous for irrigation practices. However, if the anthropogenic discharge of wastes into the feeding streams (tributaries) is not checked, the concentration of toxic metals in the water phase will increase abnormally overtime and this will endanger the growth of plants, the health of aquatic organisms and finally man that feed on the aquatic animals. Nevertheless, based on the averages of all the analyses carried out, the lake may be regarded as potable for drinking and for domestic usage and not applicable for irrigation purposes.

It is recommended that sewage and refuse disposal facilities should be made available for the masses. The use of respective chemicals, manure and fertilizers for fishing and cropping should be checked as this could endanger the lives of the aquatic organisms and indirectly enters the food chain in the ecosystem. Further studies should include microbial investigations, heavy metals and isotopic compositions so as to ascertain other quality parameters and hence prescription of necessary treatment measures since the lake is a source of water supply in the area.

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**APPENDIX 1: THE MEASURED PHYSICO-CHEMICAL PARAMETERS OF THE LOCATIONS**

| SAMPLE ID | TEMP, oC | PH | EC,µS/cm | TDS, mg/l |
|---|---|---|---|---|
| LI | 28.2 | 7.31 | 268 | 186 |
| L2 | 28.4 | 7.64 | 264 | 185 |
| L3 | 28.4 | 6.87 | 645 | 452 |
| L4 | 28.7 | 7.37 | 284 | 199 |
| L5 | 29.2 | 7.63 | 290 | 203 |
| L6 | 30.9 | 7.46 | 1494 | 1050 |
| L7 | 29 | 6.84 | 710 | 499 |
| L8 | 34 | 7.29 | 273 | 192 |
| L9 | 32.1 | 7.08 | 309 | 214 |
| L10 | 30.2 | 7.3 | 274 | 192 |
| L11 | 30.4 | 7.27 | 275 | 191 |
| L12 | 30.3 | 7.29 | 276 | 194 |
| L13 | 30.5 | 7.43 | 276 | 194 |
| L14 | 30.5 | 7.94 | 279 | 195 |
| L15 | 30.8 | 7.69 | 275 | 193 |
| L16 | 30.9 | 7.47 | 276 | 193 |
| L17 | 31.5 | 7.35 | 282 | 198 |
| L18 | 32 | 7.27 | 281 | 197 |
| L19 | 31.8 | 7.24 | 181 | 197 |
| L20 | 31.7 | 7.2 | 297 | 195 |
| L21 | 31.7 | 7.23 | 277 | 194 |
| L22 | 32.4 | 7.73 | 277 | 194 |
| L23 | 31.5 | 7.87 | 271 | 190 |
| L24 | 31.9 | 7.74 | 259 | 181 |
| L25 | 32.2 | 8.67 | 256 | 180 |
| L26 | 32.8 | 8.05 | 248 | 174 |
| L27 | 32.6 | 8.28 | 238 | 167 |
| L28 | 32.2 | 8.4 | 277 | 154 |
| L29 | 32.7 | 8.02 | 236 | 165 |
| L30 | 32.9 | 8.23 | 274 | 173 |
| L31 | 33.1 | 7.99 | 258 | 180 |
| L32 | 32.1 | 7.85 | 241 | 170 |
| L33 | 32.3 | 7.73 | 263 | 184 |
| L34 | 31.4 | 7.75 | 264 | 183 |
| L35 | 31.7 | 8.27 | 263 | 184 |
| L36 | 32.2 | 8.34 | 266 | 186 |

**APPENDIX 2: COMPARISON OF THE AVERAGE HYDROCHEMICAL RESULTS WITH WHO. STANDARD FOR POTABLE WATER (1993 AND 2006)**

| MEASURED PARAMETERS | AVERAGE FOR THE STUDY AREA | MIN. FOR THE STUDY AREA | MAX. FOR THE STUDY AREA | ACCEPTABLE LEVEL | MAXIMUM PERMISSIBLE LEVEL |
|---|---|---|---|---|---|
| Ph | 7.655 | 6.840 | 8.670 | 6.5 | 8.5 |
| TDS(mg/l) | 227.17 | 154 | 1050 | 500 | 1000 |
| EC(µS/cm) | 327.19 | 181 | 1494 | 400 | 1400 |
| Ca(mg/l) | 25.23 | 17.612 | 70.160 | 75 | 200 |
| Mg(mg/l) | 8.714 | 6.099 | 25.545 | 30 | 150 |
| Na(mg/l) | 31.464 | 18.841 | 149.55 | 20 | NO GUIDELINE |
| K(mg/l) | 13.307 | 7.456 | 85 | 10 | NO GUIDELINE |
| Al(mg/l) | 0.234 | 0.1 | 0.628 | - | 0.2 |
| Fe(mg/l) | 0.668 | 0.1 | 3.351 | 0.3 | 1.0 |
| Mn(mg/l) | 0.267 | BDL | 1.328 | - | 0.4 |
| Sr(mg/l) | 0.174 | 0.135 | 0.435 | - | - |
| Ba(mg/l) | 0.139 | 0.084 | 0.51 | - | 0.7 |
| Cu(mg/l) | 0.012 | BDL | 0.039 | - | 2.0 |
| Zn(mg/l) | 0.037 | 0.024 | 0.068 | - | 5.0 |
| Co(mg/l) | 0.01 | BDL | 0.039 | - | - |
| V(mg/l) | 0.028 | 0.021 | 0.043 | - | - |

BDL= below detection limit

**APPENDIX 3: COMPARISON OF THE AVERAGE HYDROCHEMICAL RESULTS WITH WHO STANDARD FOR POTABLE WATER (1993 AND 2006)**

| MEASURED PARAMETERS | AVERAGE FOR FEEDING STREAMS | AVERAGE FOR MAIN LAKE | ACCEPTABLE LEVEL | MAXIMUM PERMISSIBLE LEVEL |
|---|---|---|---|---|
| Ph | 7.3 | 7.8 | 6.5 | 8.5 |
| TDS(mg/l) | 397.7 | 182.9 | 500 | 1000 |
| EC(µS/cm) | 567.1 | 261.5 | - | 1400 |
| Ca(mg/l) | 32.16 | 22.68 | 75 | 200 |
| Mg(mg/l) | 12.77 | 7.22 | 30 | 150 |
| Na(mg/l) | 54.71 | 22.9 | - | NO GUIDELINE |
| K(mg/l) | 23.98 | 9.38 | - | NO GUIDELINE |
| Al(mg/l) | 0.33 | 0.197 | - | 0.2 |
| Fe(mg/l) | 1.15 | 0.49 | 0.3 | 1.0 |
| Mn (mg/l) | 0.56 | 0.16 | - | 0.4 |
| Sr(mg/l) | 0.22 | 0.16 | - | |
| Ba(mg/l) | 0.19 | 0.12 | - | 0.7 |
| Cu(mg/l) | 0.004 | 0.015 | - | 2.0 |
| Zn(mg/l) | 0.047 | 0.033 | - | 5.0 |
| Co(mg/l) | 0.003 | 0.013 | - | - |
| V(mg/l) | 0.022 | 0.03 | - | - |

BDL= below detection limit