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USING EF, PLI AND IGEO FOR THE ASSESSMENT OF HEAVY METAL POLLUTION AND SEDIMENT QUALITY OF ASEJIRE RESERVOIR, SOUTHWEST NIGERIA

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ABSTRACT: *Asejire Reservoir is the largest lake in Southwest Nigeria, supplying domestic and industrial water to more than two million inhabitants of Ibadan and adjoining villages and towns in Oyo and Osun States. A study on the characteristic of sediment quality was conducted to evaluate the heavy metal content of the reservoir. Twenty stations were selected, sampled and analyzed using standard methods.Standard pollution indices such as Igeo, Enrichment Factor, Contamination Factor and Pollution Load Index were deployed to assess the level of heavy metals contamination in the reservoir. The result showed that the sediment was slightly acidic across the study stations, with low conductivity and organic matter content. The heavy metals order of dominance was: Fe>Pb>Cu>Zn>Mn>Ba>Ni>Cr. The mean concentration levels of all the heavy metals were lower than mean background value except Fe and Pb. Analysed data shows that the sediments in the area are rich in Fe with Igeo values > 6, high enrichment and contamination factor. Igeo and CF levels of Pb indicate moderate to no pollution, while other heavy metals indicated low calculated Igeo, EF and CF respectively. The calculated PLI values for all the heavy metals in all the location were < 1, indicating low anthropogenic contamination by these elements and suggesting that the heavy metals were derived mainly from natural sources such as bedrock materials and weathering processes.*

KEYWORDS: Sediment, Heavy Metals, Asejire, Pollution Load Index, Geo-accumulation Index

INTRODUCTION

Jones (1969) defined sediments as materials formed due to transportation and deposition of organic and mineral matter found at the bottom of oceans, lakes, ponds and rivers. The sediments are formed either from allochthonous or autochthonous materials or from both. The materials ranged fine to coarse grain minerals (Ogbeibu, *et. al*. 2014). Data from sediments provide information on the impact of distant human activity on the wider ecosystem.

Heavy metals accumulate in sediments through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Ankley*et al*., 1992, Caccia*et al*., 2003). The dissolution and adsorption processes are influenced by several physicochemical parameters such as pH, dissolved oxygen, salinity, redox potential, organic and inorganic carbon contents and the presence in water phase of some anions and cations that can bind or co-precipitate the water-dissolved or suspended pollutants (Calmano*et al.* 1993). Heavy metals play important roles in our society as most of them are vital raw materials in most industries, (Cu, Se, Zn, etc.) and as essential materials in the

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maintenance of some metabolic activities in human bodies, but at certain concentrations, they have been implicated in health complications in the liver, lung, intestine, blood etc.

Sediment-associated contaminants especially the heavy metals have the potential to cause direct effects on sediment-dwelling organisms and can indirectly adversely affect man and other animals at the higher trophic levels. The high contamination of aquatic system with toxic heavy metals is of major concern to the society because these elements are not biodegradable and their elevated uptake by crops and aquatic organisms may also affect food quality and safety (Barakat*et al.,* 2012).The determination of the chemical characteristics of sediments, on which benthic invertebrate animals live, is very important in the assessment of the health of the aquatic environment (Aller, 1982).

In Nigeria, most domestic sewage and industrial effluents from both rural and urban areas are released into the environment without proper treatment. These wastewaters eventually find it way to lakes and reservoirs within their catchment basins. About 30% of human generated waste found their way into rivers and reservoirs. Thus, information on sediment quality conditions is essential for evaluating the overall status of aquatic ecosystems.

Various studies have demonstrated that several watercourses are contaminated by heavy metals from discharged human wastes (Bellucci, *et al.*, 2003; Omoigberale, *et al*., 2014;Faboya*et al.*, 2012; Emoyan, *et al*., 2006; Akan, *et al*., 2012). Recent studies on the sediment heavy metal quality of water bodies in Nigeria include the works ofPuyate, *et. al.*(2007); Oribhabor and Ogbeibu (2009); Adepoju and Adekoya(2012).

