Ethiopian Journal of Environmental Studies & Management 17(1): 121 – 134, 2024
ISSN:1998-0507 doi: https://ejesm.org/doi/v17i1.10
Submitted: February 21, 2024 Accepted: March 22, 2024

POLLUTION CHARACTERISTICS AND GEOCHEMICAL STUDY OF CORE SEDIMENTS FROM RIVER OSSIOMO, SOUTHERN NIGERIA

***BIOSE, E. AND OYAGHA, E.O.**
Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria
*Corresponding author: ekene.biose@uniben.edu

Abstract

This study assessed the pollution characteristics and geochemical study of core sediments from the Ossiomo River. Sediment samples were air-dried, crushed and sieved through a 2mm sieve and analysed for physicochemical and heavy metals using standard methods. The average mean concentration of physicochemical properties in sediments were 5.43±0.37 pH, 186.28±59.15 (uS/cm) EC, 1.41±0.94 % TOC, 89.25±1.20 % sand, 5.03±1.81 % silt and 4.95±0.65 % clay. Mean concentration of heavy metals in bottom sediments were 1137±760.55 for Fe, 6.83±1.24 for Cu, 28.94±11.93 for Zn, 0.14±0.06 for Cd, 5.80±5.27 for Pb, 9.02±3.80 for Mn, 4.30±1.04 mg/kg for Cr. Total hydrocarbon content (THC) had an average mean value of 826.80±457.27 mg/kg. Heavy metal concentration was in the order: Fe>Zn>Mn>Cu>Pb>Cr>Cd. The computed Enrichment factor indicated that there is a moderate enrichment for Fe and Zn, a significant enrichment for Fe, Cr, Cd and a very high enrichment for Pb. Geoaccumulation index showed that Cu and Mn were practically unpolluted, Cr and Cd were moderately to heavily polluted, Pb was extremely polluted. Contamination factor showed a very high contamination exists for Cr, Cd, and Pb across the sample stations. Pollution load Index was greater than 1 (PLI>1) indicating pollution. Potential ecological risk index showed a very strong pollution degree of Pb while Cd exhibited an extremely strong pollution degree. The risk degree indicated an extremely strong risk degree across the stations. The potential ecological risk showed that station 1 and 3 had considerable ecological risk (300<RI≤600) while station 2 have a very high ecological risk (RI>600). Heavy metals content exhibited a positive and significant correlation and therefore, it is important to take heavy metal contamination in Ossiomo River sediments seriously.

Key Words: *Heavy metals, Ecological risk, Enrichment factor, Contamination factor, Pollution load index, Geo-accumulation index*

Introduction

Water bodies are major recipients of pollutants from land. These pollutants are transported into water bodies through runoff, underground seepage and wet or dry deposition from the atmosphere (Tchounwou *et al.,* 2012). Sediments are an essential component of aquatic systems. This is due to the roles they play in sedimentation and silting, chemical pollution and eutrophication in water bodies (Anyahara, 2021). Sediments are composed of unconsolidated materials which result from weathered rocks and soil, and organic matter which have passed through processes such as weathering, transportation, transformation and deposition (Hong *et al.,* 2020). They receive and accumulate portions of every material or compound that enters water bodies ranging from organic matter to contaminants depending on several factors including morphology, residence time of water and hydrologic conditions (Cardoso *et al.,* 2019). Due to the ability of sediments to accumulate contaminants, they are considered as secondary sources of pollution. In this regard, the chemicals of most concern are heavy metals and organic pollutants (Sobek *et al.,* 2014).

Heavy metals occur naturally in the earth crust. They characteristically have high densities and are toxic to living organisms at low concentrations (Duffus, 2002). Contamination of water bodies by heavy metals may occur due to corrosion of these metals, atmospheric deposition, soil erosion and leaching, among others (Tchounwou *et al.,* 2012). Human activities such as mining and smelting operations, industrial activities and use of heavy metals in domestic and agricultural products are contributors to the problem of heavy metal contamination in water bodies (He *et al.,* 2005). Heavy metals react with various contents of the aquatic environment and can associate with geochemical processes in sediments (Morillo *et al.,* 2004). When heavy metals are washed from contaminated soil into water bodies, they can affect aquatic organisms by inducing toxic effects that disturb their growth, metabolism or reproduction (Gheorghe *et al.,* 2017). The health of aquatic ecosystems is a key facet of environmental health in general given the important roles these ecosystems play. Ossiomo River in Edo State, Nigeria is one of such ecosystems which also supports the surrounding communities. Natural runoff from rainfall and human activities such as agriculture in nearby areas, disposal of waste and domestic activities among others are sources from which heavy metals are inputted to the river (Ikhuoriah and Oronsaye, 2016). The presence of these pollutants in the sediments of the river present both short- and long-term environmental health threats. Therefore, this study attempts to determine pollution characteristics and geochemical study of core sediments from Ossiomo River.

