Evaluation And Characterization Of Trace Metals Contamination In The Surface Sediment Using Pollution Load Index (PLI) And Geo-Accumulation Index (Igeo) Of Ona River, Western Nigeria

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Abstract: Evaluation and Characterization of Trace Metal Contamination in the Surface Sediment Using Pollution Load Index (PLI) and Geo-accumulation Index (Igeo) Index of Ona River was conducted for six months. From the result of this study, the mean values of lead ranged between 0.004 mg/kg and 0.330 mg/kg, while the mean iron was highest (5.05 mg/kg) in station 4 and lowest (2.26 mg/kg) in station 5. The mean chromium value ranged from 0.007 mg/kg (station 1 and 2) to 0.021 mg/kg (station 3 and 4). The mean copper was highest (3.97 mg/kg) in station 1 and lowest (0.008 mg/kg) in station 2. Analysis of variance (ANOVA) revealed the same trend in spatial variation of these heavy metals. There was a significant difference ($P< 0.05$) in lead, chromium and copper among the study sampling stations and insignificant difference ($P>0.05$) in iron among the study sampling station. The PLI values recorded for all the stations were below 1. Thus the sediment of the study stretch that Ona River is unpolluted. The Igeo values for chromium and iron fall in class '0' in all the five sampling stations, indicating that there is no pollution from these metals in the Ona River sediments, lead fall in class '3' in station 4indicating moderately to heavily contaminated condition and class '0'in station 1, 2, 3 and 5 and copper fall in class '3' in station 4 and 5, in class '6' in station 3 indicating extremely contaminated condition. The Igeo values were consistent with those derived for PLI. All trace metals had concentrations below the EPA regulatory limits for sediment except iron. From the results of this study, sediment quality reflects the impacts of anthropogenic activities on quality of the river. However, the continuous build-up of the metal contaminants can be checked if relevant government agencies ensure strict compliant of industrial standards which stipulate treatment of industrial waste before discharging such contaminated effluents/wastes into River. Therefore, perpetual assessment is highly recommended to minimize the potential health hazards of the people who surely depend on the River water for fishing and agricultural purposes.

Keywords: Trace metals, Sediment, Characterization, Ona River, Nigeria

1 Introduction

Sediment is the loose sand, clay, silt and other soil particles that is deposited at the bottom of body of water or accumulated at other depositional sites. Sediments can emanate from the erosion of bedrocks and soil or from decomposition of plants and animals [1]. Heavy metals are among the most common environmental pollutants and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources.

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The existence of trace metals in aquatic environments has led to serious concerns about their influence on plant and animal life [2]. Geo-accumulation index is the quantitative measure of the degree of pollution in aquatic sediment. It consists of seven grades ranging from unpolluted to very extremely polluted and the Pollution load index is a quick tool in order to compare the pollution status of different places, the pollution load index is use to determine the pollution severity and its variation along the different sample stations [3]. Heavy metals are chemical elements having atomic weights between 63.546 and 200.590 and a specific gravity that is 5 times greater than that of water. They exist in water in colloidal, particulate and dissolved phases with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin(that is; solid waste disposal, industrial or domestic effluents, harbour channel dredging) [4]. Furthermore, trace toxic metals are not easily removed from the environment nor are readily detoxified or degraded by metabolic activities in the body of the organism, thereby resulting in accumulation [5, 6]. Research has been that, they are no studies on sedimentology and geochemistry of the sediment in Ona River. To provide baseline information and also enlightened the people of the area about the immediate effect of the water body studied, they is need to determine trace metals pollution in sediment using pollution load index and Geo-accumulation Index. This study reports the levels of trace metals in sediments quality of Ona River with the aim of investigating the pollution status of the River.