The need to assess the state of the sediment quality of the Asejire Reservoir, one of the biggest man-made lakes in Nigeria has become imperative in view of the health implications since untreated effluents from the basins are discharged into the rivers that fed it, and the reservoir water is used for both domestic and industrial activities by people living in the catchment area as well as far away where the water is piped to supply thousand of inhabitants far away from its catchment basins. This study reports the levels of somephysico-chemical parameters and the heavy metals of the sediments along the stretch of reservoir with the aim of evaluating its pollution status.

Study Area

Asejire Reservoir is a manmade lake that was created in November 1970 by the impoundment of River Osun and officially opened in 1972. River Osun catchment basin extends from longitudes 003^0 55'E to 005^0 05'E and latitudes 06^0 35'N to 08^0 20'N. However, the catchment area of Asejire Reservoir is from longitudes 004^0 07'017"E to 004^0 08'925"E and in length from latitudes 07^0 21'48"N and 07^0 26'84"N. It was primarily created to supply domestic and industrial water, although some ancillary benefits such as fishing activities have also emerged (Asibor, 2008). The reservoir receives the bulk of its water input from two rivers, Rivers Osun and its main tributary River Oba.

From the data supplied by the Oyo State Water Corporation of Nigeria, the catchment area of the dam is 7,800 km^2 and the impounded area is 23.42 km^2 (2,342 hectares). The dam has a normal pool elevation (water level) of 150 m and maximum flood elevation of 152.4 m. The surface area of the reservoir is about 24km^2. Its gross storage capacity is approximately 7,403.4 million litres per day while its discharge capacity is 136.26 million litres per day with maximum water capacity of about 675m^3**.**

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The reservoir supply water to more than two million inhabitants of Oyo and Osun states. It is used by industries located within these states, while more that 20 artisanal fishermen depends on it for their daily living. With the aforementioned enormous significance of the reservoir, no detailed scientific investigation has been carried out to investigate heavy metals concentration and distribution in the sediments of the reservoir which is an important component of the food web and fishery of the reservoir.

MATERIAL AND METHODS

Sampling was carried out aboard canoe every two months for two annual cycles using an improvised Van Veen grab sampler of $0.04m^2$ (0.2m X 0.2m) for sediment collection. The reservoir was divided into three sections (lower reach, mid-basin and upper reach), with an established 20 stations.

Analysis of sediments was based on air-dried samples. The samples were spread in a flat tray and allowed to dry under normal room temperature. The air-dried sediment samples were gently crushed with a pestle in a porcelain mortar and sieved through a 2mm sieve. Samples were digested in 10ml of concentrated nitric acid (70%) for two hours at 170^0C before the residue was diluted, filtered in volumetric flasks (APHA *et al*., 1998). After digestion, the concentrations of the metals were analyzed by flame atomic absorption spectrophotometer using Perkin Elmer 3100 Flame Atomic Absorption Spectrophotometer with direct aspiration.

Data Analysis

All the statistical analyses were carried out using the Paleontological Statistics (Hammer *et al.*, 2003), Statistical Package for Social Sciences (SPSS) Software package for biological data analysis and Statistical Ecology (Ludwig & Reynolds, 1988). To determine the magnitude of heavy metal contamination in the sediment, the Pollution Load Index (PLI), Enrichment Factor (EF), contamination factor and geo-accumulation Index (Igeo) were employed.

PLI is a potent tool in heavy metal pollution evaluation.Pollution load index for each site was evaluated using the procedure developed by Tomlinson *et al.* (1980).

PLI = (CF1xCF2xCF3x.....CFn)1/n

Where: n = number of metals

Contamination factor (CF) = Metal concentration in sediment/Background values of the metal

According to Chakravarty and Patgiri(2009) the PLI value > 1 is polluted while PLI value < 1 indicates no pollution. Contamination factor and level of contamination advancedinitially by (Muller 1969) and modified by (Muller 1979) and several otherworkers and universally used, is shown below (Table 1);

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Table 1:Classification of Contamination factor and level of contamination

S/N	Contamination Factor (Cf)	Level of Contamination
1	Cf< 1	Low contamination
2	1 ≤ Cf< 3	Moderate contamination
3	3 ≥ Cf< 6	Considerable contamination
4	Cf> 6	Very high contamination

The enrichment Factor (EF) is used to evaluate the level of soil and sediment contamination and seeks to know the possible natural or anthropogenic input and impacts insoils and sediments (Sallau*et al,* 2014). EF of a heavy metal in sediments can be calculated usingthe following equation;

Enrichment Factor (EF) = (metal/Fe) sample/(metal/Fe) crust

According to (Szefer *et al,* 1996), EF values lower than and around 1.0indicates that the element in the sediment originatedpredominantly from the rustal/background material and /orweathering process. EF values greater than 1.0 displaysanthropogenic origin of the element.