Materials and Methods

Description of the Study Area

Ossiomo River has a length of about 250km and is stretched between Edo and Delta States latitudes 6°30' - 6°32'0"N and longitude 5°39'- 5°40'30"E. It is the main water body that supports communities such as Ologbo, Okuku, Ovade, Egho, Asabor, Ugbenu and Ogbogilete. The river receives water from tributaries Akhaianwan, Okhuaihe and Ikpoba Rivers. It empties into the Benin River at Koko in Delta State. Three sampling stations were designated to show the upstream (N 06° 03. 197° and E 005° 39. 905'), midstream (N 06° 03. 127° and E 005° 39. 835°), and down-stream (N 06° 03. 121° and E 005° 39. 779°) points of the river (Figure 1).

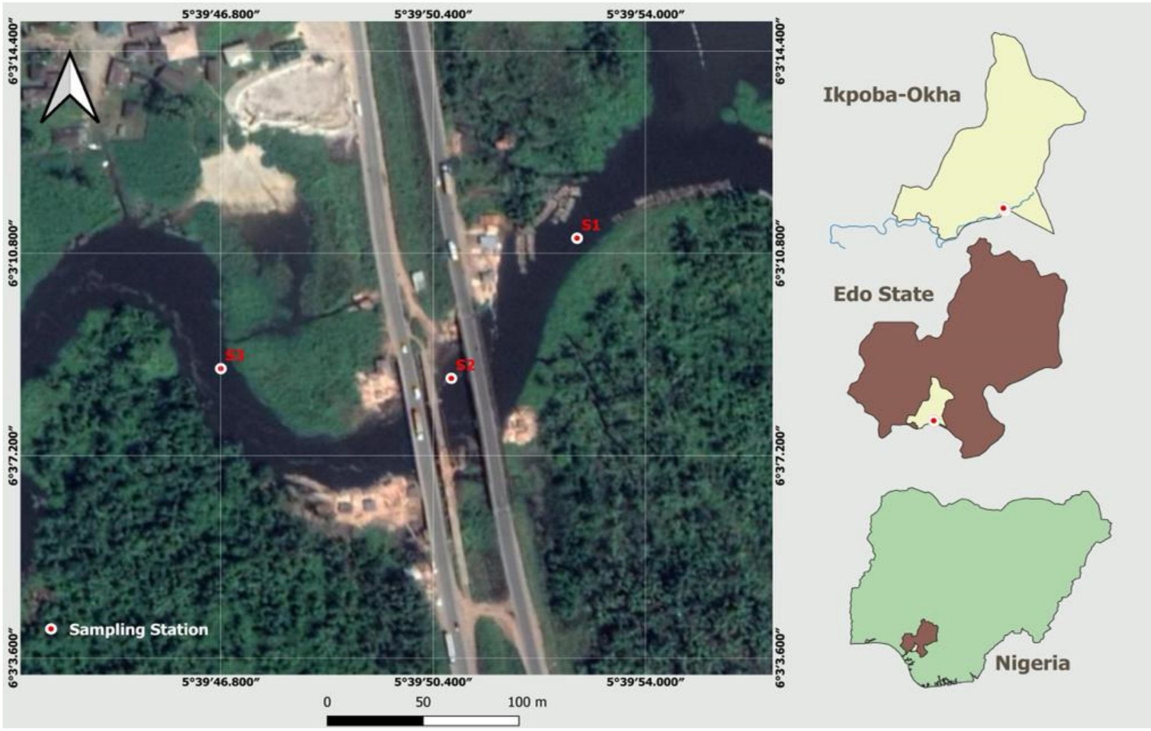

Fig. 1: A map of the study area with sampling locations indicated

Sample Collection and Preparation

Sediment samples were collected from the three sampling sites situated along the river's path. A 20cm Birge-Eckman grab sampler was used to collect sediments, which were then placed into sanitized polyethylene bags. The bags were properly labeled and delivered to the lab for examination. The sediment samples were air-dried in the laboratory at room temperature (25°C - 27°C) for three days. Samples were crushed, sieved through a 2mm mesh sieve and stored pending analysis.

Laboratory Analysis

Physicochemical properties such as pH, electrical conductivity (EC), total hydrocarbon content (THC) and particle size distribution of sand, silt and clay were determined according to standard method (APHA, 2005). The amount of organic carbon present in the sediment samples was determined using the Walkley and Black (1934) method. Sediment samples were digested by a modified procedure and determined for heavy metal concentration using Atomic Absorption Spectrophotometer (Bulk Scientific 210 VGP) according to the procedure of the Association of Analytical Chemists, (AOAC, 2000).

Geochemical Assessment of Heavy Metals

Enrichment Factor (EF)

As proposed by Duce, (1975), Fe was chosen as the normalizing element while determining EF values: Enrichment factor is calculated as stated below

Enrichment Factor = (X/Fe) sediment / (X/Fe) background ………. Levy *et al.,* (1992)

For the sediment analysis in this investigation, the normalizing element, Fe, with a natural background value of 226.7 mg/kg, was used. According to Sutherland (2000), five categories are recognized on the basis of EF and they include:
When EF < 2 depletion of mineral enrichment or no enrichment,
2≤EF<5 moderate enrichment,
5≤EF<20 significant enrichment,
20≤EF<40 very high enrichment,
EF>40 extremely high enrichment
(Nweke and Ukpai, 2016).

