Nigerian Research Journal of Engineering and Environmental Sciences 6(2) 2021 pp. 530-539
p ISSN: 2635-3342; e ISSN: 2635-3350

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Evaluation of Heavy Metal Distribution in Sediments of Lake Geriyo, Adamawa State, Nigeria

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http://doi.org/10.5281/zenodo.5805112

ARTICLE INFORMATION

Article history:
Received 08 Oct, 2021
Revised 14 Nov, 2021
Accepted 16 Nov, 2021
Available online 30 Dec, 2021

Keywords:
Heavy metals
Enrichment factor
Geo-accumulation index
Contamination factor
Pollution load index

ABSTRACT

Monitoring of pollution level in Lake Geriyo, Adamawa State, Nigeria was conducted to assess concentration of metals (Zn, Cu, Pb and Cd) in sediments of the lake. The order of the mean concentrations of the metals investigated were Zn > Cu > Pb > Cd. Zn and Cd were below the background concentration while Pb and Cu were slightly above. The results indicated that the metals exhibit lower values than sediment quality guideline (SQG). Thus, Lake Geriyo sediment can be classified as unpolluted. Geo-accumulation index (Igeo), enrichment factor (EF), contamination factor (CF), degree of contamination (DC) and pollution load index (PLI) were also used to evaluate the level of metal contamination in the sediments. Igeo values of the sediment with respect to Pb and Zn range from slightly contaminated to uncontaminated. EF values with respect to Cu and Pb indicate minimum enrichment depletion. CF values with respect to Cu and Pb indicate slight contamination while DC values indicate low degree of contamination and PLI values suggest that the sediments of lake Geriyo were unpolluted by these metals. The results show that the sediments did not present any serious threat to the aquatic life of the lake. However, there is need for regular monitoring of the lake as Pb is believed to be carcinogenic.

1. INTRODUCTION

Heavy metal contamination mostly from anthropogenic activities constitutes a serious problem for human health (Obaidy *et al*., 2013). However, the terrestrial and aquatic ecosystem receive high inputs of heavy metals as a result of an increase in atmospheric deposition and anthropogenic activities (Maina, 2005). More so, it has been reported that heavy metal pollution in aquatic environs is of critical concern, because of its toxicity and build up in aquatic environment (Waghmode and Muley, 2013).

In the aquatic environments, sediments are a cardinal part of water especially when flowing, and have been generally used as environmental indicators due to their high physicochemical stability (MacDonald *et al.,* 2003). Sediments are a consolidation of materials, consisting of inorganic components, mineral particulates and organic matter in different stages of decomposition. When sediments are chemically analyzed, they can provide considerable information on the appraisal of anthropogenic activities (Malhotra *et al.,* 2014). Sediments provide substrate for organisms and their interaction with the overlying waters serves an important role both as a transporter and possible source of pollutant in aquatic environments (Burden *et al.*, 2003).

Analysis of sediments deposited at the bottom of a water body, which attract most of the heavy metal and other contaminants enables the assessment of a unified account of metals pollution (Davies and Kent, 1990). This is because the level of metals in bottom sediments is the result of prolong sedimentation processes and does not undergo accelerated changes due to changeable external conditions (Soares *et al*., 1999).

Lake Geriyo is a natural Lake close to River Benue in the North eastern part of Nigeria. The area is a prominent settlement centre for livestock breeding. It lacks a planned waste disposal system. Also, liquid waste flow through the major drainage networks and empties into the lake and the Benue River. Additionally, the Lake is a major source of water for the cultivation of rice, provision of water for communal livestock breeding, fishing and vegetable production which is consumed by the immediate urban population. Yet, information concerning the impact of pollution on the lake is scanty or not available. As a step towards identifying the implications of pollution load on the lake environment, it was considered necessary to evaluate the concentration of chemicals especially metal elements in the lake matrices (water, soil/sediment, plant and fish). This will facilitate understanding their speciation, bioavailability, and remedial options. This paper presents findings from a study conducted to determine the level of some heavy metal concentrations and sediment quality of Lake Geriyo located in Adamawa State in Nigeria.

2. MATERIALS AND METHODS

2.1. Study Area

Lake Geriyo occupies a natural depression near the upper Benue River in the North eastern part of Nigeria. It is located in Yola, the Adamawa State capital and situated on latitude 09°10'N and longitude 12°20'E (Figure 1). The lake is about 250 hectares in size, and it is a shallow water body with a mean depth of about 3 meters. Aquatic vegetation on the lake consists of a mass of floating weeds such as water spinach, water hyacinth, water lily and water lettuce which move around the lake surface due to the prevailing wind (Ekunday *et al.*, 2014). Waste disposal practiced in the area surrounding the lake is the open dumping of solid waste (Figure 2).