2 MATERIALS AND METHODS

2.1 Description of Study Area

The city of Ibadan in south western Nigeria (7°23, N, 3°5' E) is the largest urban centre in Africa south of the Sahara [7]. It is characterized by a West African Monsoon type of climate with hot dusty dry season (Nov-April) and cold, humid rainy season (May-October) [8]. Ona River has a length of 55km^2 an area of 81.0km^2 and it flows through the low density western part of Ibadan [8]. The river flows in a north-south direction from its source at Ido Local Government Area) where it is dammed and also flows through Apata Genga (Ibadan south-west Local Government Area) to Oluyole Local Government (Fig.1). Companies located along this river include 7up Nigeria Plc, Zartech, Sumal and Interpac a paper mill industry (not in operation). Channelled effluents from these industries are connected by a network of canals channelled directly into Ona River [9]. Ona River receives allochtonous input of organic matter from the surrounding vegetation, derived through run-offs from the surface of the soil. The water body receives a lot of wastes ranging from industrial, agricultural and domestic sources, which apart from adversely affecting the normal hydrochemistry of the river, also decreases its channel capacity at various points, and this has been largely responsible for flood disasters in the river [8]. The river is often used as a 'latrine' which makes it offensive to sight and smell and therefore not good as a natural resource [9].

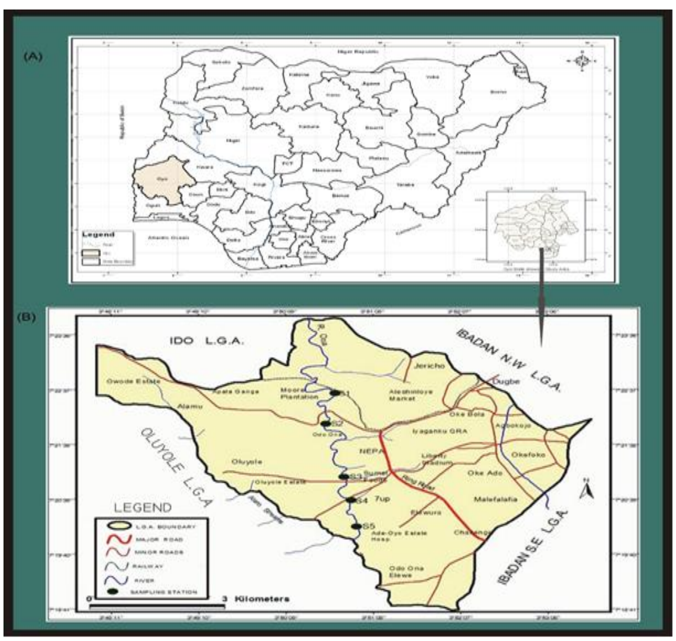

Figure 1: *Map of Ibadan South-West Local Government Area Showing Ona River and Sampling Station (1-5), (Map of Nigeria and Oyo State Inserted).*

2.1.1 Sampling stations

Five sampling stations (1-5) were chosen along the river course. The co-ordinates of the sampling stations were taken using GPS and approximate distances of the stations were calculated, each station was 500m apart from the other.

Station 1

This was the upstream station used as the control point because it was assumed to be unpolluted since waste/effluent was not discharge into the station. It is located at Moore plantation, Apata, Ibadan (Lat: N7^0 22' 4.81"; Lon: E3^0 50' 09.84"). In this station, there is no emergent vegetation. Bank side vegetation is predominantly melina tree (*Commelina nodiflora*). This river bed is basically coarse sand, granite and fast flowing, it appears undisturbed, unaltered and clean.

Station 2

Station 2 is the discharge point, located at Odo-Ona (Lat: N7^0 22' 4.85"; Lon: E3^0 50' 09.88"). It receives effluents from human household and wastes disposal. This is the station, in which the river at this point flows along a concrete channelled of about 5m wide and through some residential area. The river here is dirty brown and fast moving, speed was not uniform because of midstream eddies and side water friction with debris and land.

Station 3

Station 3 receives effluents from Sumal Food Company, that produces biscuit and sweet and it is located along Ring Road between Ibadan northwest and southwest L.G.A (Lat: N7^0 21' 4.89"; Lon: E3^0 51' 09.92"). The river at this station is also insensitively used for disposal of domestic waste. The river is also very dirty, contaminated with heavily disposed domestic, solid wastes and other activities are like washing of cars, clothes, bathing and human defecation.

Station 4

Station 4 receives effluents from 7up Bottling Company and also some industrial wastes around. It is located at 7up Road, Ring Road, Ibadan (Lat: N7^0 20' 4.92"; Lon: E3^0 51' 09.96"). This station; is probably turbid due to the effect of discharged effluents. The vegetation is composed mainly of trees which form a partial shade over this station, with *Panicum maximum* (Guinea grass) and some banana cover. The substratum is muddy.