Contamination Factor, Contamination Degree and Pollution Load Index

According to Hakanson (1980), CF values will be interpreted as follows:

If CF < 1: it means that low contamination exists.
If 1 < CF > 3: it means that moderate contamination exists.
If 3 < CF < 6: it means that considerable contamination exists.
If CF > 6: it means that very high contamination exists.

Contamination degree estimates the total degree of overall contamination of a site. Adopting Hakanson (1980), it is expressed as CD < 6 = low degree of contamination, 6 ≤ CD < 12 = moderate degree of contamination, 12 ≤ CD < 24 = considerable degree of contamination, and CD ≥ 24 = very high degree of contamination.

However, the PLI can be expressed as

$$PLI\ of\ a\ study\ area\ = n\sqrt{C_f^i\ 1 \times C_f^i\ 2 \times C_f^i\ 3 \times C_f^i\ \ldots \times C_f^i\ n} \quad - - -$$

For assessing the level of heavy metal pollution, this empirical index provides a simple, comparative means.
When PLI > 1, it means that a pollution exists; otherwise,
If PLI < 1, there is no metal pollution (Tomlinson *et al.,* 1980).

Geo-accumulation index (Igeo)

As proposed by Ihenyen, (1998), geo-accumulation index (Igeo) is expressed by

Igeo = Log2 (C_n / 1.5 B_n) or $I_{geo} = Log_2 \frac{C_n}{1.5 \times B_n}$

Here, Cn represents the concentration of metals in the sediment sample, while Bn denotes the metal's geochemical background concentration (n). The geo-accumulation index consists of seven classes (0 to 6); Class 0 (practically unpolluted): Igeo ≤ 0, Class 1 (unpolluted to moderately polluted): 0<Igeo<1, Class 2(moderately polluted): 1<Igeo<2; Class 3 (moderately to heavily polluted): 2<Igeo<3; Class 4 (heavily polluted):3<Igeo<4; Class 5 (heavily to extremely polluted):4<Igeo<5; Class 6 (extremely polluted):5>Igeo

Potential Ecological Risk Index (PERI)

The potential ecological risk index method of Hakanson, (1980) was used to evaluate heavy metal contamination from the perspective sedimentology reflected in equation below.

$Er = Tr \cdot Cf$

Where *Tr* is the toxic-response factor for a given substance and *Cf* is the contamination factor.
The potential ecological risk index (RI) was in the same manner as degree of contamination defined as the sum of the risk factors.

$RI = \Sigma_{i=1} Er$

The following terminologies will be used for the potential ecological risk index as given by Hakanson (1980); *RI<150*, low ecological risk; *150≤RI<300*, moderate ecological risk; and *RI>600*, very high ecological risk. See table 1.

Table 1: The adjusted grading standard of PERI of heavy metals

E^i_R	Pollution degree	RI	Risk level	Risk degree
EiR< 30	Slight	RI< 40	A	Slight
30≤EiR< 60	Medium	40 ≤ Ri< 80	B	Medium
60≤EiR<120	Strong	80≤Ri< 160	C	Strong
120≤EiR< 240	Very Strong	160≤RI 320	D	Very strong
EiR≥ 240	Extremely strong	RI≥ 320	-	-

E^i_R is the potential ecological risk index of a single element; RI is a comprehensive potential ecological risk index (Jiang *et al.,* 2014).

Data Analysis

Basic statistical measurements were carried out using Microsoft Excel 2013, PAST 4 and IBM SPSS 20.0 windows application.

Results and Discussion

Physicochemical Parameters of Sediment

The results of the physicochemical parameters and heavy metal content of sediments from Ossiomo River is presented in table 2. The pH values of the sediment obtained in this study were relatively similar and moderately acidic with an average value of 5.83 in station 1. The highest pH value was recorded at station 1, which is slightly acidic when compared to other stations that are moderately acidic. Adesuyi *et al*, (2016) obtained a different result from Nwaja Creek, Niger Delta, with the highest pH value of 8.50 in station 2. Similar results were reported by Issa *et al*, (2011) who obtained a pH value of 5.58- 6.34 which were moderately acidic from Orogodo River, Agbor, Delta State. Electrical conductivity (EC) in the study ranged between 54.00 uS/cm and 373.00 uS/cm. These variations may be as a result of dilution from rainfalls during this period. The low level of EC in this study may be attributed to the levels of ions within the considered water channels of the study.

Bottom sediment is a key site for organic matter disintegration which is principally carried out by microbes. The total organic carbon content in this study ranged between 0.11% - 3.97%. This value is comparable to those detected in Sombreiro River (2.02% - 4.1%) by Ezekiel *et al*. (2011) and Azuabie Creek (0.82% - 2.16%) by Daka and Moslen, (2013). Total nitrogen in this study had a mean ranged of 0.08% to 0.94%. Seiyaboh *et al*. (2016) reported a higher range of 2.51 – 4.01 % for total nitrogen in bottom sediments of Orashi River, from the Eastern Niger Delta of Nigeria. However lower total nitrogen values were recorded by Akachukwu *et al*., (2020) with a range of 0.30% - 2.77% from Orashi River.