Adamawa State is located in the Sahel region of Northern Nigeria. Yola is the state capital and has an estimate population of 325,925 people (NPC, 2006). The state lies in the semi- arid region which is characterized by low rainfall, low humidity and high temperature. The area experiences two distinct wet and dry seasons. The wet season is from April to October while the dry season is from November to March. Mean daily temperature fluctuates with season from 25 °C to 45 °C and mean annual rainfall received is in the range of (150-1000 mm). The climate is characterized by high evapotranspiration especially during dry season (Adebayo, 1999). The Geology of the area is entirely underlain by the cretaceous and quaternary sedimentary deposits. The Bima Sandstone is Albian in age while the river alluvium belongs to the quaternary geologic period. The Bima Sandstone is made up of clay lenses, calcareous sandstones, Limestone, Siltstones and iron stones. The river alluvium consists of poorly sorted sandstone, clays siltstone (Ishaku and Ezeigbo, 2000).

Water from the lake is primarily used for intensive irrigation, fishing and sources of water for cattle farmers in the catchment area. It has a land area of about 1500 hectares mostly dedicated for dry season irrigation farming with 1200 hectares already developed for the cultivation of rice and vegetables. The water is delivered to the farmlands through direct pumping. A map of the study area showing the irrigation site is shown in (Figure 3). Major occupation of inhabitants around the lake the area is agro-business and small-scale metallurgical works.