Station 5

Station 5 receives effluents from Adeoyo State Hospital and also some industrial wastes around. It is located at Elewura area towards Fodasis Hospital, Ring Road, Ibadan (Lat: N7^0 19' 4.96"; Lon: E3^0 51' 09.99"). In this station, the vegetation is composed mainly of trees which form a shade over this station and the substratum is also muddy.

2.2 Collection of Samples

Sediment samples were collected into a polythene bag using hand trowel from five different sample stations from the month of October 2010 to the month of March 2011 between 9am to 3pm, then the sediment sample were taken to the Department of Agronomy, University of Ibadan for analysis.

2.3. Metal Analysis

In the laboratory, Sediment samples collected were subjected to standard procedure as described by [10]. The samples were air dried and sieved in 500µm mesh. 1.5 g of the fine sediment were weighed into Teflon vessels and 3.0 ml of 37% HCL, 6 ml of 65% HNO_3 and 0.25 mL of 30% H_2O_2 were added and thoroughly mixed. The mixtures were then digested in ethos 900 microwave digester for 26 min. The digested samples were allowed to cool in a water bath for 30 min and the concentrations of the Chromium (Cr), Iron (Fe), Lead (Pb) and Copper (Cu) were determined using Perkin-Elmer Analyst 300 Atomic Absorption spectrophotometer (AAS).

2.4. Statistical Analysis

Data obtained were subjected to Descriptive Statistics for mean, range, standard error and charts. Inter station comparisons were carried out to test for significant differences in the trace metals conditions using analysis of variance (ANOVA). To determine the magnitude of heavy metal contamination in the sediment, the Pollution Load Index (PLI) and geo-accumulation Index (Igeo) were employed. Pollution load index (PLI) for each station were evaluated using the procedure of [11]

$$PLI = (CF1 \times CF2 \times CF3x............CFn)^{1/n} \quad (1)$$

Where: n = number of metals

CF = contamination factor

CF = Metal concentration in sediment/Background values of the metal

PLI is a potent tool in heavy metal pollution evaluation. According to [12] the PLI value > 1 indicates pollution

PLI value < 1 indicates no pollution.

The geo-accumulation index (Igeo) values will be calculated for the different metals using the equation of [13]

$$Igeo = \log_2 (Cn/1.5Bn) \quad (2)$$

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

Bn = geochemical background for the element n

[13] Proposed seven classes of the geo- accumulation index.

Class 0 = Igeo <0 (practically uncontaminated)

Class 1= 0 < Igeo < 1 (uncontaminated to moderately contaminated)

Class 2 = 1 < Igeo < 2 (moderately contaminated)

Class 3 = 2 < Igeo < 3 (moderately to heavily contaminated)

Class 4 = 3 < Igeo < 4 (heavily contaminated)

Class 5 = 4 < Igeo < 5 (heavily to extremely contaminated)

Class 6 = 5 < Igeo (extremely contaminated).

Class 6 is an open class and comprises all values of the index higher than Class 5. The elemental concentrations in Class 6 may be hundred fold greater than the geo-chemical background value. In these computations, certified value or the world average concentration of Cr (192 mg/kg), Fe (45.5 mg/kg), Cu (101.7 mg/kg), Pb (146 mg/kg), reported for world shale [14] were considered as the background values.

3. RESULTS

Table 1 shows the summary of the mean concentrations for the metals of sediments at the study stations, Table 2 shows the Calculated F-values of one way analysis of variance measured in Ona River and Table 3. Summary of Pollution Load Index (PLI) and Geo-accumulation Index (Igeo) on Sediment Quality of Ona River. The heavy metals determined in this study include lead, chromium, iron and copper. Spatial variations in their mean values are shown in Figure 3. The mean values of lead ranged between 0.004 mg/kg and 0.330 mg/kg, while the mean iron was highest (5.05 mg/kg) in station 4 and lowest (2.26 mg/kg) in station 5. The mean chromium value ranged from 0.007 mg/kg (station 1 and 2) to 0.021 mg/kg (station 3 and 4). The mean copper was highest (3.97 mg/kg) in station 1 and lowest (0.008 mg/kg) in station 2. Analysis of variance (ANOVA) revealed the same trend in spatial variation of these heavy metals (Table 2). There was a significant difference (P< 0.05) in lead, chromium and copper among the study sampling stations and insignificant difference (P>0.05) in iron among the study sampling station (Table 2).