The variability of minerals such as Ca, Mg, Na and K in this study were different and fluctuated between the range of 12.83-132.75 mg/kg, 3.89-49.00 mg/kg, 9.51-15.33mg/kg and 6.45-30.10 mg/kg respectively. Similar results for Ca were reported by Senze *et al.,* (2020) from Nysa Szalona River, Poland. However, lower calcium values of 3.00 to 42.88 mg/kg were recorded by Abdo, (2005) from Bardawil lagoon.

Table 2: Summary of physico-chemical properties and heavy meatl content of Bottom Sediments

Parameters	Station 1			Station 2			Station 3			Anova Value
	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.	
pH	5.83 ± 0.93	4.87	6.73	5.09 ± 0.47	4.80	5.63	5.37 ± 0.52	4.80	5.81	0.237
E. Conduct (uS/cm)	142.07 ± 76.47	54.00	191.70	253.47 ± 103.56	190.70	373.00	163.30 ± 60.89	93.00	199.20	0.160
Total organic carbon (%)	$0.47^{b} \pm 0.39$	0.11	0.87	$2.35^{a} \pm 1.41$	1.41	3.97	$1.41^{ab} \pm 0.59$	0.81	1.98	0.031
Nitrogen (%)	0.37 ± 0.50	0.02	0.94	0.40 ± 0.35	0.06	0.75	0.09 ± 0.02	0.08	0.11	0.335
Calcium (mg/kg)	41.01 ± 26.46	12.83	65.32	77.17 ± 48.34	44.89	132.75	71.09 ± 4.89	66.50	76.24	0.228
Magnesium (mg/kg)	$10.85^{c} \pm 6.58$	3.89	16.98	$42.38^{a} \pm 5.88$	37.78	49.00	$26.22^{b} \pm 7.50$	18.27	33.16	0.040
Sodium (mg/kg)	12.86 ± 2.43	10.48	15.33	12.46 ± 3.28	9.51	15.99	9.89 ± 0.11	9.76	9.98	0.186
Potassium (mg/kg)	10.50 ± 4.61	6.45	15.51	18.73 ± 10.09	10.82	30.10	13.15 ± 2.87	10.38	16.11	0.191
Sand	90.61 ± 5.73	85.08	96.52	88.83 ± 4.35	84.52	93.22	88.32 ± 6.42	83.21	95.52	0.643
Silt	3.13 ± 2.63	0.30	5.50	6.73 ± 3.90	2.50	10.30	5.23 ± 4.35	0.30	8.50	0.294
Clay	4.19 ± 0.97	3.18	5.12	5.27 ± 1.03	4.28	6.34	5.38 ± 1.25	4.18	6.67	0.246
Iron (mg/kg)	821.17 ± 592.56	226.70	1411.80	2005.33 ± 1460.96	555.00	3476.70	586.43 ± 188.54	435.00	797.60	0.117
Copper (mg/kg)	5.47 ± 2.28	3.00	7.50	7.90 ± 4.37	3.30	12.00	7.13 ± 3.14	4.80	10.70	0.425
Zinc(mg/kg)	18.53 ± 10.54	9.70	30.20	41.97 ± 17.57	30.60	62.20	26.33 ± 14.05	11.40	39.30	0.102
Cadmium (mg/kg)	0.10 ± 0.06	0.10	0.10	0.21 ± 0.01	0.20	0.22	0.11 ± 0.06	0.10	0.11	0.039
Lead (mg/kg)	3.50 ± 0.06	3.00	4.00	11.83 ± 10.13	0.50	20.00	2.07 ± 1.62	0.20	3.00	0.104
Manganese (mg/kg)	8.40 ± 3.60	4.50	11.60	13.10 ± 6.90	6.30	20.10	5.57 ± 0.70	4.90	6.30	0.096
Chromium (mg/kg)	3.44 ± 2.78	0.32	6.67	5.46 ± 2.20	3.08	7.42	3.99 ± 1.26	2.77	5.29	0.313
THC (mg/kg)	700.49 ± 129.42	578.43	836.19	445.96 ± 462.88	31.11	945.25	1333.94 ± 636.40	741.11	2006.41	0.063

x ± SD = average mean generated from values across the months per station, ± standard deviation; min–max = minimum and maximum values for each parameter per station

Higher Mg values recorded in station 2 could be attributed from anthropogenic activities by indigenes of Ologbo community who engaged in indiscriminate activities such as bathing, washing of clothes and motor bikes, saw milling activities at the bank of the River during the period of sampling. Similar result for potassium (K) was obtained by Goher, (2002) from Quarun Lake, Egypt with average mean values of 6.57-40.39 mg/kg. The variability of the particle size distribution in this study were determined as sand > silt > clay. Daka and Moslen (2018) obtained similar results from Azuabie Creek of the Upper Bonny Estuary, Niger Delta.