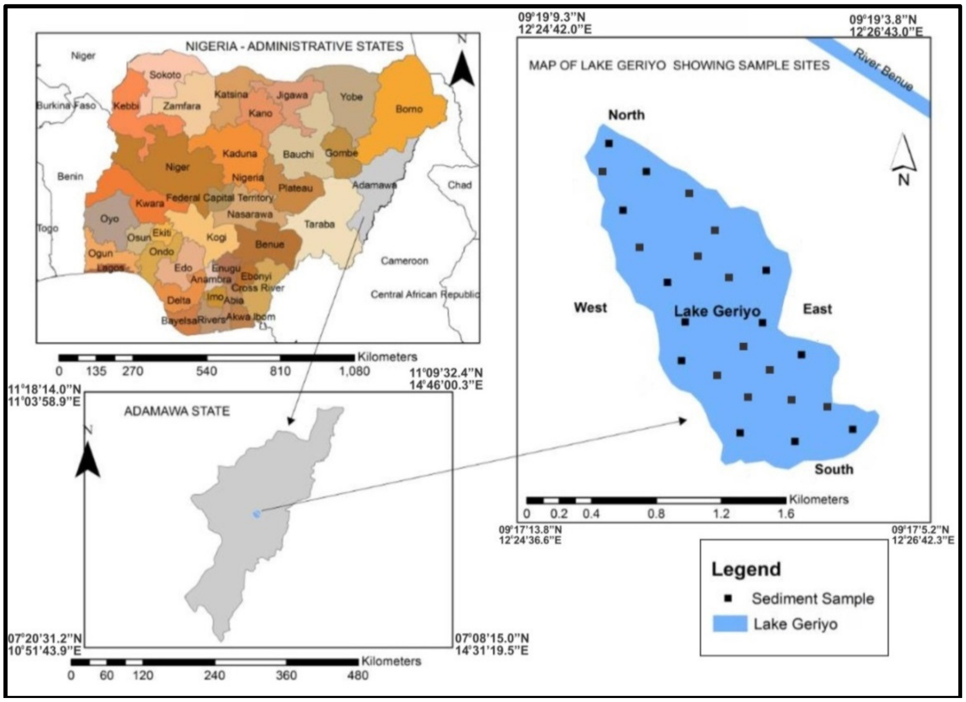

Figure 1: Map of Nigeria showing the study area and sampling locations

Figure 2: Heap of solid wastes in a dumpsite close to the lake

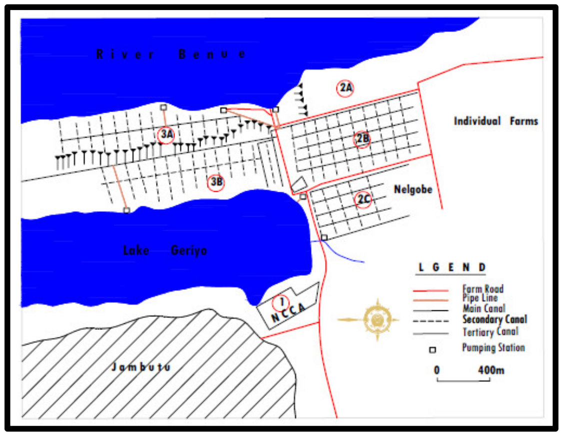

Figure 3: Map of the study area showing the irrigation sites

2.2. Sample Collection, Preparation and Analysis

Sediment samples were collected as described by Radujevic and Bechlin, (1999) in triplicate at an interval of three meters in a random pattern at four locations namely North, East, West and South (Figure 1) during the dry and wet seasons. They were collected by means of a scooper sediment sampler operated from a boat and can scoop sediment samples with water from about four meters below the water surface. These samples were air dried, homogenized and sieved through a 2 mm nylon mesh sieve after which they were disaggregated with the aid of an agate mortar and pestle (Binning and Baird, 2001; Voegborlo *et al*., 2010). The powdered sediment samples were then stored in clean sample bottles at room temperature for analysis.

A quantity of 1 g of the homogenized sediment samples was weighed into a 50 ml digestion tube and digested by the method described by Atta *et al.* (2012). In the procedure the samples were digested with perchloric acid and nitric acid ($HClO_4$-HNO_3) (ratio 1:1) then followed by addition of sulphuric acid and the mixture was heated at 200 ºC for 30 mins. The complete digest was then cooled down to room temperature and made up to 50 ml with distilled water and analysed for Cu, Zn Pb and Cd using a flame atomic absorption spectrophotometer (AAS Model Agilent AA55). An analytical blank was prepared in a similar manner.

2.3. Quality Assurance

All the reagents used were of analytical grade. Glass wares were soaked in 10% nitric acid for 24 h and rinsed with distilled water followed by 0.5% (w/v) $KMnO_4$ solution and finally with distilled water. Accuracy and precision were verified by using reference material (CRM IAEA-SL-I) provided by the International Atomic Agency (IAEA). Analytical results of the quality control samples indicated a satisfactory performance of heavy metal determination within the range of certified values 95-111% recovery for the metals studied.

2.4. Indices of Assessing Metal Pollution levels

Numerous indices were used to determine the metal pollution levels in sediment samples namely Geo-accumulation index (I-geo), Pollution load index (PLI), enrichment factor (EF), contamination factor (CF) and degree of contamination (DC). Background concentration values used were taken from Hakanson (1980). Background concentration is that portion of the measured ambient levels of the metals that is not attributable to emissions or any single identifiable source within the study area.

2.4.1. Geo-accumulation index

Geo-accumulation index was selected to assess the heavy metals contamination in sediments of the Lake. The I-geo was computed following a method prescribed by Muller (1969) and presented as Equation (1).

$$\mathrm{I-geo} = \frac{log_2}{Cn/_{1.5Bn}} \quad (1)$$

Where Cn is the measured content of the examined metal in sediment samples and Bn is the geo-chemical background content of the same metal. The constant 1.5 is introduced to minimize the effect of possible variations in the background values, which may be attributed to anthropogenic activity. The following classification is given for I-geo: <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.

2.4.2. Enrichment factor

EF was considered to determine the level of contamination and provide knowledge of the distribution of the metal with respect to anthropogenic origin in the sediment samples (Sinex and Helz, 1981). EF was calculated by a comparison of concentration of each investigated metal with that of a reference metal. The metals usually used for this purpose are Mn, Al and Fe (Nyanabado *et al.*, 2005; Kamaruzzaman *et al.,* 2008). In this work, Fe was used as a conservative tracer to differentiate natural from anthropogenic components (Loska *et al.*, 2003). In addition, soils in Nigeria have been found to be rich in Fe. According to Rubio and Vilas (2000), the EF is defined as follows:

$$\mathrm{EF} = \frac{(M/_{Fe})\, sample}{(M/_{Fe})\, background} \quad (2)$$

Where EF is the enrichment factor, (M/Fe) sample is the ratio of metal and Fe concentration of the sample and (M/Fe) background is the ratio of metals and Fe concentration of a background. Five contamination categories are reported on the basis of the enrichment factor (Sutherland, 2000). EF= < 2 depletion to minimal enrichment, EF = 2-5 moderate enrichment, EF = 5-20 significant enrichment, EF = 20-40 very high enrichment EF = > 40 extremely high enrichment.