According to Chen *et al*., 2001);

EF = < 3 indicates minor or minimal enrichment,

EF = 3-5 indicates moderate enrichment,

EF = 5-10 indicates moderately severe enrichment,

EF = 10-25 indicates severe enrichment,

EF = 25-50 indicates very severe enrichment,

EF > 50 indicates extremely severe enrichment.

As the EF values increases, the contribution of theanthropogenic origins also increases (Sutherland, 2000).

The geo-accumulation index is generally used to determinethe anthropogenic contamination in sediments as introducedby Muller (*op cit*) and corroborated by prominent works of Forster *et al*. (1993),Loska*et al*. (1997) and Lokeshewari and Chandrappa (2006). This index evaluates thecontamination levels by comparing present concentrationswith background levels. The Igeo is expressed using thefollowing Muller equation:

Igeo = log2 (Cn/1.5Bn)

Where: Cn = measured concentration of element n in the sediments

Bn = geochemical background for the element n

1.5 is incorporated in the relationship to account for possible variation in background data (the background matrix correction factor) owing to lithogenic effects.The geo-accumulation index, consist of seven grades (0 to 6) based on the increasing numerical value of the index and ranges

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from unpolluted to extremely polluted. The standard Igeo values are presented below (Table 2).

Table 2: Muller'sclassification for geo- accumulation index

Igeo value	Class	Sediment Quality
≤0	0	Unpolluted
0-1	1	unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	Moderately polluted to strongly polluted
3-4	4	Strongly polluted
4-5	5	strongly polluted to extremely polluted
>5	6	Extremely polluted

The world average concentration of metals as reported for world shale Taylor (1964) and Onyari*et al*. (2003)were considered as the background values in the computations.

RESULTS AND DISCUSSION

Physico-chemical Characteristics

Sediment like water is usually employed as a pollution indicator by contaminants (Ogbeibu *et al*., 2014). Using sediment heavy metals, a deeper insight into the long-term pollution state of the aquatic environment can be enumerated (Yau and Gray, 2005; Ogbeibu *et al*., 2014). Sediments have been described as a ready sink of pollutants where they concentrate according to the levels of pollution (Onyari*et al*., 2003, Iwegbue*et al*., 2007). The levels of physico-chemical parameters and heavy metals in river water determine the quality of the sediment.

The summary of the meanconcentrations of the physico-chemical and heavy metals in the reservoir sediments from the study area are presented in Table 3, while Tables 4, 5 and 6 shows the calculated EF, Igeo/PLI and CF of stream sediments in the area.

In Table 3, the pH was shown to be slightly acidic for all the locations with a mean range of between 5.49– 6.54 as indicated in Stations 2 and 6 with a mean value of 5.94 ± 0 32. The slightly acidic nature of all the sampling points in the reservoir may be due to the humic acid formed from decaying organic matter. The level of homogeneity observed in pH of the sediment is similar to the observations with reported works for bottom sediment of other water bodies in Nigeria (Okoye, 1991; Horsfall and Spiff, 2002; Puyate*et al*., 2007). Iwegbue*et al*. (2007) and Davies and Tawari (2010) reported that lower pH value is typical of the anaerobic sediments.

Fluctuations in mean conductivity values ranged from the lowest value (242.8 µS/cm) in station 5 to the highest value (571.7 µS/cm) in station 6, while the mean organic carbon values ranged from 1.06% in Station 11 to 3.88% in Station 7. The low conductivity may be attributed to the low content of soluble salts in sediments as reported by Mohammad and Mazahreh (2003).The low organic matter (2.54 ± 0.62) may be related mainly to the low organic matter flux to sediments due to low discharge of domestic and industrial wastewaters from the catchment basin. Similar low values from selected major rivers in South-western Nigeria have been documented by Puyate*et al*., 2007; Etim and Adie (2012);Ogbeibu*et al*., (2014). Extreme concentrations of organic carbon levels below 0.05% and above 3% have been implicated in decreased benthic abundance and biomass (Ogbeibu*et. al*. 2014). The mean organic content obtained in the

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sediments from the study was within the risk-associated values recommended by Hyland *et al.* (2000).