Heavy Metal in Sediments

The mean concentration of heavy metals in (mg/kg) in the sediments were in the following order; Fe>Zn>Mn>Cu> Pb> Cr>Cd. Similar results have been obtained by Ogbeibu *et al.* (2014) from Benin River, Anani and Olomukoro (2017) from Ossiomo River. Ayoade and Nathaniel (2018) recorded higher Fe concentrations of 11346.62mg/kg in sediments from a tropical manmade lake southwestern Nigeria while Emmanuel *et al.* (2018) also obtained higher Fe concentrations ranging between 8928 – 13657 mg/kg in River Benue, North-Central Nigeria. However, Fe values in this study exceeded those obtained in a previous study on Ossiomo River by Anani and Olomukoro (2017). The concentrations of copper obtained in this study ranged from 5.47mg/kg in station 1 to 7.90mg/kg in station 2 as similar Cu concentration of 4.52 – 10.73mg/kg was recorded in previous study by Anani and Olomukoro (2017). The Cu values obtained in this study showed no significantly different ($p>0.05$).

The variability of Zn concentrations in this study had an average mean value of 18.53, 41.97 and 26.33mg/kg. Lower zinc values were obtained by Anani and Olomukoro, (2017) and Jabbi *et al.,* (2018). The mean values obtained for Cd were 0.10, 0.21 and 0.11mg/kg respectively. Cd in this study was lower than 1.80 - 5.89mg/kg from previous study by Anani and Olomukoro (2017). Lower Cd concentrations of 0.09mg/kg were reported by Abata *et al.* (2013) in sediments from River Ala while higher values of Cd (1.85 - 2.80mg/kg) were obtained by Emmanuel *et al.* (2018) from River Benue, North-Central Nigeria. The variability of lead in this study were higher in station two. Previous studies in Ossiomo River showed that Pb content has increased overtime as Anani and Olomukoro (2017) reported lower Pb values of 1.41 - 6.36mg/kg concentrations in sediments from Ossiomo River. The concentrations of Mn in this study was lower than the concentration recorded in previous study by Anani and Olomukoro, (2017) in the same river. Higher manganese concentration (75 - 253.5mg/kg) was observed by Emmanuel *et al.* (2018) in sediments of River Benue. Okafor and Opuene (2007) recorded very high Mn values of 177.51 - 266.9mg/kg from Taylor Creek, Nigeria and attributed the high value of Mn to the introduction of run offs and other human activities from surrounding aquatic environment.

The lowest variability of chromium in this study fluctuated with a range of 0.32mg/kg in station 1 while the highest level of variability was 7.42mg/kg in station 2. These levels can be attributed to the presence of hydrocarbons. The Cr values in this study is similar to the values of 2.26 - 3.71mg/kg obtained by Okafor and Opunene (2007) from Taylor Creek, Nigeria. Previous study by Ogbeibu *et al.* (2014) from Benin River and Anani and Olomukoro (2017) from Ossiomo River recorded similar values of Cr concentrations while Abata *et al.,* (2013) obtained very high concentration of Cr (20.30mg/kg) from River Ala. The Total hydrocarbon content obtained in sediments samples from Ossiomo River had mean values of 700.49, 445.96 and 1333.94mg/kg. A review of existing data on the Niger Delta by Niger Delta Environmental Survey (1999) and Osuji *et al.* (2005) affirms that such hydrocarbon levels affect both above-ground and subterranean flora and fauna, which are essential adjuncts in the biogeochemical cycle that affects availability of plant nutrients (Osuji and Nwoye 2007). The level of hydrocarbon in sediments from Ossiomo River provided evidence of hydrocarbon contamination. Elevated values of these contaminant indicators could pose serious threat to human health and environment. This calls for immediate attention because most living organisms depend on the aquatic environment for survival and humans also depend on it for fishing purpose.

Assessment Indices

Enrichment Factor (EF*) and *Geo-accumulation Index (Igeo)

Table 3 shows the EF, *igeo,* CF, CD, PLI and PERI values of heavy metal contamination in bottom sediments in this study. There was very high enrichment for Pb in stations 1 and 3 ($20 \leq EF < 40$) and an extremely high enrichment of Pb in station 2 ($EF > 40$). The findings from this study indicated that there is a significant enrichment for Fe, Cr, Cd and a very high enrichment for Pb in Ossiomo River. Similar values for enrichment factor of heavy metals in sediments were obtained by Jiao *et al.* (2018) from Pearl River, China. The findings using *Igeo* indicates Cu and Mn were practically unpolluted ($Igeo \leq 0$), Cr and Cd were moderately to heavily polluted ($2 < Igeo < 3$) in station 2, while Pb extremely polluted ($5 > Igeo$) in station 2. Thus, it is possible to ascertain that the anthropogenic activities carried out in the study area are relatively detrimental to the aquatic environment which has shown to increase the level of metals in the sediments.