2.4.3. Contamination factor and degree of contamination

Contamination factor was calculated to establish the extent of anthropogenic pollution and heavy metals load in sediment at the various sampling locations. CF was calculated according to Equation (3).:

$$\mathrm{CF} = \frac{MC}{BC} \quad (3)$$

Where MC is the measured concentration of the metal, and BC is the background concentration of same metal. Four contamination categories are documented on the basis of the contamination factor (Hakason, 1980). These are CF<1 Low contamination; I<CF>3 moderate contamination, 3<CF<6 Considerable contamination, CF>6 very high contamination.

The degree of contamination (DC) was defined as the sum of all contamination factors. According to Hakanson (1980), the following terms are adopted to illustrate the degree of contamination; DC<6 low Degree of contamination, 6<DC<12 Moderate Degree of contamination, 12<DC<24 Considerable Degree of contamination, DC>24 very high Degree of contamination.

2.4.4. Pollution load index

Pollution load index was used to evaluate the extent of pollution by heavy metals in the environment. PLI was calculated following the method of Tomilson *et al.* (1980) as presented by Equation (4).

$$\mathrm{PLI} = (CF_1 \times CF_2 \times CF_3 \times \ldots CF_n)^{1/n} \quad (4)$$

Where n is the number of metals and CF is the contamination factor.

2.5. Statistical Analysis

All analyses were performed in triplicates. Statistical data analyses of the results were performed using Graph Pad Instat and Past Windows 2010. The means of the replicates and evaluation of significant differences between different samples were determined using descriptive statistics and analysis of variance (ANOVA). A two- way and one- way analysis of variance (ANOVA) was used to test for significant difference in the concentrations of heavy metals in the samples between the seasons and the sites. For comparison of means, ANOVA test and post hoc Duncan test were used. Results of the test were considered significant if the calculated p-values were less than 0.05. Pearson correlation was used to examine the relationship between the elements in sediments and t-test was used to show the variation of data between the two seasons.

3. RESULTS AND DISCUSSION

3.1. Heavy Metal Concentration in Sediment of Lake Geriyo

The concentrations of heavy metals determined in forty eight (48) sediment samples obtained in two seasons are presented in Table 1. As seen in Table 1, the concentrations of Zn and Cd were lower than the background values obtained from Hakanson (1980) except at West locations for Wet and Dry seasons (82.32 mg/kg and 0.8 mg/kg) respectively. Similarly, Pb and Cu concentrations were higher than the background values except at West location (2.67 mg/kg) and North location (13.58 mg/kg), during wet season. This may suggest influence of anthropogenic input as sources of Cu and Pb could be due to industrial wastes, paints, batteries and pesticides (Milan, 2012). Analysis of variance indicate significant difference among the parameters considered at ($p<0.05$). The concentration trend follows a decreasing order of Zn>Cu >Pb >Cd. Wet season recorded higher metal accumulation than the dry season. The trend obtained could be attributed to the properties of the metals and influence of environmental factors triggering the deposition and speciation of the metals.

Table 1: Mean concentrations of heavy metals in sediment vis-a-vis background value and sediment quality guidelines

Location	Season	Mean concentrations of heavy metals (mg/kg)			
		Zn	Pb	Cd	Cu
North	Dry	57.77 ±860	14.87 ±6.71	0.1±0.017	18.08±1.23
	Wet	66.60 ±5.10	16.63±11.66	0.58 ±0.42	13.58 ±24
South	Dry	49.12 ±1.24	11.18 ±0.96	0.1 ±0.017	19.63 ±0.21
	Wet	62.92 ±5.0	13.28 ±4.83	0.57 ±0.81	15.20 ±2.90
East	Dry	49.12 ±1.24	11.18 ±0.96	0.1 ±0.017	17.08 ±0.43
	Wet	60.98 ±8.64	16.38 ±3.68	0.22 ±0.16	18.85 ±5.60
West	Dry	59.10 ±4.71	13.62 ±2.14	0.8 ±0.52	19.97 ±10.67
	Wet	82.32 ±3.71	2.67 ±0.28	0.23 ±0.23	16.17 ±1.67
Background value		67	8	0.6	14
SQG non-polluted		< 90	< 40	< 5	< 25
SQG moderately polluted		90-200	40-60	< 10	25-50
SQG heavy polluted		> 200	> 60	> 20	> 50
TEL/PEL		123/315	35/91.3	0.60/3.53	35.7/97
ERL/ERM		120/220	35/110	5/9	70/390