Heavy metals

The heavy metals determined in this study include iron, zinc, copper, lead, barium, chromium, manganese and nickel. Spatial variations in their mean values are shown in Table 3. The mean values of iron ranged between 26298 mg/kg and 56966 mg/kg. The mean concentrations of Fe were higher when compared with the reported values of 28.1-33.7 mg/kg for Orogodo River sediments (Puyate*et al.*, 2007), 31.19-58.34 mg/kg in the sediments of River Ngada (Akan *et al*., 2010) and 475.2 – 704.2 mg/kg in Ala River (Abata*et al*., 2013). These changes may be attributed to the nature of the bedrock materials

Table 3: Summary (mean) of spatial variability in Physico-chemical and Heavy metals characteristics of sediment from Asejire Reservoir

Stn.	EC (μScm^{-1})	pH	Temp. °C	OC. (%)	Fe (Mg/kg)	Zn (Mg/kg)	Cu (Mg/kg)	Pb (Mg/kg)	Ba (Mg/kg)	Cr (Mg/kg)	Mn (Mg/kg)	Ni (Mg/kg)
1	571.66	5.55	28.99	2.82	36974.81	18.40	60.93	120.01	0.54	0.03	1.06	0.04
2	538.31	5.49	29.26	3.12	55354.50	22.41	72.74	121.05	0.51	0.03	2.13	0.06
3	528.33	5.66	29.12	2.7	45393.80	25.30	75.40	104.93	0.70	0.03	1.54	0.03
4	502.87	5.68	28.98	2.69	56333.67	25.21	66.33	121.94	0.58	0.02	1.79	0.09
5	242.8	6.25	28.74	2.79	33076.69	17.09	24.44	35.68	0.58	0.04	2.03	0.07
6	278.47	6.54	29.03	2.11	30074.96	23.09	26.61	48.85	0.63	0.02	1.08	0.07
7	540.0	5.52	28.68	3.88	52138.13	20.62	57.88	106.74	0.59	0.03	1.77	0.06
8	466.38	5.57	29.03	3.36	50609.63	23.08	70.26	91.69	0.50	0.02	1.78	0.07
9	460.19	5.6	29.15	2.33	56966.00	22.81	72.08	80.46	0.52	0.03	2.07	0.04
10	259.63	6.3	28.61	1.07	26808.88	22.06	20.61	40.23	0.40	0.02	1.38	0.10
11	263.94	6.07	28.85	1.06	28293.44	15.12	18.45	48.11	0.43	0.02	0.32	0.06
12	298.06	6.13	28.7	1.86	26298.19	20.66	23.85	49.31	0.47	0.04	0.66	0.06
13	329.68	6.43	28.75	2.11	32828.09	26.21	27.38	43.71	0.47	0.04	0.63	0.04
14	290.14	6.21	28.83	2.63	37643.16	28.31	31.57	34.26	0.36	0.03	1.86	0.07
15	421.5	5.62	28.78	3.34	44339.59	17.73	60.55	76.52	0.47	0.03	2.01	0.04
16	394.24	5.74	28.81	3.3	36759.72	19.29	66.33	98.53	0.49	0.03	1.94	0.06
17	451.13	5.85	28.83	3.26	45796.83	22.63	50.17	65.81	0.49	0.04	1.94	0.03
18	293.94	6.17	28.79	1.94	37876.00	11.67	14.83	59.79	0.55	0.05	1.13	0.03
19	308.5	6.22	29.11	1.56	34447.00	17.36	14.86	60.66	0.50	0.02	1.09	0.02
20	314.37	6.24	28.95	2.78	31562.59	18.25	18.40	32.15	0.54	0.03	1.87	0.03
min.	242.8	5.49	28.61	1.06	26298.19	11.67	14.83	32.15	0.36	0.02	0.32	0.02
max.	571.66	6.54	29.26	3.88	56966.00	28.31	75.40	121.94	0.70	0.05	2.13	0.10
x	387.71	5.94	28.9	2.54	39978.78	20.86	43.68	72.02	0.52	0.03	1.50	0.05
S.d.	99.75	0.32	0.15	0.62	8710.19	3.25	21.58	27.37	0.06	0.01	0.47	0.02