Table 3: Assessment Indices for Bottom Sediments

Parameters	Enrichment factor (EF)			Parameters	Geoaccumulation index (Igeo) values		
	Station 1	Station 2	Station 3		Station 1	Station 2	Station 3
Fe	3.622	8.846	2.587	Fe	1.272	2.560	0.786
Cr	10.707	16.999	12.440	Cr	2.836	3.502	3.052
Cd	10.000	20.667	10.500	Cd	2.737	3.784	2.807
Cu	1.822	2.633	2.378	Cu	0.281	0.812	0.665
Zn	1.911	4.326	2.715	Zn	0.349	1.528	0.856
Mn	1.867	2.911	1.237	Mn	0.316	0.957	-0.278
Pb	35.000	118.333	20.667	Pb	4.544	6.302	3.784

	Contamination Factor, Contamination Degree and Pollution Load Index							
	Fe	Cr	Cd	Cu	Zn	Mn	Pb	CD	PLI
Station 1	3.622	10.707	10.000	1.822	1.911	1.867	35.000	64.929	5.088
Station 2	8.846	16.999	20.667	2.633	4.326	2.911	118.333	174.716	10.288
Station 3	2.587	12.440	10.500	2.378	2.715	1.237	20.667	52.523	4.765

	Potential Ecological Risk Index (PERI)		
Cr	21.414	33.998	24.881
Cd	300.000	620.000	315.000
Cu	9.111	13.167	11.889
Zn	1.911	4.326	2.715
Mn	1.867	2.911	1.237
Pb	175.000	591.667	103.333
	509.303	1266.069	459.055

Contamination Factor, Contamination Degree and Pollution Load Index

The findings from this study shows a moderate contamination exist for cu and Mn, a very high contamination exist for Cr, Cd and Pb across the three sampled stations. Adopting Hakanson (19800, a very high degree of contamination (CD ≥ 24) exists across all sampled stations. The PLI values across the three sampled stations indicates that PLI > 1 which signifies that pollution of the study area. The PLI values obtained in this study were in the following order station 2 > station 1 > station 3 (figure 2). The values for PLI in this study were higher than those reported for heavy metals in sediments in the Benin River by Ogbeibu *et al*. (2014)

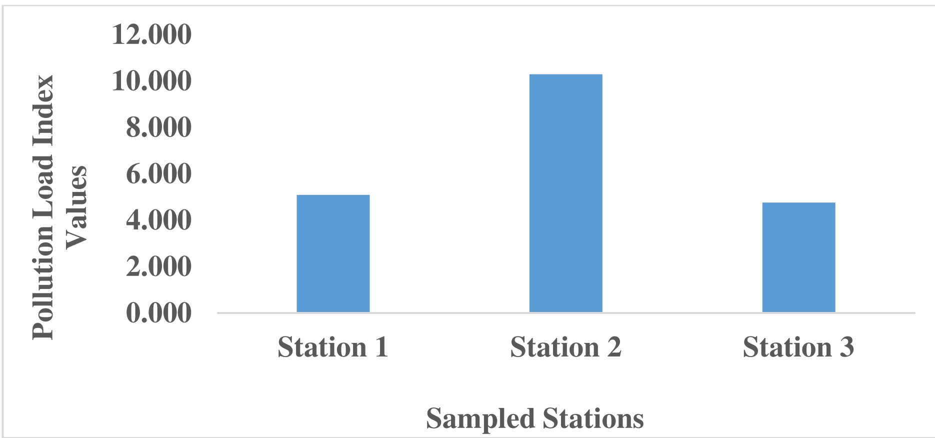

Figure 4.3: Pollution load index (PLI) values in bottom sediments from Ossiomo River

Potential Ecological Risk Index (PERI)

The results reveals that there is a slight pollution degree of Cu, Zn, and Mn across all the three sample stations ($Ei_R<30$), a medium pollution degree of Cr in station 2 ($30\leq Ei_R<60$), a very strong pollution degree of Pb in station 1 ($120\leq Ei_R<240$) while Cd exhibited an extremely strong pollution degree ($Ei_R\geq 240$) across the sampled stations from Ossiomo River. Interpreting the risk degree, there is an extremely strong risk degree or level D across the bottom sediments. Adopting Hakanson (1980), station 1 and 3 indicates considerable ecological risk (300<RI≤600), while station 2 indicates a very high ecological risk (RI>600). Cadmium have been reported as one of the most eco-toxic metals with highly undesirable effects on aquatic health, humans, animal health and plant metabolism (Kabata-Pendias, 2000). Chronic exposure to very low cadmium concentrations can result to insomnia, cardiovascular diseases, anaemia and renal problems (Simsek et al., 2021).

Conclusion

Heavy metal contamination in the aquatic environment is a source of concern for environmental and public health concern due to their adverse effects. The concentrations of heavy metals in the sediments did not exceed their respective reference values. However, ecological risk analysis via several indices including EF, Igeo, CF, Cd, PLI and PERI showed that the heavy metals present in the sediments were a potential threat to ecological health especially cadmium, lead and chromium. The contamination of sediments by these metals is of anthropogenic origin and measures should be implemented to arrest the release of these metals into aquatic media.

References

Abata, E.O., Aiyesanmi, A.F., Adebayo, A.O. and Ajayi, O.O. (2013). Assessment of heavy metal contamination and sediment quality in the urban river: a case of Ala River in southwestern Nigeria. *IOSR Journal of Applied Chemistry*, 4(3): 56 - 63.