TABLE 1
SUMMARY OF TRACE METALS ON THE SURFACE SEDIMENT OF ONA RIVER

	Stations							
Parameters/(mg/kg)	**S1**	**S2**	**S3**	**S4**	**S5**	**$\bar{X}$ ±S.D**	**Min**	**Max**
Lead	0.004	0.018	0.034	0.33	0.026	0.082±0.139	0.004	0.330
Chromium	0.007	0.007	0.021	0.021	0.014	0.014±0.007	0.007	0.021
Iron	2.840	3.40	4.88	5.050	2.260	3.686±1.237	2.260	5.050
Copper	3.971	0.008	0.625	0.279	0.219	1.022±1.663	0.008	3.970

TABLE 2
CALCULATED F - VALUES OF ONE WAY ANALYSIS OF VARIANCE MEASURED IN ONA RIVER

Parameters	F	F-critical	P-value	Inferences
Lead(mg/kg)	27.332	5.987	0.002	P<0.05
Chromium(mg/kg)	29.135	5.987	0.002	P<0.05
Iron(mg/kg)	0.185	5.987	0.682	P>0.05
Copper(mg/kg)	23.901	5.987	0.003	P<0.05

The Pollution Load Index (PLI) was calculated for each of the study stations according to the methods of Tomlinson *et al.* (1980). A PLI value of > 1 signifies pollution, while PLI value < 1 indicates no pollution. The PLI values recorded for all the stations were below 1 (Table 3 and Figure 2). Thus the sediment of the study stretch of Ona River is unpolluted. The calculated Igeo values are presented in Table 3 and the variations are shown graphically (Figure 3). It is evident from the figure that the Igeo values for chromium and iron fall in class '0' in all the five sampling stations, indicating that there is no pollution from these metals in the Ona River sediments, lead fall in class '3' in station 4 and class '0'in station 1, 2, 3 and 5 and copper fall in class '3' in station 4 and 5, in class '6' in station 3. The Igeo values were consistent with those derived for PLI. All traces metals had concentrations below the EPA regulatory limits for sediment except for iron which was detectable (Table 4).

TABLE 3
SUMMARY OF POLLUTION LOAD INDEX (PLI) AND GEO-ACCUMULATION INDEX (IGEO) ON SURFACE SEDIMENT OF ONA RIVER

	STATIONS				
	S1	**S2**	**S3**	**S4**	**S5**
PLI	0.00056	0.050	0.0043	0.020	0.00033
Geo-accumulation Index (Igeo)					
Lead(mg/kg)	0.027	0.12	0.23	2.26	0.18
Chromium(mg/kg)	0.036	0.036	0.11	0.11	0.07
Iron(mg/kg)	0.062	0.06	0.11	0.11	0.049
Copper(mg/kg)	0.039	0.078	6.15	2.92	2.15

TABLE 4
EPA TRACES METAL GUIDELINE FOR SEDIMENT

	Trace metals (mg/kg)			
EPA Limit	**Lead**	**Chromium**	**Iron**	**Copper**
Not polluted	<40	<25	ND	<25
Moderately polluted	40-60	25-75	ND	25-50
Heavily polluted	>60	>75	ND	>50
Present study	**0.007-0.330**	**0.007-0.021**	**2.26-5.05**	**0.088-3.97**