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Table 4: Calculated Enrichment Factor (Ef) of Heavy Metals in the Reservoir Sediment

S/N	Al	Fe	Zn	Cu	Pb	Cr	Mn	Ni	Ba
1	1.971E-	2.317E+01	2.148E-	1.351E-	6.654E-	3.311E-	1.304E-	6.727E-	1.411E-
2	1.434E-	2.317E+01	1.655E-	1.064E-	4.284E-	2.502E-	1.748E-	5.084E-	8.285E-
3	1.722E-	2.317E+01	2.405E-	1.362E-	4.739E-	3.412E-	1.546E-	3.808E-	1.479E-
4	1.449E-	2.317E+01	1.931E-	9.655E-	4.437E-	1.456E-	1.450E-	9.989E-	9.898E-
5	2.341E-	2.317E+01	2.230E-	6.059E-	2.211E-	5.050E-	2.800E-	1.215E-	1.685E-
6	2.739E-	2.317E+01	3.313E-	7.256E-	3.330E-	3.029E-	1.638E-	1.403E-	2.027E-
7	1.689E-	2.317E+01	1.707E-	9.104E-	4.197E-	2.330E-	1.547E-	7.478E-	1.096E-
8	1.709E-	2.317E+01	1.968E-	1.138E-	3.714E-	2.025E-	1.599E-	8.712E-	9.451E-
9	1.193E-	2.317E+01	1.728E-	1.038E-	2.895E-	2.499E-	1.659E-	4.234E-	8.886E-
10	2.587E-	2.317E+01	3.551E-	6.305E-	3.076E-	3.930E-	2.344E-	2.165E-	1.440E-
11	2.599E-	2.317E+01	2.306E-	5.347E-	3.486E-	3.120E-	5.082E-	1.279E-	1.479E-
12	2.774E-	2.317E+01	3.391E-	7.435E-	3.843E-	7.146E-	1.147E-	1.376E-	1.721E-
13	2.267E-	2.317E+01	3.445E-	6.838E-	2.730E-	5.377E-	8.786E-	7.691E-	1.394E-
14	2.325E-	2.317E+01	3.246E-	6.877E-	1.866E-	3.479E-	2.249E-	1.151E-	9.315E-
15	2.031E-	2.317E+01	1.725E-	1.120E-	3.538E-	2.748E-	2.067E-	5.949E-	1.032E-
16	2.330E-	2.317E+01	2.264E-	1.480E-	5.494E-	3.176E-	2.403E-	9.841E-	1.286E-
17	1.466E-	2.317E+01	2.133E-	8.983E-	2.946E-	4.103E-	1.932E-	3.456E-	1.041E-
18	1.861E-	2.317E+01	1.330E-	3.211E-	3.236E-	6.044E-	1.358E-	5.472E-	1.405E-
19	2.728E-	2.317E+01	2.175E-	3.538E-	3.610E-	3.141E-	1.445E-	3.063E-	1.393E-
20	2.189E-	2.317E+01	2.495E-	4.780E-	2.088E-	3.969E-	2.705E-	4.776E-	1.643E-

Table 5: Summary of Geo-accumulation Index (Igeo) and Pollution Loading Index (PLI) in the Stations