Abdo, M.H. (2005). Physicochemical pharacteristics of Abu za'baal Ponds, Egypt. *Egyptian Journal of Aquatic Research*, 31: 1 – 15.

Adesuyi, A.A., Ngwoke, M.O., Akinola, M.O., Njoku, K.L. and Jolaoso, A.O. (2016). Assessment of physicochemical characteristics of sediment from Nwaja Creek, Niger Delta, Nigeria. *Journal of Geoscience and Environment Protection*, 4: 16 – 27.

Akachukwu, D., Nnaji, J.C., Ojimelukwe, P., Onoja, S. and Odo, S. (2020). sediment quality of orashi river at four oil producing communities of Nigeria, *Journal of Applied Sciences and Environmental Management*, 24 (7): 1145 – 1151.

American Public Health Association APHA (2005). Standard Methods for the Examination of Water and Wastewater Analysis, American Water Works Association and Water Environment Federation 6th Edition, Washington DC.

Anani, O.A. and Olomukoro, J.O. (2017). The evaluation of heavy metal load in benthic sediment using some pollution indices in Ossiomo River, Benin City, Nigeria. *FUNAI Journal of Science and Technology*, 3(2): 103 - 119.

Anyahara, J.N. (2021). Effects of polycyclic aromatic hydrocarbons (PAHs) on the environment: a systematic review. *International Journal of Advanced Academic Research*, 7(3): 12 - 26.

Association of Analytical Chemistry (2000). Official methods of analysis of chemistry A.O.A.C, International 17TH edition. Gaithen burf, M.D. USA. *Official methodology,* 2: 920 – 957.

Ayoade, A.A. and Nathaniel, O.G. (2018). Assessment of heavy metals contamination of surface water and sediment of a tropical manmade lake southwestern Nigeria. *International Journal of Environment and Pollution Research*, 6(3): 1 - 16.

Cardoso, S.J., Quadra, G.R., Resende, N. and Roland, F. (2019). The role of sediments in the carbon and pollutant cycles in aquatic ecosystems. Available at https://doi.org/10.1590/S2179-97X8918. Accessed November 2nd, 2022.

Chakravarty, M. and Patgiri, A. D. (2009). Metal pollution assessment in sediments of the Dikrong River, NE India. *Journal of Human Ecology*, 27(1): 63-67.

Daka, E.R. and Moslen, M. (2013). Spatial and temporal variation of physico-chemical parameters of sediment from Azuabie Creek of the Upper Bonny Estuary, Niger Delta. *Research Journal of Environmental and Earth Sciences*, 5: 219 – 228.

Duce, R.A., Hoffmann, G.L. and Zoller, W.H. (1975). Atmospheric trace metals at remote northern and southern Hemisphere sites. *Pollution on Natural Science*, 187: 59–61

Duffus, J.H. (2002). Heavy metals - a meaningless term? *Pure and Applied Chemistry*, 74: 793 - 807.

Emmanuel, E., Sombo, T. and Uqwuanyi, J. (2018). Assessment of heavy metals concentration in shore sediments from the bank of River Benue, North-Central Nigeria. *Journal of Geoscience and Environmental Protection*, 6: 35 - 48.

Ezekiel, E.N., Hart, A.I. and Abowei, J.F.N. (2011). The sediment physical and chemical characteristics in Sombreiro River Niger Delta, Nigeria. *Research Journal of Environmental and Earth Sciences*, 3: 341 – 349.

Gheorghe, S., Stoica, C., Vasile, G.G., Nita-Lazar, M., Stanescu, E. and Lucaciu, I.E. (2017). Metal toxic effects in aquatic ecosystems: Modulators of water quality, In: Tutu, H. (ed) Water Quality: Edited volume. IntechOpen Limited: London, UK. pp. 142 - 179.

Goher, M.A. (2002). Chemical studies on the precipitation and dissolution of some chemical elements in Lake Qarun, Ph.D. Thesis, Faculty of Science Azhar University Cairo, Egypt.

Hakanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control. A Sedimentological Approach. Water Research, 14(8): 975–1001

He, Z. L., Yang, X. E. and Stoffella, P. J. (2005). Trace elements in agroecosystems and impacts on the environment. *Journal of Trace Elements in Medicine and Biology*, 19: 125 - 140.

Hong, Y., Liao, W., Yan, Z., Bai, Y., Feng, C., Xu, Z. and Xu, D. (2020). Environmental behaviour and effects of pollutants in water. Available online at https://doi.org/10.1155/2020/9010348. Accessed January 9th, 2022.

Ihenyen, A.E (1998). Heavy metal pollution studies on roadside sediments in metropolitan Lagos Nigeria. *Environmental Science*, 6: 1-6.

Ikhuoriah, S.O. and Oronsaye, C.G. (2016). Assessment of physicochemical characteristics and some heavy metals of Ossiomo River, Ologbo - a tributary of Benin River, Southern Nigeria. *Journal of Applied Science and Environmental Management*, 20(2): 472 - 481.