Source: Background value data from Hakanson (1980), SQG values from Perin *et al.* (1997); TEL/PEL Threshold effect level, probably effect, values taken from Smith *et al.* (1996); ERL/ERM values taken from Adams *et al.* (1992) and Macdonald *et al.* (2000)

The rates of generation of metals via man made cycles (anthropogenic activities) are more rapid relative to natural occurrence of the metals. Relatively, the trend found is just about the same with findings by Al-Muazaini and Jacob (1996) who reported the dispersion of some metals in top soils of an industrial area in Kuwait in the order of Cr >Ni>V>Pb>Cd. The high metal concentration in the wet season may be due to discharges as a result of intensive agricultural activities around the lake and flooded water coming upstream from River Benue and the lake surroundings. The result obtained is in agreement with findings by Akoto *et al.* (2008), Asante *et al.* (2005) and Maina (2005). Furthermore, comparison of the mean concentrations of the heavy metals studied in Lake Geriyo with the corresponding global based sediment quality guideline (SQG) (Perin *et a*l., 1997) was done. The results show that the concentrations of Zn, Pb, Cd and Cu in lake Geriyo sediment is classified as unpolluted with respect to these metals since the recorded values fell below 90, 40, 5, and 25mg/kg respectively. A comparison of Zn, Pb, Cd, and Cu concentrations in sediment of the lake with values in threshold effect level (TEL), probable effect level (PEL) (Smith *et al.*, 1996) effect range median (ERM), and effect range low (ERL) (Adams *et al.,* 1992; Macdonald *et al.*, 2000) showed that the levels were below the permissible limit which suggest that the sediment of lake Geriyo did not pose any serious threat to the local fauna and flora within the lake ecosystem.

3.2. Geo-accumulation Index of the Lake

The calculated values of the I-geo are presented in Table 2. The results indicate that Cu, Cd and Zn show value less than 0 (I-geo<0) indicating practically uncontaminated except Zn (0.80) at North location in dry season which displayed uncontaminated to slightly contaminated. With the exception of three locations, Pb show I-geo values 0-1 indicating uncontaminated to slightly contaminated level. On the basis of the mean values of I-geo, sediments of lake Geriyo are enriched with metals in the following order: Pb>Zn>Cu>Cd and the pollution level was uncontaminated to slightly contaminated with metals Pb and Zn having the highest values. The trend obtained may be due to environmental factors and possibly changes in chemical forms of the metals which may influence their presence and availability. Due to disturbance and acceleration of geochemical cycle of metals as a result of anthropogenic activities and other environmental factors, the sediments may accumulate one or more of the metals higher than the others or have higher concentration than background values. Moreover, the distribution of metals is believed to be controlled by their reactions in soils or sediment such as mineral precipitation and dissolution, ion exchange, adsorption, and desorption, aqueous complexation, biological immobilization and mobilization, and plant uptake (Levy *et al.*, 1992).

Table 2: Results of geo-accumulation index of sediment of lake Geriyo

Location	Season	I-geo			
		Zn	Cu	Cd	Pb
North	Dry	0.80	-0.22	-3.17	0.31
	Wet	-0.59	-0.63	-0.63	0.47
South	Dry	-1.03	-0.10	-3.17	-0.10
	Wet	-0.68	-0.47	-0.66	0.15
East	Dry	-1.033	-0.30	-3.17	-0.10
	Wet	-0.72	-0.16	-2.03	0.45
West	Dry	-0.77	-0.07	-0.17	0.18
	Wet	-0.29	-0.38	-1.97	-2.17

3.3. Enrichment Factor

As presented in Table 3, average EF values for heavy metals have an order Cu > Pb > Zn > Cd suggesting that sediment samples exhibit significant enrichment with Cu. According to Sutherland (2000), EF < 1 indicates that the recorded concentration of the metal is at background concentration level, EF of 1 - 2 indicates depletion to minimal enrichment and EF of 2 - 5 indicates moderate enrichment. The result reveals that Zn and Cd had EF < 1 except for West location in wet and dry seasons respectively. Depletion to minimal enrichment was found for Cu and Pb except for Cu at South location of the sampling sites in wet season while Pb at North and East locations in wet seasons indicate moderate enrichment. According to Akoto *et al.* (2008), EF values between 0.5 and 1.5 indicate that the source of the metal is from natural processes and above 1.5 suggest anthropogenic sources. This result showed that EF values of most of the metals at the sampling locations were below 1.5, indicating that the metals in the sediments were derived mainly from natural processes. On the other hand, EF values above 1.5 were found for Cu at South location in wet season and for Pb at North and East locations in wet seasons which suggest that their sources are likely to come from anthropogenic activities.