Station	Index of Geo-accumulation (igeo)									PLI
	Al	Fe	Zn	Cu	Pb	Cr	Mn	Ni	Ba	
1	-	12.55	-	-	2.00	-	-	-	-	0.09
2	-	13.13	-	-	1.94	-	-9.312	-	-	0.11
3	-	12.85	-	0.008	1.80	-	-9.775	-	-9.839	0.10
4	-	13.16	-	-	2.02	-	-9.557	-	-	0.11
5	-	12.39	-	-	0.25	-	-9.375	-	-	0.08
6	-	12.25	-	-	0.70	-	-	-	-9.979	0.08
7	-	13.04	-	-	1.83	-	-9.574	-	-	0.11
8	-	13.00	-	-	1.61	-	-9.570	-	-	0.11
9	-	13.17	-	-	1.42	-	-9.346	-	-	0.10
10	-	12.09	-	-	0.42	-	-9.935	-	-	0.07
11	-	12.16	-	-	0.68	-	-	-	-	0.06
12	-	12.06	-	-	0.71	-	-	-	-	0.07
13	-	12.38	-	-	0.54	-	-	-	-	0.07
14	-	12.58	-	-	0.19	-	-9.504	-	-	0.09
15	-	12.81	-	-	1.35	-	-9.390	-	-	0.10
16	-	12.54	-	-	1.71	-	-9.443	-	-	0.10
17	-	12.86	-	-	1.13	-	-9.441	-	-	0.09
18	-	12.58	-	-	0.99	-	-	-	-	0.07
19	-	12.45	-	-	1.01	-	-	-	-	0.06
20	-	12.32	-	-	0.10	-	-9.492	-	-	0.07

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Table 6: Contamination Factor (Cf) of heavy metals in the Asejire Reservoir sediment

Station	**Al**	**Fe**	**Zn**	**Cu**	**Pb**	**Cr**	**Mn**	**Ni**	**Ba**
1	0.178	9018.247	0.194	1.219	6.000	0.000	0.001	0.001	0.001
2	0.194	13499.902	0.223	1.437	5.783	0.000	0.002	0.001	0.001
3	0.191	11071.659	0.266	1.508	5.246	0.000	0.002	0.000	0.002
4	0.199	13739.919	0.265	1.327	6.097	0.000	0.002	0.001	0.001
5	0.189	8067.486	0.180	0.489	1.784	0.000	0.002	0.001	0.001
6	0.201	7335.356	0.243	0.532	2.443	0.000	0.001	0.001	0.001
7	0.215	12716.618	0.217	1.158	5.337	0.000	0.002	0.001	0.001
8	0.211	12343.811	0.243	1.405	4.585	0.000	0.002	0.001	0.001
9	0.166	13894.146	0.240	1.442	4.023	0.000	0.002	0.001	0.001
10	0.169	6538.750	0.232	0.412	2.011	0.000	0.002	0.001	0.001
11	0.179	6900.838	0.159	0.369	2.405	0.000	0.000	0.001	0.001
12	0.178	6414.192	0.218	0.477	2.465	0.000	0.001	0.001	0.001
13	0.182	8006.852	0.276	0.548	2.186	0.000	0.001	0.001	0.001
14	0.213	9181.258	0.298	0.631	1.713	0.000	0.002	0.001	0.001
15	0.220	10814.535	0.187	1.211	3.826	0.000	0.002	0.001	0.001
16	0.209	8965.785	0.203	1.327	4.926	0.000	0.002	0.001	0.001
17	0.164	11169.958	0.238	1.003	3.290	0.000	0.002	0.000	0.001
18	0.172	9238.049	0.123	0.297	2.990	0.001	0.001	0.001	0.001
19	0.229	8401.707	0.183	0.297	3.033	0.000	0.001	0.000	0.001
20	0.168	7698.193	0.192	0.368	1.607	0.000	0.002	0.000	0.001

Table 7: EPA heavy metal Guidelines for Sediments (mg/kg)

S/N	Metals	Not polluted	Moderately polluted	Heavily polluted	Present study
1	Iron	ND	ND	ND	26298-56966
2	Zinc	<90	90 - 200	>200	11.67-28.31
3	Copper	<25	25 – 50	>50	14.83-75.40
4	Lead	<40	40 – 60	>60	32.15-121.94
5	Chromium	<25	25 – 75	>75	0.36-0.70
6	Manganese	<300	300 – 500	>500	0.32-2.13
7	Nickel	<20	20 – 50	>50	0.02-0.10