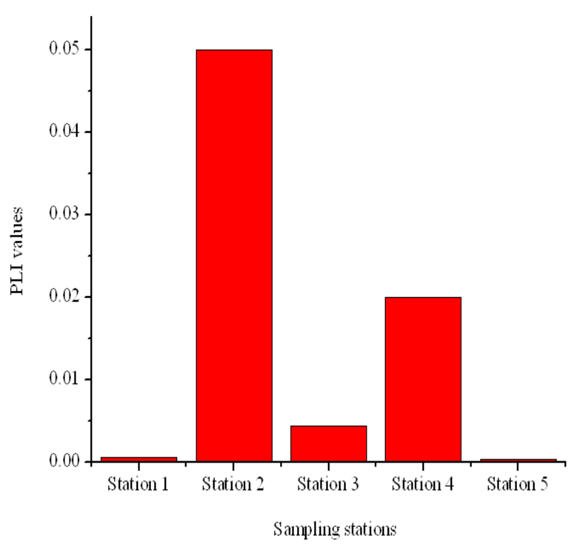

Figure 2: *Spatial varations in the PLI values*

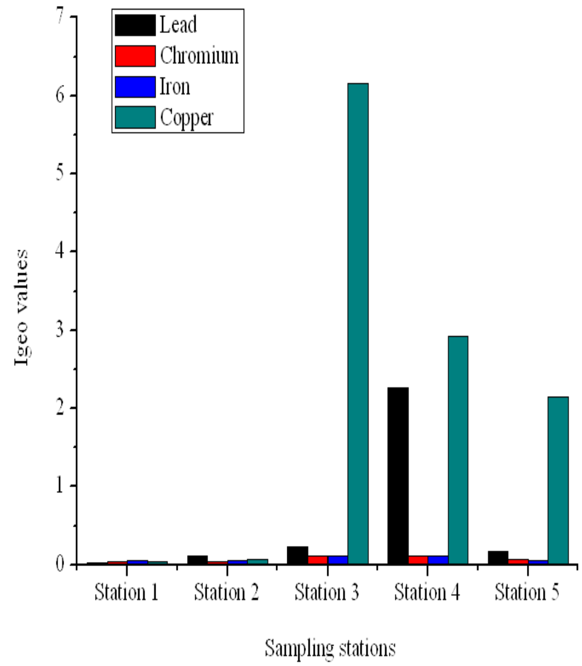

Figure 3: *Spatial varations in the Igeo values*

4. DISCUSSION

Sediment quality is usually employed as a pollution indicator by contaminants including trace metals; sediments can provide a deeper insight into the long-term pollution state of the aquatic environment. Sediments have been described as a ready sink of pollutants where they concentrate according to the levels of pollution [15]. High levels of copper have been implicated in anaemia, liver and kidney damage, stomach and intestinal irritation. 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 untreated waste effluents, sewage sludge from shipping activities and the use of pesticides containing lead compounds [16]. The concentrations of the heavy metals in Lead was higher in station 4 while copper was higher in station 3, these could be as a result of anthropogenic disturbances associated with some untreated wastes produce by human and sewage sludge around the River. The mean concentrations of these elements were lower when compared to that of [17] in River Ngada. These could attribute to the fact that anthropogenic disturbances embedded in the shoreline were discharge into the River. Chromium is an abundant element in the earth crust. It occurs in oxidation states ranging from Cr^{2+} to Cr^{6+}. Only Cr^{3+} and Cr^{6+}, however, are of biological importance. Industrial effluent discharged a major source of chromium followed by urban run-off [18]. The values recorded in this study were lower when compared to the mean values of [19] in Ekpan Creek and higher when compared to the mean value of [16] in Benin River. These differences could result in different sampling frequency and period. The pollution load index (PLI) and the Geo-accumulation Index (Igeo) have been used extensively in the assessment of sediment pollution by trace metals [12, 20, 21]. The results of the present evaluation revealed that the sediment of the study stretch of the Benin River is unpolluted by heavy metals. The PLI was less than 1 for all stations indicating unpolluted and the Igeo values for chromium and iron fall in class '0' in all the five sampling stations, indicating that there is no pollution from these metals in the Ona River sediments, lead fall in class '3' in station 4 indicating moderately to heavily contaminated condition in these stations and class '0'in station 1, 2, 3 and 5 indicating practically uncontaminated condition in these stations and copper fall in class '3' in station 4 and 5 also indicating moderately to heavily contaminated condition in these stations , in class '6' in station 3 indicating extremely contaminated condition. These results were corroborated by the fact that the values of trace metals in the sediments were below the EPA guidelines for sediment, an indication that the sediment of the Ona River was polluted in some areas around the River and unpolluted in some areas also around the River by trace metals. The level of these metals in the environment has increased tremendously as a result of anthropogenic activities. The implication of this is that these trace metals pose risk of contamination to the sediments of the River.

5. CONCLUSION

Ona River is one of the major Rivers in Oyo State; local communities used this River for fishing and agricultural activities. From the results of this study, the evaluation and characterization of sediment quality reflects the impacts of anthropogenic activities on quality of the river. However, the continuous build-up of the metal contaminants can be checked if relevant government agencies ensure strict compliant of industrial standards which stipulate treatment of industrial waste before discharging such contaminated effluents/wastes into River. Therefore, perpetual assessment is highly recommended to minimize the potential health hazards of the people who surely depend on the River water for fishing and agricultural purposes.

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