Table 3: Results of enrichment factor of sediments of lake Geriyo

Location	Season	EF			
		Zn	Cu	Cd	Pb
North	Dry	0.86	1.29	0.16	1.86
	Wet	0.99	0.97	0.94	2.08
South	Dry	0.73	1.40	0.16	1.40
	Wet	0.94	5.12	0.94	1.66
East	Dry	0.73	1.22	0.16	1.40
	Wet	0.91	1.34	0.39	2.05
West	Dry	0.88	1.42	1.34	1.71
	Wet	1.23	1.15	0.39	0.34

3.4. Contamination Factor and Degree of Contamination

The CF values for the heavy metals in the sediments of the lake were in the order Pb > Cu > Zn > Cd as presented in Table 4. For all the sites and seasons, the sediment of lake Geriyo recorded CF value for Pb and Cu as 1<CF<3, indicating that this environment was moderately contaminated with Pb and Cu due to anthropogenic input. Similarly, Zn and Cd had a CF < 1 which showed low contamination. Furthermore, low degree of contamination (DC< 7) was observed for the sediments of the lake.

Table 4: Results of contamination factor and degree of contamination

Location	Season	Contamination factor (CF)				Degree of contamination
		Zn	Cu	Cd	Pb	
North	Dry	0.86	1.92	0.17	1.86	4.18
	Wet	0.99	0.97	0.97	2.08	5.01
South	Dry	0.73	1.40	0.17	1.40	3.70
	Wet	0.94	1.09	0.95	1.66	4.64
East	Dry	0.73	1.22	0.17	1.40	3.52
	Wet	0.91	1.35	0.37	2.05	4.68
West	Dry	0.88	1.43	1.33	1.70	5.34
	Wet	1.23	1.16	0.38	0.33	3.10

3.5. Pollution Load Index

The calculated values of the pollution load index are presented in Table 5. The results show that the values of the PLI range between 0.65 and 1.30. According to Seshan *et al.* (2010) PLI < 1 refers to no pollution and PLI > 1 indicates presence of pollution. PLI values at East location, North and South locations in dry season and West location in wet season indicate PLI<1 which shows no pollution.

Table 4: Results of pollution load index

Location	Season	PLI
North	Dry	0.77
	Wet	1.18
South	Dry	0.70
	Wet	1.13
East	Dry	0.68
	Wet	0.98
West	Dry	1.30
	Wet	0.65

However, the results at North and South locations in wet season and West in dry season indicate PLI>1 suggesting the presence of pollution. There are only few exceptions (North and South locations in wet season and West location in dry season), where values of PLI were greater than one (PLI > 1. Based on Seshan *et* *al* (2010) where values of PLI are less than one it refers to no pollution. This suggests that the sediments of lake Geriyo were unpolluted by these metals.

4. CONCLUSION

Wet season recorded higher metal concentration than the dry season when the mean metal concentrations were compared with global based sediment quality guidelines. Levels of the heavy metals were within the set standard limit of TEL, PEL, ERM, and ERL. These suggest that the sediment did not present any serious threat to the fauna and flora of the lake. Contamination factor index showed that sediments can be classified as moderately contaminated by Cu and Pb probably due to anthropogenic input. The calculated degree of contamination indicates low degree of contamination and pollution load index suggests sediments of lake Geriyo were unpolluted by these metals. The geo-accumulation index suggests that the metal concentrations in the sediments can be classified as uncontaminated to slightly contaminated with metals of Pb and Zn. Enrichment factor indicates depletion to minimum enrichment with Cu and Pb. However, there is need for regular monitoring of the lake as Pb is believed to be carcinogenic.

5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and support of Tertiary Education Trust Fund (TETFUND) of Nigeria for sponsorship of the studies. Also, the authors wish to express their appreciation to Mr. Vincent Torve for the support rendered during the laboratory work and instrumental analysis carried out during this study.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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