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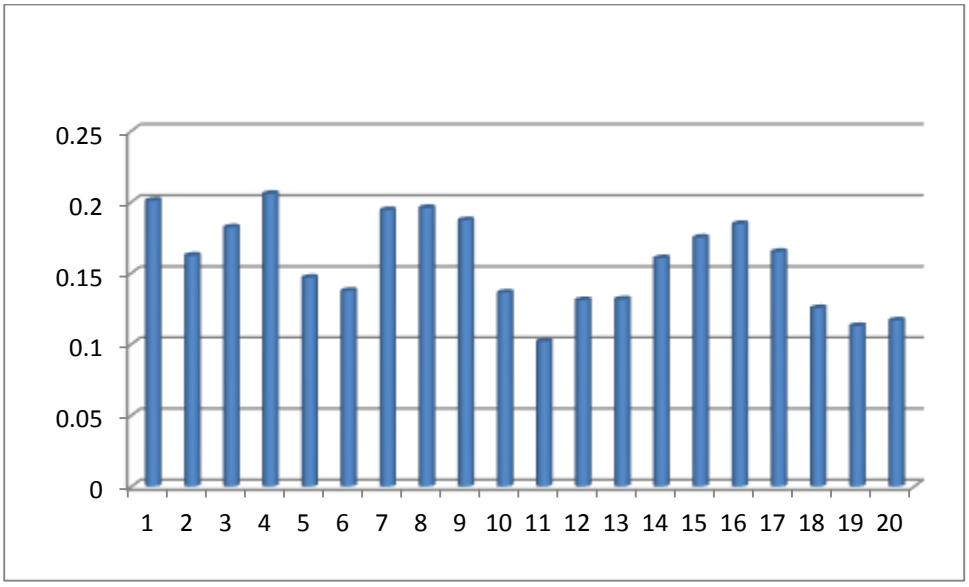

Figure 1: Spatial Variations in the PLI Values in the twenty stations

Within and around the reservoir as well as to the anthropogenic activities carried out around the catchment basin of the reservoir. The pH of the water influences the solubility of the metals and this in turn affects their ability to settle on the sediment. Iron has been reported to occur at high concentrations in Nigerian soil/sediment (Adefemi*et al*., 2010). Concentrations of Zn ranged from 11.67 – 28.31mg/kg. The values of zinc recorded werehigher compared with the mean values obtained by Ihenyen (2001); Uwah*et al*., (2013); and Faboya*et al*. (2012)but lower to the values obtained by Akan et al. (2012) in Lake Chad. The differences might be due to temporal and spatial variation and pollution from sewage effluent that has high zinc content (Tumland, 1988). Copper concentrationsshowed similar variation with zinc. Puyate*et al.* (2007) and Salau*et al.*,(2014) recorded higher values in the sediments of Orogodo River and Benin River respectively. High levels of copper have been implicated in anaemia, liver and kidney damage, stomach and intestinal irritation (Priju and Narayana, 2007). The concentrations of lead in the reservoir range from 32.25 – 121.94mg/kg. The concentrations of lead recorded in this study was higher than the values obtained by Akan *et al*. (2012) and Abata*et al*. (2013) in sediments of Lake Chad and Ala River respectively. The high concentration of lead recorded in these stations can be associated with activities of the large number of mechanic workshop and mechanic villages located close to the reservoir, whose waste products are channelled through a canals and drainages into the reservoir. Lead is toxic to humans and its major anthropogenic sources include the use of lead as a petrol additive, runoff from the cities, discharge of improperly treated waste effluents, sewage sludge and the use of pesticides containing lead compounds (Radojevic and Bashkin, 1999). The mean concentrations of chromium, nickel, barium and manganese were generally low ranging from 0.02 – 0.05mg/kg (Cr), 0.02 – 0.10mg/kg (Ni), 0.36 – 0.70mg/kg (Ba) and 0.32 – 2.13mg/kg (Mn). These heavy metals reach water bodies primarily from the discharge from the few industrial wastes and disposal of products containing the metal (Rodojevic and Bashkin, 1999; Akan *et al*., 2010). The Cr, Ni, Ba and Mn values recorded in this investigation were lower when compared to the mean values of Ekpan Creek (Olomukoro and Azubuike, 2009), Qua Iboe River (Uwah*et al*., 2013) and Tailor Creeek (Okafor and Opuene, 2007). These low values might be due to the low industrial activities within the reservoir catchment.