Issa, B.R., Arimoro, F.O., Ibrahim, M., Birma, G.J. and Fadairo, E.A. (2011). Assessment of sediment contamination by heavy metals in River Orogodo Agbor, Delta State Nigeria. *Current World Environment*, 6(1): 29 – 38.

Jabbi, A.M., Rabiu, A.T., Sani, Z.R., Balarabe, M.L. and Adamu, A.K. (2018). Assessment of heavy metals contamination in the sediment of Yardantsi Reservoir, Gusau, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 11(1): 73 - 78.

Jiang, X., Lu, W.X., Zhao, H.Q., Yang, Q.C. and Yang, Z.P. (2014). Potential ecological risk assessment and prediction of soil heavy-metal pollution around coal gangue dump.

Natural Hazards and Earth System Science, 14: 1599-1610

Jiao, Z., Li, H., Song, M. and Wang, L. (2018). Ecological risk assessment of heavy metals in water and sediment of the Pearl River Estuary, China. *IOP Conference Series: Materials Science and Engineering*, 394: 52 - 65.

Kabata-Pendias, A. and Pendias, H. (2001). Trace Metals in Soils and Plants. CRC Press, Boca Raton, Fla, USA, 2nd edition. Pp 11- 32

Levy, D.B., Barbarick, K.A., Siemer, E.G. and Sommers, L.E. (1992). Distribution and partitioning of trace metals in contaminated soils near Leadville, Colorado. *Journal of Environmental Quality*, 21(2): 185–195

Morillo, J., Usero, J. and Gracia, I. (2004). Heavy metal distribution in marine sediments from the southwest coast of Spain. *Chemosphere*, 55(3): 431 - 442.

Nweke, M.O. and Ukpai, S.N. (2016). Use of Enrichment, Ecological Risk and Contamination Factors with Geoaccumulation Indexes to Evaluate Heavy Metal Contents in the Soils around Ameka Mining Area, South of Abakaliki, Nigeria. *Journal of Geography, Environment and earth Science International*, 5(4): 1-13

Ogbeibu, A.E., Omoigberale, M.O., Ezenwa, M.I., Eziza, J.O. and Igwe, J.O. (2014). Using Pollution Load Index and Geoaccumulation Index for the assessment of heavy metal pollution and sediment quality of the Benin River, Nigeria. *Natural Environment,* 2(1): 1 - 9.

Okafor, E. C. and Opuene, K. (2007). Preliminary assessment of trace metals and polycyclic aromatic hydrocarbons in the sediments. International 233 - 240. *Journal of Environmental Science and Technology*, 4(2):

Osuji, L.C. and Nwoye, I. (2007). An appraisal of the impact of petroleum hydrocarbons on soil fertility: the Owaza experience. African Journal of Agricultural Research, 2(7): 318-324.

Osuji, L.C., Egbuson, E.J. and Ojinnaka, C.M. (2005). Chemical Reclamation of Crude-Oil-Inundated Soils from Niger Delta Nigeria. *Chemistry and Ecology*, 21(1): 1-10.

Otari, M. and Dabiri, R. (2015). Geochemical and Environmental Assessment of heavy metals in soils and sediments of Forumad Chromite mine, NE of Iran. *Journal of Mining and Environment*, 6(2): 251-261

Seiyaboh, E.I., Alagha, W.E. and Angaye, T.C.N. (2016). Sedimentary assessment of basic river in the niger delta: a case study of Orashi River in the Eastern Niger Delta of Nigeria. *Greener Journal Geology and Earth Science*, 4(3): 051 – 055.

Senze M., Monika, Katarzyna, C. (2020). Cations Ca, Mg, Na, K in bottom sediment of the lower Silesian Dam Reservoir. Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis, 68(4): 687 – 698.

Simsek, A., Ozkoc, H.B. and Bekan, G. (2021). Environmental, ecological and human health risk assessment of heavy metals in sediments at Samsun-Tekkekoy, North of Turkey. Available online at https://doi.org/10.1007/s11356-021-15746-w. Accessed March 1st, 2022.

Sobek, A., Wiberg, K., Sundqvist, K.L., Haglund, P. and Jonsson, P. (2014). Coastal sediments in the Gulf of Bothnia as a source of dissolved PCDD/Fs and PCBs to water and fish. *The Science of the Total Environment*, 487: 463 - 470.

Tawari-Fufeyin, P., Imoobe, T.O.T. and Awana, B. B. (2008). The impact of bridge construction on the crustacean zooplankton of Ossiomo River, Niger Delta Nigeria. African Scientist, 9:117 – 122.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. and Sutton, D.J. (2012). Heavy metal toxicity and the environment, In: Luch, A. (Ed) Molecular, Clinical and Environmental Toxicity. *Experientia Supplementum*, 101. Springer: Basel, Switzerland. pp. 133 - 164.

Tomlinson, D.C., Wilson, D.J., Harris, C.R. and Jeffrey, D.W. (1980). Problem in heavy metals in estuaries and the formation of pollution index. *Helgol. Wiss. Meere-sunlter*, 33(1-4): 566-575

Walkley, A. and Black, C.A. (1934). An Examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chronic acid titration method. *Soil Science*, 37:29.