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Using the Pollution Indices for Assessment

Enrichment factor (EF), geo-accumulation index (Igeo), pollution load index (PLI) and contamination factor (CF) were the contamination measurement indicators used for the assessment of the reservoir sediments in the study area. Calculated values of the pollution indices are presented in Tables 4, 5 and 6 and Figure 1.

Enrichment Factor (EF)

Heavy metals assessment using EF in the reservoir indicates that sediment of the area is minimally enriched by all the heavy metals, having EF values of less than 3.0 except Fe which has an EF of 23.1. This indicates that apart from Fe which enriched the sediment from anthropogenic sources and probably bedrock materials, all the other assessed heavy metals in the reservoir sediment originated predominantly from the background material and weathering process (Szefer*et al.*, 1996).

Geo-accumulation index (Igeo)

Using the Muller scale for Igeo, iron (Fe) was detected as the most enriched heavy metal in sediment of the study area, withIgeo value of 12.09 - 13.16with an Igeo class of 6 (Table 4), indicating that the reservoir sediment is extremely polluted by Fe. This was followed by lead (Pb) which has an Igeo of between 0.10 – 2.00, indicating an Igeo Class of moderately polluted. The other heavy metals showed an Igeo of less than 0, indicating that the reservoir sediment are not polluted by these metals.

Contamination factor (Cf) and pollution load index (PLI)

Contamination factor was very high for Fe (>6 for all the twenty sampling areas) and showing a very high contamination by Fe. This was followed by Pb and Cu ranging from 1.71 – 6.00 and 0.30 – 1.51 respectively. This indicates that copper level of contamination is moderate while lead fluctuates between moderate to considerable contamination. The other heavy metals showed low level of contamination as they were all < 0 in all the locations sampled.The Pollution Load Index (PLI) was calculated for each of the study stations according to the methods of Tomlinson *et al.* (1980). The PLI values recorded for all the stations were below 1 (Figure1). Thus the sediment of the study stretch of Asejire Reservoir is unpolluted for the assessed heavy metals.

The pollution load index (PLI) and the Geo-accumulation Index (Igeo) have been used extensively in the assessment of sediment pollution by heavy metals (Priju and Narayana, 2007; Akan *et al*., 2010; Harikumar *et al*., 2009; Mohinddin *et al*., 2010; Bentum *et al*., 2011; Rabee *et al*., 2011 and Iwuoha*et al*., 2012). The results of the present evaluation revealed that the sediment of the Asejire Reservoir is unpolluted by heavy metals even though there is high contamination from Fe and to a less extent Pb, based on the calculated PLI for the heavy metals. The PLI wasless than 1 for all stations thus indicating practically uncontaminated condition. These results were corroborated by the fact that the values of heavy metals in the sediments were below the EPA guidelines for sediment limit(Table 7) except Cu and Zn in some of the locations. This indicates that the sediment of the Asejire Reservoirris not polluted by heavy metals.

However, the levels of these metals are not static in the environment and there is tendency for increase as a result of increased human input and activities (Prater, 1975). Studies have shown

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that the concentrations of physico-chemical parameters in sediments are positively correlated with the concentration levels in the overlying water; therefore, continuous assessment is highly essential to control and minimize the potential health hazards of the inhabitants in the catchment areas who depend on the river water for drinking, domestic, industrial, agricultural and fishing purposes.

In summary, although there is enrichment from Pb and Fe to the reservoir sediment which leads to moderate to high contamination and enrichment factor; a trend which is also supported by the calculated Igeo, the overall assessment based on pollution loading index of the reservoir sediment indicates low pollution load index (PLI). This shows that sediment in the reservoir is not polluted.

CONCLUSION

The Asejire Reservoir is a major source of water for both the local communities and the industrial areas surrounding the catchment basin. It isalso an important source of fish and shrimps. The quality of the sediment and surface water is of great importance for the sustainable use of the reservoir. The significant spatial variation recorded in the concentrations of some heavy metals used in characterizing the sediment quality is a reflection of impacts of anthropogenic activity on quality of this reservoir. This study, however, allayed the fear of possible heavy metal pollution in the sediment of the study area, but there is the need for continuous monitoring of both sediment and water quality to match the potential threat from increased anthropogenic sources especially increased industrialization of the catchment basin.

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